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TWENTY YEARS OF UNDERWATER ELECTROACOUSTIC STANDARDS

NAVAL RESEARCH LABORATORY

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Twenty Years of Underwater Electroacoustic Standards

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Standards Branch
Underwater Sound Reference Division

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This report is intended as a ready reference concerning the standard underwater sound transducers stocked by the Underwater Sound Reference Division. It also summarizes a few of the highlights of many years spent in investigating materials, design, and construction techniques to satisfy the requirements of widely varying underwater sound measurement problems. Twenty-nine appendices present descriptions and performance characteristics of as many individual transducer types.

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Contents

Abstract

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TWENTY YEARS OF UNDERWATER ELECTROACOUSTIC STANDARDS

Historical Background

At the end of World War II, the Navy Underwater Sound Reference Laboratory inherited from its predecessor, Columbia University's Underwater Sound Reference Laboratories, a small inventory of hydrophones and projectors consisting principally of standards developed by the Bell Telephone Laboratories (BTL) during the early war years. The designs were remarkably good, considering the urgency of development and the state of the art at that time, although the electroacoustic response characteristics were a little less than smooth and the difficulty of repair was high.

Transducers available at that time for issue to other naval activities and their contractors included the crystal hydrophones (BTL designations) type 5E containing 45-deg Y-cut Rochelle salt crystals and type 3A containing 45-deg Z-cut ammonium dihydrogen phosphate (ADP) crystals, as well as the crystal transducers types 5A and 6B. In all these units, metal diaphragms soldered around the periphery protected the crystals from water entry into the housing. In this respect, these transducers were superior to many types developed much later.

Two moving-coil (dynamic) transducers, types 1K and 4B, were available for use as sound sources. Each of these was fitted with a beryllium copper diaphragm and permanent magnets. Hydrostatic pressure was compensated in the 1K by an air-filled rubber bag. An integral part of the 4B housing was a high-pressure air tank from which air was admitted to the chamber behind the diaphragm through a solenoid-actuated valve. The solenoid was energized by a microswitch that was tripped by a float. When this mechanism was properly adjusted and a source of voltage for operating the solenoid was provided, the transducer was quite reliable.

An additional BTL-designed hydrophone that was available, although little used after World War II, was the pressure-gradient type 2A. The sensitivity was low and the model was physically rather delicate. The sensor in these hydrophones was protected from the water by a thin metal housing covered with a coating of neoprene.

The first few years after the Navy took over operation of the USRL were devoted to learning how to repair or rebuild these BTL units and how to modify them to improve their characteristics. It was not unusual for repairs to require two to three weeks in those days. In contrast, two or three days suffice for the newer standards.

It has been more than twenty-five years since the Navy assumed the operation of the USRL, now the Underwater Sound Reference Division of NRL, and began the development of standard transducers for calibration of underwater electroacoustic sonar transducers and other acoustic devices. During those years, twenty-four different types of standards have been developed for use in the frequency range from 0.3 Hz to 2 MHz. These transducers are now in widespread use throughout the Navy and industry, and have completely displaced the earlier BTL models. In addition, a hundred or more unique designs have been produced for use in special measuring systems.

An interesting fact is that the two oldest USRL/USRD-designed standards in use currently were designed for the lowest frequencies (type H11) [1] and the highest frequencies (type E8) [2]. Both of these standards contain crystals of lithium sulfate, which has proved to be the most reliable and predictable piezoelectric material for many standard transducer designs, especially those for use at high hydrostatic pressures and over a wide temperature range. A unique feature of the type H11 is the Teflon acoustic window with its low water permeability, which has been used since 1953. Using the fluorocarbon for the acoustic window rather than natural rubber or polychloroprene elastomer increased the lifetime for underwater submergence from less than 3 months to more than 10 years. The only other elastomer whose water permeability even approaches the low value for Teflon and at the same time provides a better rho-c match with water is butyl rubber. The type H17 hydrophone [3], which is used from 20 Hz to 150 kHz, was the first USRL design to be fitted with a butyl boot (1959).

Most of the standards developed during the first 15 years were designed for laboratory use rather than for measurements in the sea. To make certain that superior acoustical characteristics were achieved, a minimum of physical protection was provided. Some of the materials used were satisfactory in contact with fresh water but corroded when immersed for extended periods in salt water. Fortunately, alloys with high copper content and butyl rubber boots or covering were chosen for many designs. These materials have proved to be superior in the salt water environment. Housings of type 316 stainless steel in contact with salt water developed crevice corrosion at some of the seals.

Although the earlier standard hydrophones were designed with as little support structure as possible around or near the sensor element, it was found subsequently that expanded metal can be formed into cylinders and used as a support member for the sensor element as well as to provide a strong protective guard without seriously affecting the acoustical performance. A certain amount of electrostatic shielding also is furnished by the expanded metal. This design feature has been incorporated in transducers for use at frequencies as high as 80 kHz with little or no effect on the directional characteristics. When additional electrostatic or magnetic shielding was needed, thin sheets of dead soft iron or flattened expanded metal with a very fine mesh has been used around the heavier expanded-metal support frame. These thin expanded materials do not affect the acoustical characteristics at frequencies as high as 200 kHz.

Standard Transducer Development

The primary objective of USRD's underwater electroacoustic transducer development has been the design of transducers whose acoustical characteristics are stable and predictable. Transducer sensor elements have been kept as simple as possible. All pressure release materials like corprene, air cell rubber, and other materials whose acoustic or mechanical characteristics change markedly as functions of temperature or pressure, have been avoided.

In general, sensor element materials, whether natural or man-made piezoelectric crystals or ferroelectric ceramics, usually are more consistent and predictable than are the mechanical mountings, housings, acoustic pressure-release materials, potting compounds, and elastomers used in transducer construction.

Most USRD standard hydrophone designs call for lithium sulfate crystals with a natural rubber support. Lithium sulfate is a volume expander and does not require that some of the surfaces be masked with an acoustic pressure-release material to produce an element sensitive to small acoustic sound pressures. Its volume resistivity is high; therefore, it can be used to frequencies as low as 0.3 Hz. ADP, on the other hand, does require such masking if it is to have adequate sensitivity, and its volume resistivity limits its use to frequencies higher than 10 Hz.

When it has been necessary or desirable to block the radiation in one direction, this has been done by using a high-density material with a high Young's modulus. Pure tungsten or alloys such as Kennametal or Mallory 1000 have been used with good results. Lithium sulfate crystals cemented directly to disks or blocks of these materials have produced sensor elements that are little affected by hydrostatic pressure or temperature. The F30 transducer, whose electroacoustic characteristics are independent of hydrostatic pressure, is a good example of this kind of construction [4].

Ferroelectric ceramic tubes have been used in a number of transducers. Here, again, removal of all passive materials whose characteristics are functions of hydrostatic pressure or temperature was required to achieve the desired stability, which led to the use of capped tubes usually supported by a single natural rubber ring around the center of the tube. This construction prevents the sound pressure from reaching the inside of the tube and produces about the optimum sensitivity for a simple construction. The single rubber mount keeps the acceleration sensitivity low without complicating the design.

The end caps have been made of glass, fused quartz, magnesium, beryllium, aluminum, alumina, or steel. This arrangement has produced sensor elements whose characteristics usually are independent of time, temperature, and pressure. Even though the values of several of the ferroelectric ceramic parameters are a function of time, the receiving sensitivity of these standards has changed less than 0.5 dB during a 5-year period. The free-field voltage sensitivity changes as a function of temperature in the range 5 to 30°C and of hydrostatic pressure in the range from 0 to 3447 kPa by less than the normal accuracy of measurement (±1.0 dB).

Most USRD designs for operation at high hydrostatic pressure have contained volume expander sensor elements of lithium sulfate or lead metaniobate. In some applications, however, pressure-compensated oil-filled capped ceramic tubes [5] are used with excellent results up to static pressures of 58 MPa (5800-m depth). Acceleration-balanced mounts and a predetermined orifice size regulate the sensitivity at low frequencies. The orifice diameter must be computed for the operating environmental conditions (temperature and hydrostatic pressure), if the exact frequency of the response roll-off is important.

Coupling Medium to Sensor

Almost without exception, all of the standard hydrophones have contained Baker's DB-grade castor oil as the coupling medium between the elastomer boot and the sensor element. Only in applications where change in viscosity as a function of temperature or compressibility of the fluid was the more important consideration have silicone fluids been used. Castor oil has the advantage of being compatible with most materials used in transducers, including the elastomeric boot. It is less expensive than silicone fluids and far less irritating to the skin or eyes of the workers. Experience with castor oil in more than 2000 transducers during a 22-year period has proved the reliability and value of this coupling fluid. Castor oil whose viscosity has been reduced by additives or chemical changes is not compatible with some elastomers.

Moving-Coil (Electrodynamic) Transducers

Development of the USRD type J9 [6] moving-coil transducer for use as a sound source in the audio-frequency range 40 to 20,000 Hz has contributed extensively to measurement accuracy and is considered an outstanding achievement. This transducer and its higher powered companion type J11 are used in underwater calibration measurements worldwide by both naval and commercial activities.

The newer types J13 and J15 have increased the source strength that can be obtained in the frequency range 10 to 600 Hz from small sound sources. The J15-1 will provide a level of 170 dB re 1 μPa at 50 Hz; the J15-3 can produce 180 dB re 1 μPa. The J15 transducers with a closed gas compensating system can be used to depths from 165 to 240 m without high-pressure gas bottles or scuba-type pressure-regulating equipment.

USRD Stock Standards

USRD-developed standards include both hydrophones (receivers) and transducers (reversible, sources or receivers). Hydrophones are equipped with preamplifiers and normally can be used only for receiving. Transducers can be used as the reversible auxiliary transducer in reciprocity calibration measurements. Each hydrophone is sent to the user with its own calibration curve. Most of the projectors are furnished with only an instruction book containing a typical calibration curve, which is adequate for determining whether the projector is functioning properly.

Transducers usually used both for receiving and transmitting are provided with free-field receiving sensitivity and transmitting voltage response calibration curves.

It usually is better practice to determine the sound pressure level (SPL) by inserting a standard hydrophone into the sound field and measuring the sound pressure than to rely on a transmitting current or voltage response curve for that purpose. Widely varying environmental conditions and the presence of objects or boundaries near the measurement location can cause variation of the SPL that may not be apparent if total dependence is placed on the transmitting characteristics of the projector.

Approximately 600 experimental models of hydrophones have been constructed and calibrated. From these have evolved 64 different types, providing designs to meet almost any measurement problem in the frequency range below 150 kHz. Hundreds of other transducer designs ranging from probes 2 mm in diameter to sound sources 30 cm in diameter and weighing 150 kg have been evaluated.

The Appendices contain data for each USRD-developed standard transducer that is stocked in sufficient quantities to make it available for issue to other users. Although there may appear to be an overlap in frequency range of many transducers, each has its own special characteristics (directivity, low noise, high sensitivity, stability at great depth, high output) that make it uniquely suitable for a particular measurement.

Transducers developed by the USRD have been designated in the same manner for more than 23 years. The letter prefix indicates the general type and the digits are the model number. Prefixes are explained in Table I.

The data presented for each transducer in this report have been taken, for the most part, from the instruction books; however, some additional data are given here for the self-noise of the hydrophones. Figure 1 gives an overview of all the transducers, providing a ready reference for the operating frequency range of each as a receiver, a source, or both.

Table I. Transducer type designations.

Prefix	*Type of transducer*
A	Probe transducers (usually have preamplifier)
E	High-frequency transducers (operate above 150 kHz)
F	Reversible transducers (1 to 150 kHz)
G	Miscellaneous, unique, unusual design
H	Hydrophones (with preamplifier)
J	Moving-coil (electrodynamic) transducers

Calibration of Standard Transducers

Each standard transducer is calibrated throughout its normal operating frequency range. The free-field voltage sensitivity of hydrophones and reversible transducers usually is determined either by the comparison (a secondary) or the reciprocity (a primary) method. Both of these calibration methods have been fully discussed in the literature by Bobber [7] as well as many others and will not be elaborated here.

Standard transducers also are calibrated in closed tank systems where temperature and hydrostatic pressure can be controlled to simulate deep ocean conditions. The normal calibration range is from 2 to 30°C and from 0 to 70 MPa (simulated depth of 7000 m). The maximum depth that can be simulated at frequencies from 4 to 500 kHz is 700 m. USRD electroacoustic calibration systems cover the frequency range from 0.3 Hz to 2.0 MHz.

Availability of Transducers

USRD maintains a calibrated stock of approximately 1400 standard transducers that are available to qualified activities for use in research and development or underwater electroacoustic measurement programs. A service fee covering a period of one year includes the cost of calibration and maintenance of the transducers. A replacement is provided if the transducer fails or is damaged during the service period. Standards normally are to be returned to USRD after one year for preventive maintenance, repair or modification, and recalibration.

Additional information about the scientific and technical services available from the USRD can be found in the USRD Services Schedule, which is available on request.

Acknowledgments

The author wishes to acknowledge the many contributions to the design and development of these standard transducers by USRD personnel. Some of those who designed transducers or contributed to the team effort are R. J. Bobber, J. E. Donovan, T. A. Henriquez, G. D. Hugus, R. J. Kieser, C. C. Sims, J. R. Bass, W. DeRosa, L. E. Ivey, J. H. Heins, L. J. McKay, A. C. Tims, L. J. Hill, J. K. Evans, and L. J. Albrecht.

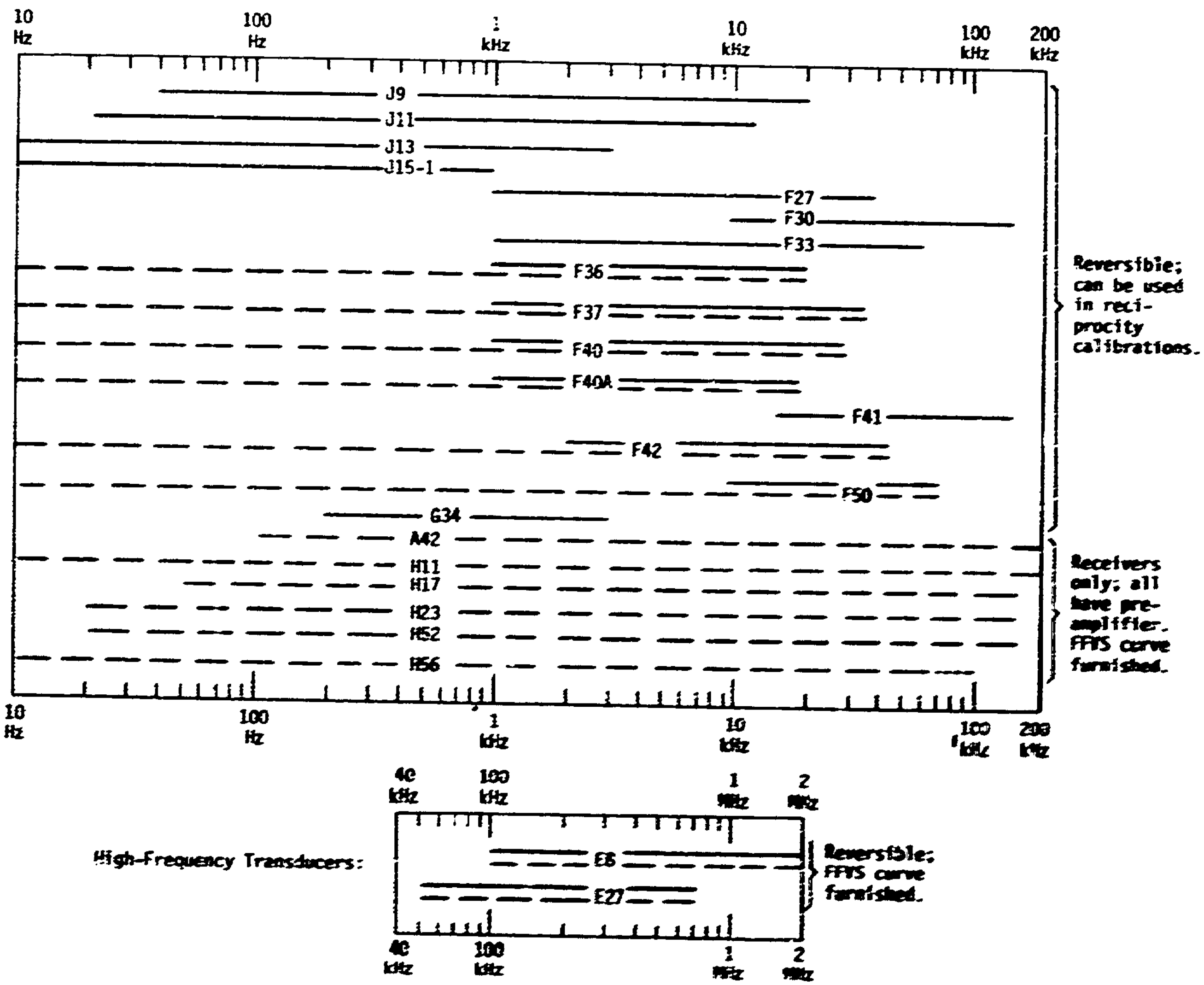


Fig. 1. Frequency ranges of standard transducers developed by NRL-USRD. Solid line: frequency range as source. Dashed line: frequency range as receiver.

References

1. I. D. Groves, "The USRL Infrasonic Hydrophone Type H11," Navy Underwater Sound Reference Laboratory Report 37, 3 Jan 1956 (AD-90 170).
2. R. J. Bobber, "The USRL Type E8 Transducer--An Underwater Sound Calibration Standard for the 100- to 1000-kHz Frequency Range," Navy Underwater Sound Reference Laboratory Report 22, 16 Jun 1952 (AD-20 093).
3. I. D. Groves, "The USRL Broadband Hydrophone Type H17," Navy Underwater Sound Reference Laboratory Report No. 59, 15 Feb 1962 (AD-271 910).
4. R. J. Bobber, C. C. Sims, I. D. Groves, "Transducers for High Pressure and Low Temperature," Navy Underwater Sound Reference Laboratory Report 58, 28 Dec 1961 (AD-268 746).
5. I. D. Groves, "The Design of Deep-Submergence Hydrophones," NRL Report 7339, 3 Sep 1972 (AD-729 643).
6. C. C. Sims, "High-Fidelity Underwater Sound Transducer," Proc. IRE 47, 866-871 (1959).
7. R. J. Bobber, *Underwater Electroacoustic Measurements* (Naval Research Laboratory, Government Printing Office, Washington, D. C., 1970).

Type A42
PROBE HYDROPHONE

General Description

The USRD type A42 probe hydrophone was designed to be used as an underwater sound measurement standard for applications in which the sound field being measured must be disturbed as little as possible by the presence of the probe. Figure A1 is a photograph of the hydrophone.

Fig. A1. USRD type A42 probe hydrophone.

The sensitive element is a 3.2-mm-diam by 3.2-mm-long lead zirconate-titanate ceramic cylinder with 0.79-mm wall, capped with 3.2-mm by 0.79-mm magnesium caps, and mounted on rubber supports in a castor-oil-filled butyl-rubber boot.

A solid-state preamplifier within the probe provides the high input impedance and furnishes an intermediate impedance to a second stage of amplification located in a separate box at the end of the cable.

Normally, the hydrophone is supplied with 9 m of 2-conductor, shielded, vinyl-covered cable, which is bonded to the hydrophone and terminated by an AN3106A14S-5P connector that mates with an MS3100C-14S-5P receptacle on the amplifier box. Longer cables can be used, however, with a reduction in dynamic range.

Specifications

Frequency range:	100 Hz to 200 kHz
Free-field voltage sensitivity:	-217 dB re 1 V/μPa (nominal, to 20 kHz) at output of amplifier, with 9-m cable to hydrophone
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Amplifier:	Ithaco Model 153B; voltage gain, 0.99 ± 1%
Amplifier output impedance:	100 Ω nominal
Power requirement:	20 to 30 V d-c, 4 to 6 mA
Weight:	Hydrophone with 9-m cable, 0.4 kg; amplifier box, 0.86 kg
Shipping Weight:	6 kg

Amplifier

The high-input-impedance stage is located within the probe housing; the low-impedance output is from the amplifier at the end of the cable. The amplifier, cable, and probe are an integral electronic unit; they cannot be operated separately.

The over-all voltage sensitivity of a hydrophone consists of the sum in decibels of (1) the voltage generated by the crystal on open circuit, (2) the voltage coupling loss between crystal and preamplifier, and (3) the voltage loss or gain of the preamplifier operating with its normal load. The impedance of the A42 sensor element is sufficiently low to ensure a negligible coupling loss; therefore, no provision has been made to measure it. The voltage gain of the amplifier is 0.99 ± 1%, so the sensitivity of the hydrophone is specified only at the output of the amplifier. The wiring diagram for the A42 is shown in Fig. A2.

Electroacoustic Characteristics

The *free-field voltage sensitivity*, determined from free-field measurements, is shown in Fig. A3. Typical sensitivity in the flat region extending from 10 Hz to 40 kHz is -217 dB re 1 V/μPa.

The *effect of temperature and hydrostatic pressure* on the sensitivity of the A42 probe hydrophone has been determined in closed tanks under controlled conditions of temperature and pressure. These measurements indicate that the free-field voltage sensitivity does not change significantly when the hydrophone is subjected to a hydrostatic pressure of 6.9 MPa (equivalent to 690-m water depth) and temperatures from 5 to 35°C.

Figure A4 shows the *equivalent noise pressure* level for the A42 probe hydrophone as measured with a 1/3-octave filter, a General Radio 1554A sound and vibration analyzer, and a low-noise transistor amplifier. The hydrophone was shock mounted under partial vacuum within a steel chamber isolated by air springs from building vibrations to frequencies as low as 2 Hz.

Dynamic Range. Figure A5 shows typical A42 hydrophone overload pressure levels for 1% distortion in output voltage. The maximum dynamic range is obtained when the preamplifier is powered from a 30-V d-c source.

Directivity. The A42 probe hydrophone is omnidirectional within ±1 dB in the horizontal (XY) plane at frequencies up to 150 kHz. Directivity patterns in the vertical (XZ) plane are shown in Fig. A6. Because of the radiating end caps on the cylinder, the beamwidth in the XZ plane is approximately half that obtainable from a 3.2-mm line with the ends acoustically shielded.

Preparation for Use

Mount the hydrophone in a fixture that can be clamped around the case near the cable gland. Wash the hydrophone thoroughly with a wetting agent or water and detergent to prevent adherence of air bubbles, which can cause erroneous results. Before any measurements are made, permit the transducer to be immersed long enough for the temperature to stabilize with that of the medium. Figure A7 is a dimensioned outline drawing showing the orientation of the hydrophone.

Cautions

Do not attempt any electrical measurements at the AN3106A14S-5P hydrophone cable connector, because the first stage of the preamplifier may be damaged thereby.

Note that the probe amplifier system has a positive ground and that the amplifier box ground shields the entire amplifier-cable-probe electronics system.

Reference

I. D. Groves, Jr. and A. C. Tims, "Standard Probe Hydrophone for Acoustic Measurements from 10 Hz to 200 kHz," J. Acoust. Soc. Amer. 48, 725-728 (1970).

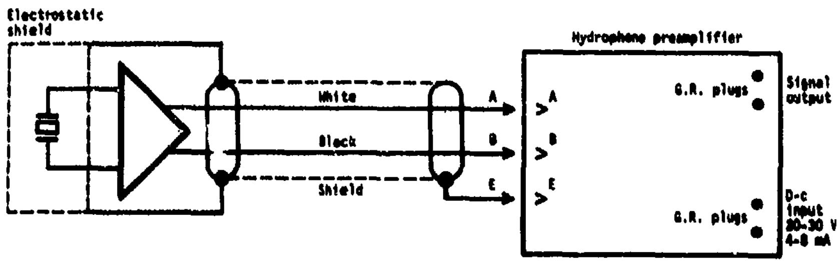
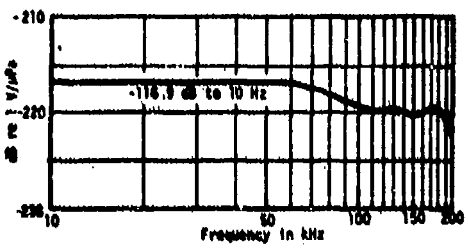


Fig. A2. Schematic circuit diagram, type A42 probe hydrophone.

Fig. A3. Typical free-field voltage sensitivity, type A42 hydrophone; open-circuit voltage at output of preamplifier.



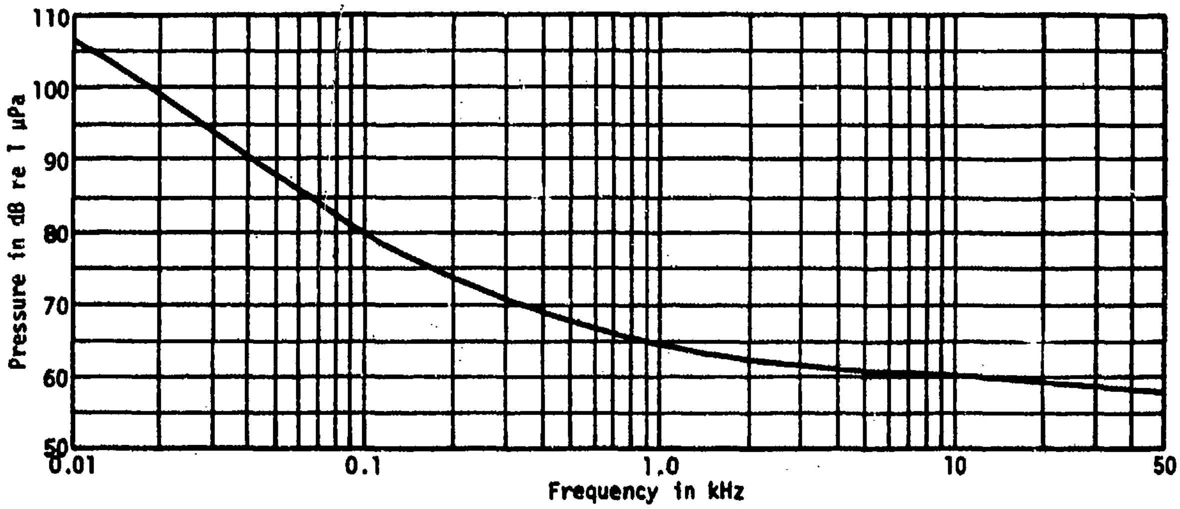


Fig. A4. Equivalent noise pressure level, type A42 hydrophone.

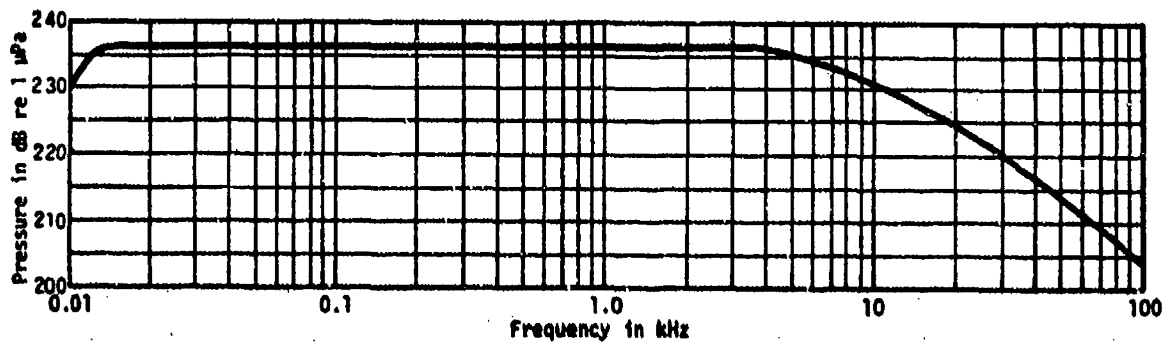


Fig. A5. Typical hydrophone pressure overload level for 1% distortion in output voltage, type A42 hydrophone.

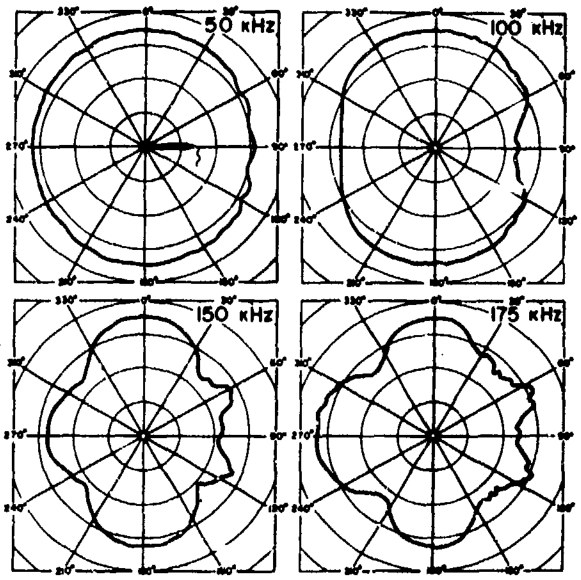


Fig. A6. Directional characteristics in the vertical (XZ) plane, type A42 probe hydrophone; center to top of grid, each pattern, equals 40 dB.

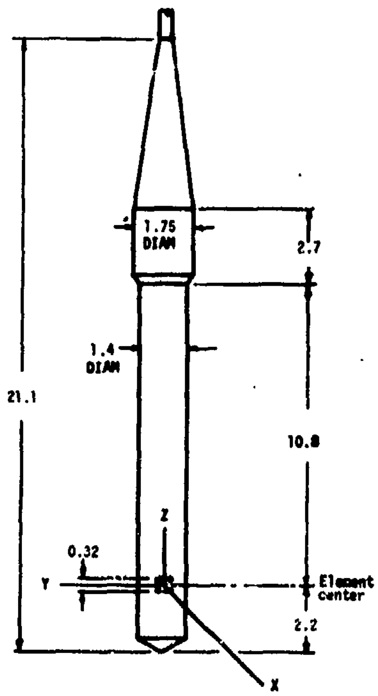


Fig. A7. Dimensions (in centimeters) and orientation of USRD type A42 hydrophone.

Type E8
TRANSDUCER

General Description

The USRD type E8 transducer is a calibrated reference standard for the frequency range 200 to 1000 kHz. It is not intended for use under high pressure. Figure B1 is a photograph of the transducer.

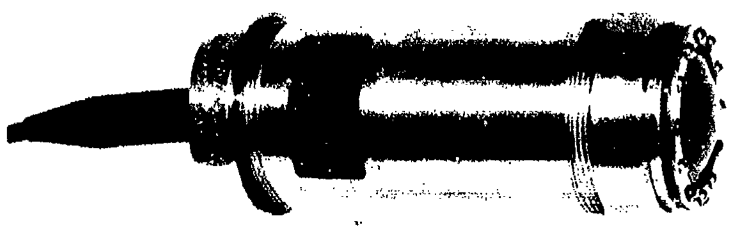


Fig. B1. USRD type E8 transducer.

The active element is a 2-cm-diam disk of lithium sulfate 0.15 cm thick cemented to a corprene disk. A pulse transformer with the impedance ratio 20:1 approximately matches the impedance of the crystal to that of the transmitting or receiving circuit through a coaxial cable. To reduce crosstalk, the case of the transducer is connected to the shield of this cable, as shown in the circuit diagram, Fig. B2.

Specifications

Frequency:	100 to 2000 kHz
Free-field voltage sensitivity:	-209 dB re 1 V/μPa at 400 kHz
Maximum hydrostatic pressure:	340 kPa (34-cm depth)
Operating temperature range:	5 to 35°C
Maximum power input:	1 W c-w; higher when pulsing with appropriate duty cycle
Nominal impedance:	600 Ω at 400 kHz with 2.4-m cable
Weight:	2 kg, without cable
Shipping weight:	6.8 kg

Electroacoustic Characteristics

Figure B3 shows typical equivalent series impedance of the E8 at the end of the 2.4-m RG-62/U coaxial cable normally supplied. Figure B4 shows the impedance at the end of a 7.6-m cable. The typical free-field voltage sensitivity shown in Fig. B5 is reduced by approximately 1 dB for each additional 1.5 m of this cable.

The directivity of the E8 transducer is very closely that of a theoretical baffled piston 2 cm in diameter, as is shown in Fig. B6.

Preparation for Use

To support the transducer, clamp a bracket around the case midway of its length. The axis of the housing is the same as the acoustic axis, which is normal to the radiating face. Acoustical alignment is advisable if precise orientation at high frequencies is required. Figure B7 is a dimensioned outline drawing showing the orientation of the transducer.

At high frequencies, minute air bubbles can resonate and cause erroneous results; to avoid air bubbles on or near the rubber window, wash the transducer with a wetting agent immediately before immersing it in water. Also, so that air bubbles will not be released by the slight heating effect of the transducer, insure that it is cooler than the water into which it is immersed. Permit the temperature of the transducer to stabilize with that of the water before making measurements.

Operating Notes

The E8 transducer is designed to operate electrically unbalanced, either as a projector or a receiver. When it is used as a projector, the impedance of the driver is not important, unless high efficiency of the driving system is required. In such case, the optimum driving impedance for the required frequency range can be determined from the impedance curves, Figs. B3 or B4. If the receiving response calibration furnished by the USRD is to be used, the transducer must be terminated in an impedance high in comparison with the impedance of the transducer.

The E8 transducer was developed for laboratory use where high power levels are not necessary. One watt c-w should not be used continuously; when pulsing, it is permissible to exceed one watt if the duty cycle is decreased appropriately as the peak power is increased. Distortion of driving current or voltage is a suggested criterion for determining the maximum power level. Overheating of the transformer is the limiting factor on power level.

Maintenance

The natural rubber used in the acoustic window is not durable. When exposed to water for long periods of time, the rubber tends to become sticky. This condition does not affect the acoustic properties, but does make the window more susceptible to damage by abrasion. If such deterioration sets in, return the transducer to USRD.

Reference

R. J. Bobber, "The USRL Type E8 Transducer--An Underwater Sound Calibration Standard for the 100- to 1000-Kilocycle Frequency Range," Navy Underwater Sound Reference Laboratory Report No. 22, 16 Jun 1952 (AD-10 093).

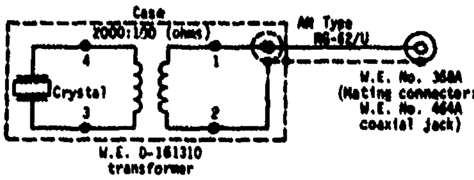


Fig. B2. Circuit diagram, type E8 transducer.

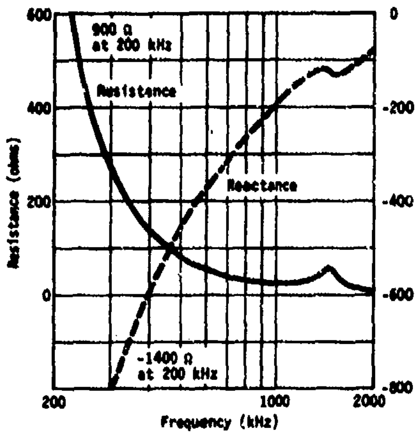


Fig. B3. Typical equivalent series impedance, type E8 transducer with 2.4 m of RG-62/U coaxial cable.

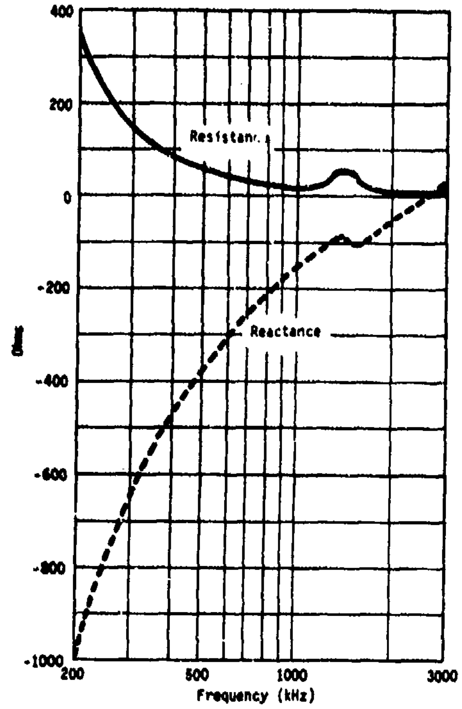


Fig. B4. Typical equivalent series impedance, type E8 transducer with 7.6-m cable.

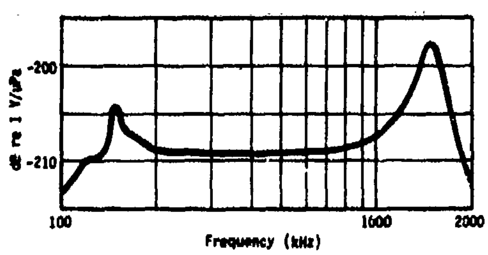


Fig. B5. Typical free-field voltage sensitivity, type E8 transducer with 2.4-m cable.

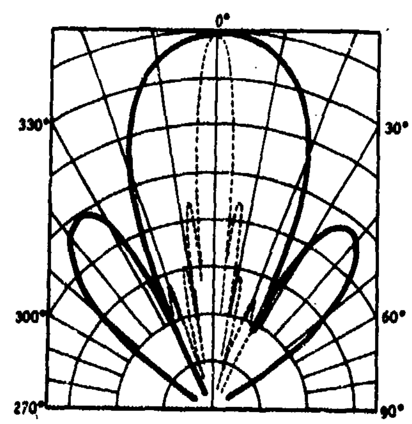


Fig. B6. Directivity, type E8 transducer, in planes that include the X axis. Scale, center to top of grid, equals 40 dB.

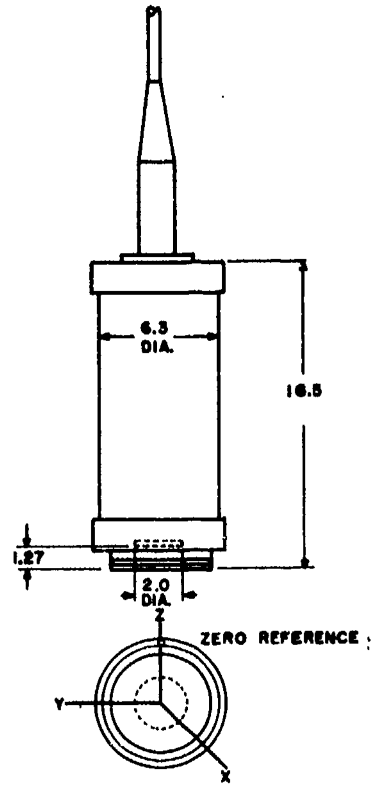


Fig. B7. Dimensions (in centimeters) and orientation of type E8 transducer.

Type E27
TRANSDUCER

General Description

The USRD type E27 transducer is a calibrated reference standard for the frequency range 50 to 500 kHz. It is not intended for use under high pressure or at high power levels. Driving voltages up to 200 V rms can be used. Figure C1 is a photograph of the transducer.

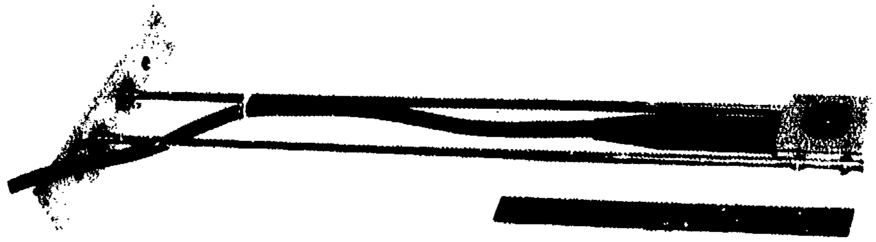


Fig. C1. USRD type E27 transducer.

The active face contains seven lead zirconate-titanate disks of 3.17-mm diameter and 1.52-mm thickness spaced inside an 11.1-mm-diam circle. The seven elements are cemented directly to the butyl acoustic window. Normally, the transducer is provided with 9.1 m of RG-62U coaxial cable terminated in a Western Electric type 358A coaxial plug.

Specifications

Operating range:	50 to 700 kHz
Free-field voltage sensitivity:	-213 dB re 1 V/μPa at end of 9.1-m cable
Transmitting voltage response:	126 dB re 1 μPa/V at 200 kHz
Maximum driving voltage:	200 V rms
Nominal capacitance:	850 pF
D-c resistance:	greater than 1000 MΩ

Maximum hydrostatic pressure:	170 kPa gage (17-m depth)
Operating temperature range:	0 to 35°C
Weight with 9.1-m cable:	0.57 kg
Shipping weight in carrying case:	4.5 kg

Electroacoustic Characteristics

Typical equivalent series impedance measured unbalanced at the end of the 9.1-m RG-62U coaxial cable is shown in Fig. C2. Typical free-field voltage sensitivity is shown in Fig. C3. Typical transmitting voltage response is shown in Fig. C4.

The directivity of the E27 transducer is very closely that of a theoretical baffled piston of 11.1-mm diameter, as shown in Fig. C5.

Preparation for Use

Normally, the transducer is equipped with a special hanger. The distance from the element center of the transducer to the top of the mounting plate on the hanger is 35 cm. Any additional fixture that might be required should be attached to this mounting plate. Acoustical alignment is advisable if precise orientation at the higher frequencies is required. Figure C6 is a dimensioned outline drawing showing the orientation of the transducer.

Bubbles in the sound field can cause erroneous measurements. To insure removal of air on or near the acoustic window, wash the transducer thoroughly with a wetting agent immediately before immersion in water. The transducer should be cooler than the water into which it is immersed, so that air bubbles will not be released by the slight heating effect from the transducer. Permit the temperature of the transducer to stabilize with that of the water before making measurements.

Operating Notes

The E27 transducer is designed to operate electrically unbalanced, either as a projector or as a receiver. When the transducer is used as a projector, the impedance of the driving source is not critical unless high efficiency of the driving system is required. In such a case, the optimum driving impedance for the required frequency range can be determined from the impedance curve furnished as part of the calibration data, or from the typical impedance curve of Fig. C2. If the receiving sensitivity calibration furnished with each transducer by USRD is to be used, the transducer must be terminated in an impedance that is high in comparison with its own impedance.

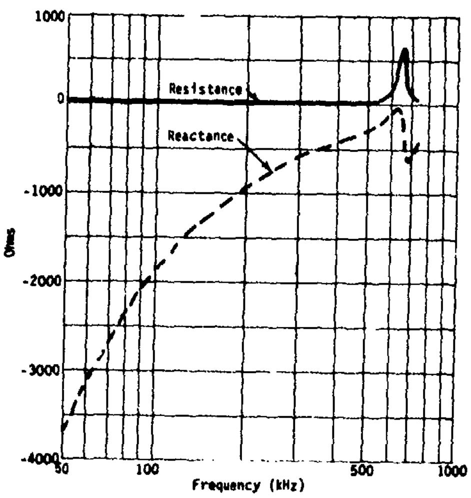


Fig. C2. Typical equivalent series impedance, type E27 transducer.

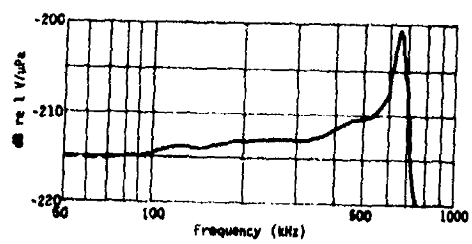


Fig. C3. Typical free-field voltage sensitivity, type E27 transducer.

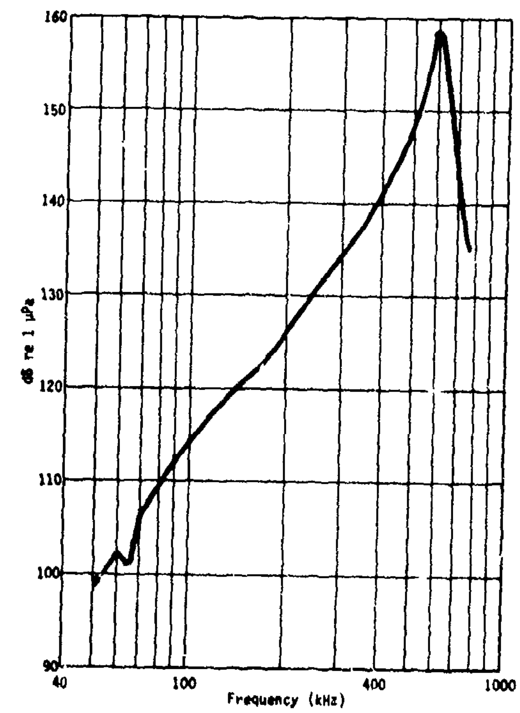


Fig. C4. Typical transmitting voltage response, type E27 transducer.

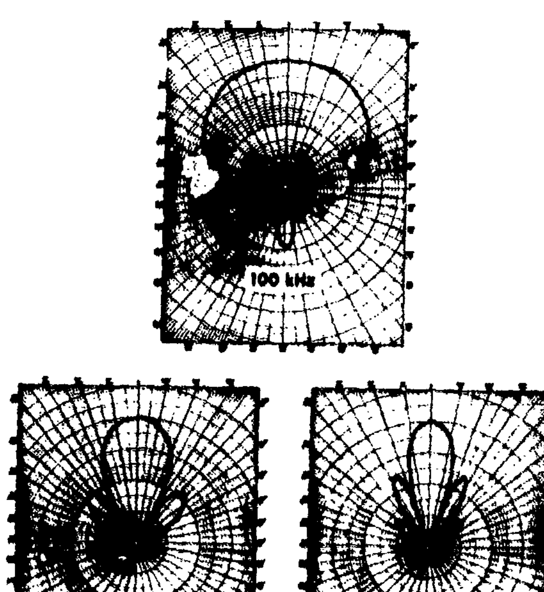


Fig. C5. (Right) Directivity type E27 transducer, in planes that include the x axis. Scale: center to top of grid equals 50 dB.

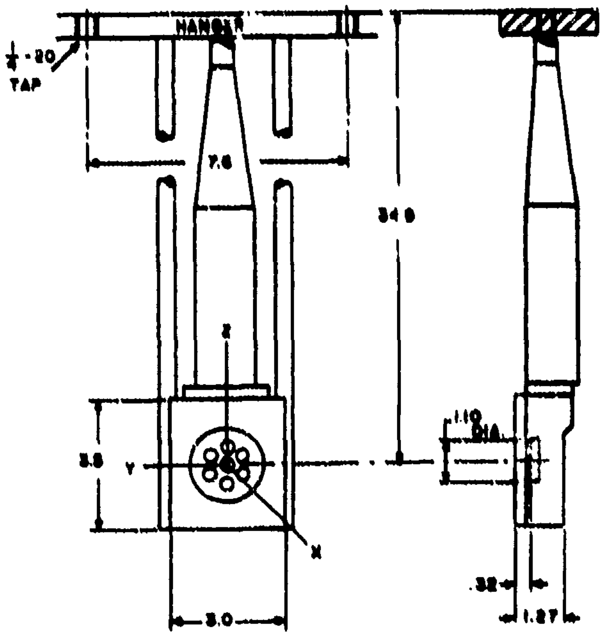


Fig. C6. Dimensions (in centimeters) and orientation of type E27 transducer (tap: UNC).

Type F27
TRANSDUCER

General Description

The USRD type F27 transducer was designed as a general-purpose unidirectional transducer for underwater sound calibration measurements in the frequency range 1 to 40 kHz, and for operation in the temperature range 1 to 35°C at hydrostatic pressures to 35 MPa. The active element consists of fifty-five 2.54-cm-diam lead metaniobate disks 0.559 cm thick, each of which is cemented to a 2.54-cm-diam, 1.27-cm-thick tungsten backing plate. The elements are arranged in a circular array that is approximately 21.4 cm in diameter. Figure D1 is a photograph of the transducer.

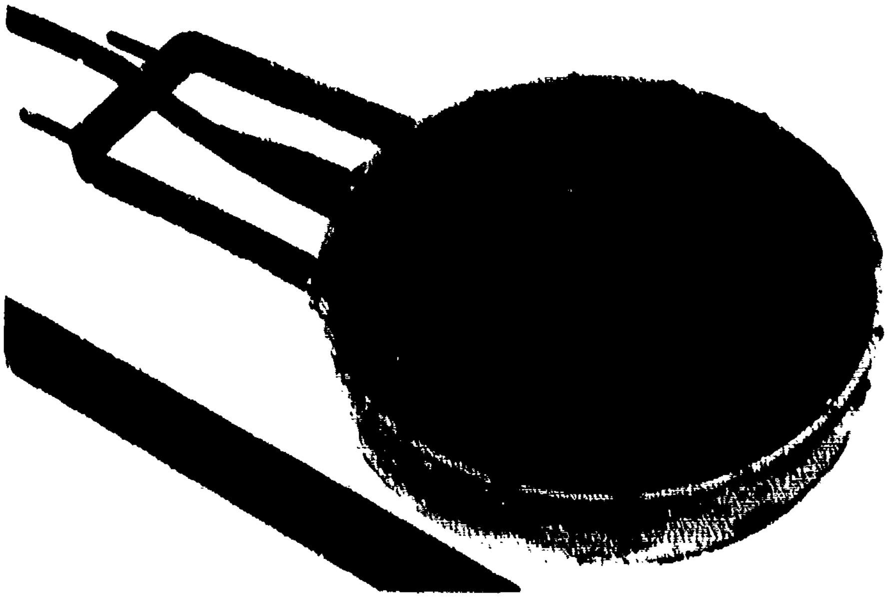


Fig. D1. USRD type F27 transducer.

The tungsten backing plates are molded in butyl rubber that supports the individual elements and provides a water seal for the rear of the transducer. The front, also, is covered with butyl rubber. The transducer is oil filled.

The F27 transducer is reversible and obeys the reciprocity principle. When used as a projector, it may be driven either balanced or unbalanced at voltages to 500 V rms.

The transducer is provided with 30 m of two-conductor shielded neoprene-sheathed DSS-2 or vinyl-sheathed Belden 8277 cable terminated in a type AN3106-14S-5P connector.

Specifications

Frequency range:	1 to 40 kHz
Transmitting voltage response:	118 dB re 1 μPa/V at 10 kHz
Maximum driving voltage:	500 V rms
Nominal capacitance:	10400 pF at end of 12-m cable
D-c resistance:	greater than 500 MΩ
Maximum hydrostatic pressure:	35 MPa (3500-m depth)
Operating temperature range:	-5 to +40°C
Weight with 30-m cable:	15 kg
Shipping weight:	23 kg

Electroacoustic Characteristics

Figure D2 is a typical *transmitting current response*. *Transmitting voltage response* is shown in Fig. D3. In the frequency range 1 to 20 kHz, the responses are independant of pressure up to 6.9 MPa and of temperature in the range 3 to 25°C. In the frequency range 20 to 35 kHz, the response varies by ±1 dB in the same pressure and temperature ranges.

Typical *equivalent series impedance* is shown in Fig. D4.

The *directivity* of the F27 transducer at frequencies up to 25 kHz is approximately that expected from an unbaffled 21.4-cm-diam piston radiator, except that the back radiation is slightly higher; above 25 kHz, the back radiation is approximately 20 dB below the front radiation level. Typical directivity patterns in the XY plane are shown in Fig. D5.

Preparation for Use

The transducer is supported during use by its bracket, to which the rigging is attached. Wash the entire transducer with a wetting agent to remove all air bubbles and thus avoid erroneous results. For best calibration data, permit the temperature of the transducer to stabilize with that of the water before making any measurements. Figure D6 is a dimensioned outline drawing showing the orientation of the transducer.

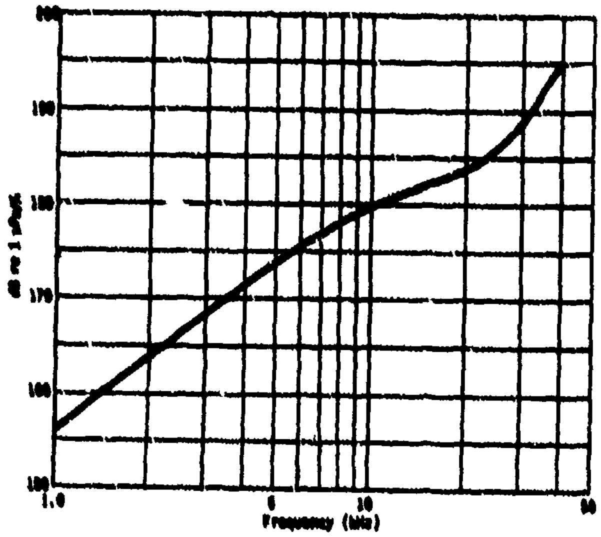


Fig. D2. Typical transmitting current response, type F27 transducer.

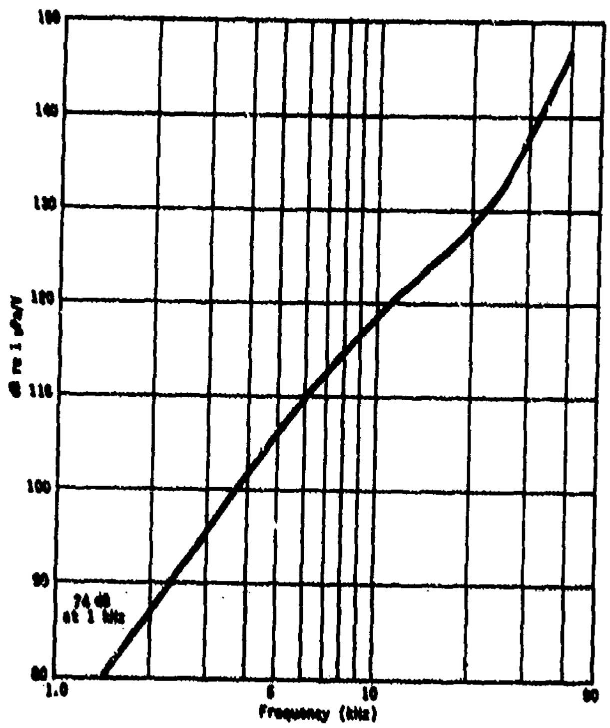


Fig. D3. Typical transmitting voltage response, type F27 transducer.

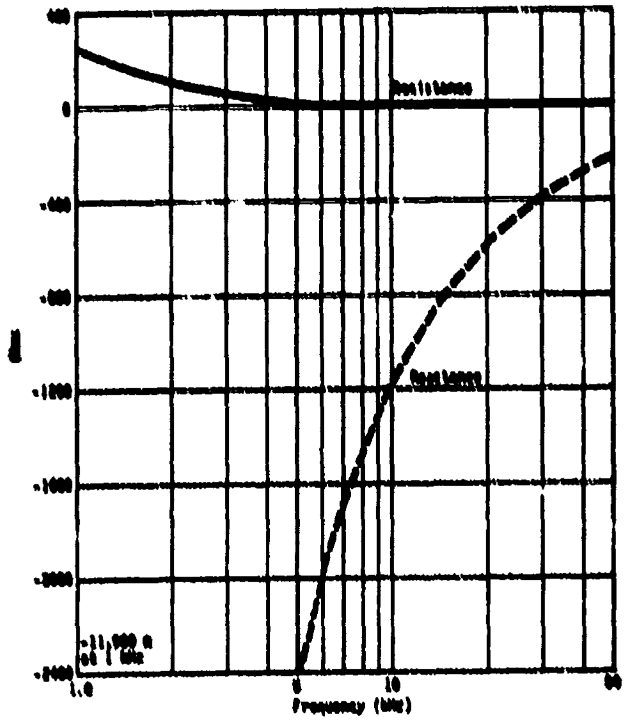


Fig. D4. Typical equivalent series impedance, type F27 transducer.

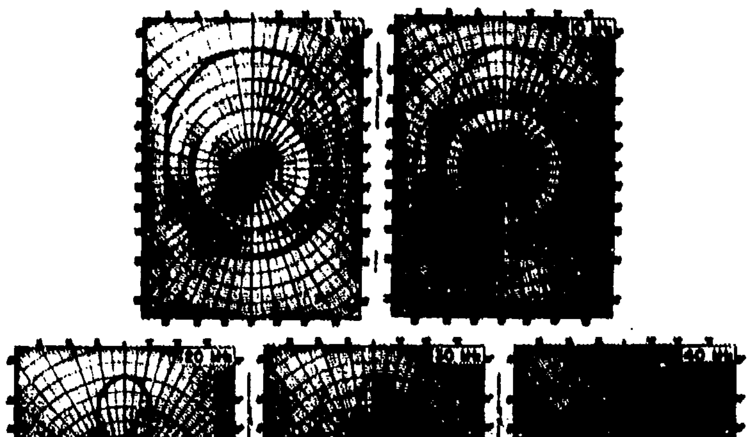


Fig. D5. Typical directivity patterns in the XY plane, type F27 transducer. Scale: Center to top of grid, each pattern, equals 50 dB.

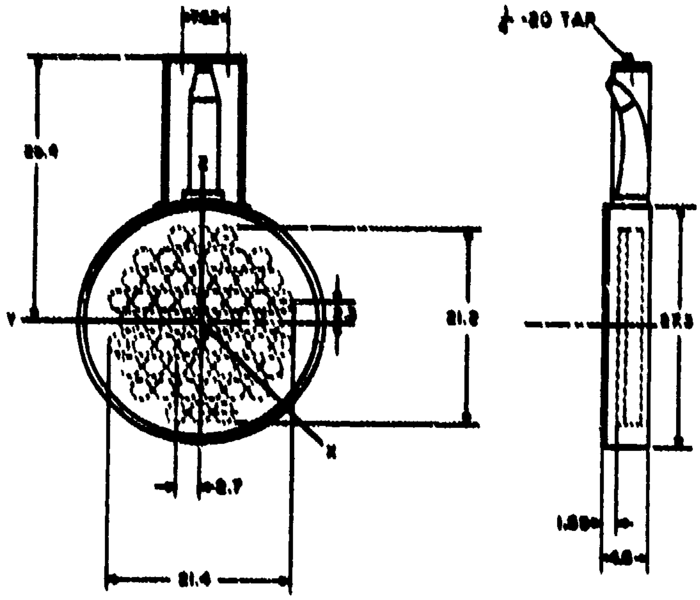


Fig. D6. Dimensions (in centimeters) and orientation of type F27 transducer (tap: UNC).

Type F30
TRANSDUCER

General Description

The USRD type F30 transducer was designed as a general purpose unidirectional transducer for calibration measurements in which stability and reciprocity are required over extended frequency, pressure, and temperature ranges. Figure E1 is a photograph of the transducer.

Fig. E1. USRD type F30 transducer.

The sensitive element is a rectangular array 5.0 cm high and 3.8 cm wide consisting of twelve 1.24×1.27×0.159-cm lithium sulfate crystals cemented to 1.27-cm tungsten cubes. The array is supported by rubber pads in an oil-filled corrosion-resistant steel housing. A transformer having the turns ratio 30:1 reduces the output impedance to the nominal value 100 Ω at 20 kHz. The transducer is designed for unbalanced operation; the circuitry is shown in Fig. E2. A 12-m, two-conductor shielded, neoprene-sheathed cable is provided.

Specifications

Frequency range:	10 to 150 kHz
Transmitting voltage response:	136 dB re 1 μPa/V at 50 kHz
Maximum power input:	0.1 W from a 600-Ω source in the range 10 to 20 kHz; 1.0 W from a 600-Ω source in the range 20 to 150 kHz
Nominal impedance:	100 Ω at 20 kHz
Maximum hydrostatic pressure:	24 MPa (2400-m depth)
Operating temperature range:	0 to 35°C
Weight with 12-m cable	3.2 kg
Shipping weight:	8 kg

Electroacoustic Characteristics

Figure E3 shows typical *transmitting current and voltage responses*. The *free-field voltage sensitivity* is shown in Fig. E4 and the *equivalent series impedance* in Fig. E5.

The response changes less than ±0.5 dB with pressure to 6.9 MPa; no greater change is expected with pressures to 24 MPa. In the frequency range 25 to 150 kHz, the response varies less than ±0.6 dB throughout the temperature range 3 to 25°C.

The *directivity* in the horizontal plane is broader than in the vertical plane because of the dimensions of the crystal array. The patterns are symmetrical and, at frequencies above 25 kHz, the back radiation is 12 to 20 dB below the front radiation. Typical directivity patterns in the XY (horizontal) and XZ (vertical) planes are shown in Fig. E6.

Preparation for Use

In normal operation, the small transformer housing extends vertically above the transducer case. Clamp a bracket around the steel case near the molded cable gland to support the transducer. Wash the entire transducer with a suitable wetting agent to remove air bubbles as completely as possible and thus avoid erroneous results. Permit the temperature of the transducer to stabilize with that of the water before making any measurements. Figure E7 is a dimensioned outline drawing showing the orientation of the transducer.

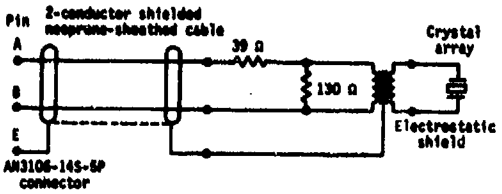


Fig. E2. Schematic circuit diagram, type F30 transducer.

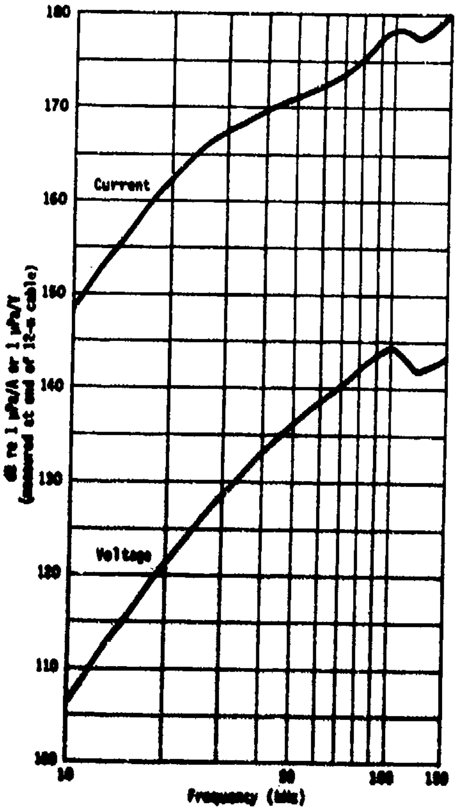


Fig. E3. (Right) Typical transmitting current and voltage responses, type F30 transducer.

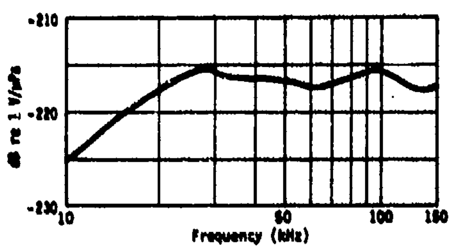


Fig. E4. Typical free-field voltage sensitivity, type F30 transducer.

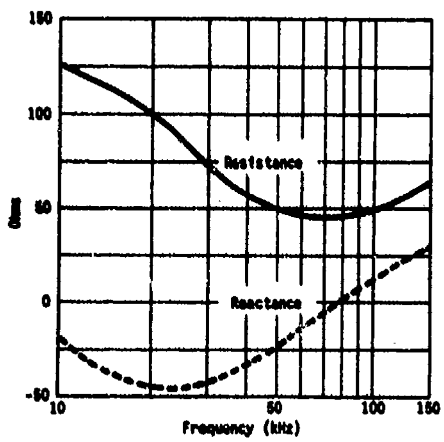


Fig. E5. Typical equivalent series impedance, type F30 transducer.

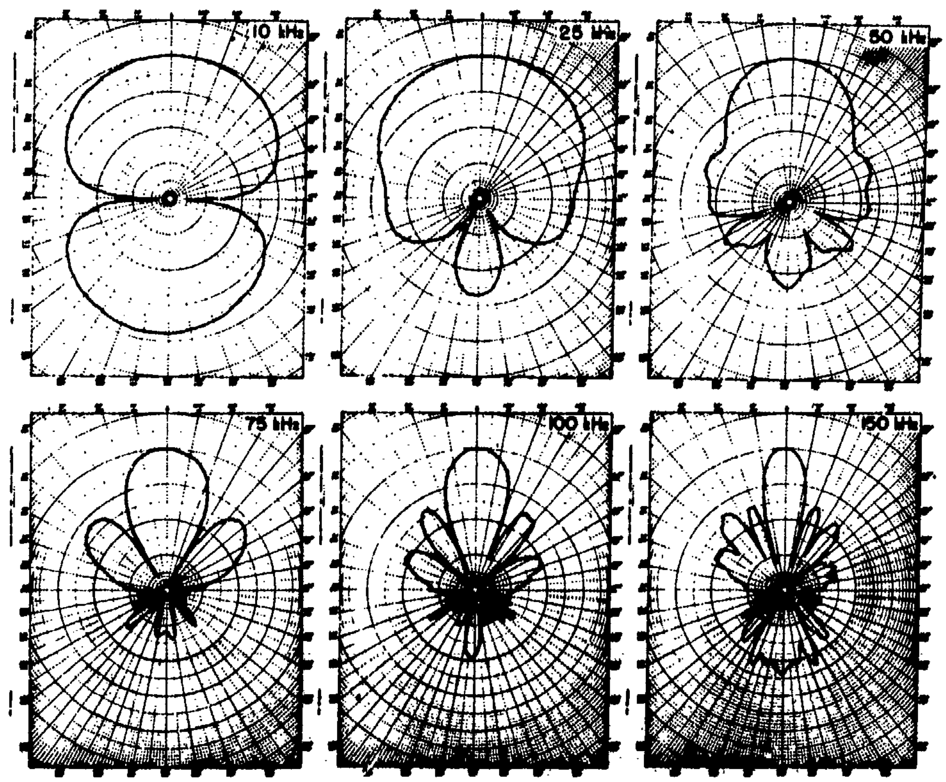


Fig. E6a. Typical directivity patterns in the XY (horizontal) plane, type F30 transducer. Scale: Center to top of grid, each pattern, equals 50 dB.

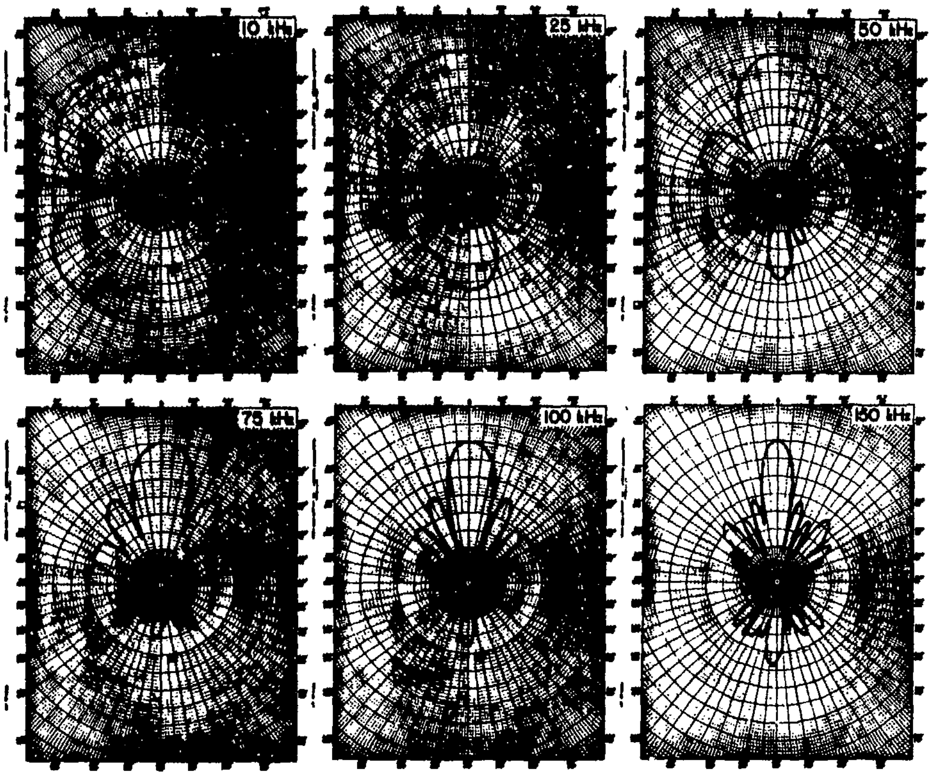


Fig. E6b. Typical directivity patterns in the XZ (vertical) plane, type F30 transducer. Scale: Center to top of grid, each patterns, equals 50 dB.

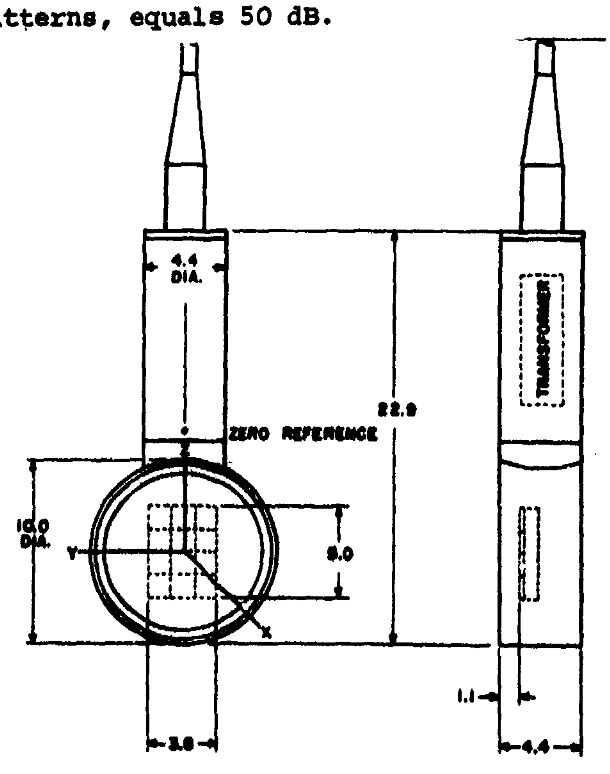


Fig. E7. (Right) Dimensions (in centimeters) and orientation of type F30 transducer.

Type F33
TRANSDUCER

General Description

The USRD type F33 transducer was designed as a general purpose unidirectional transducer for use in calibration measurements in the frequency range 1 to 150 kHz. Figure F1 is a photograph of the transducer.

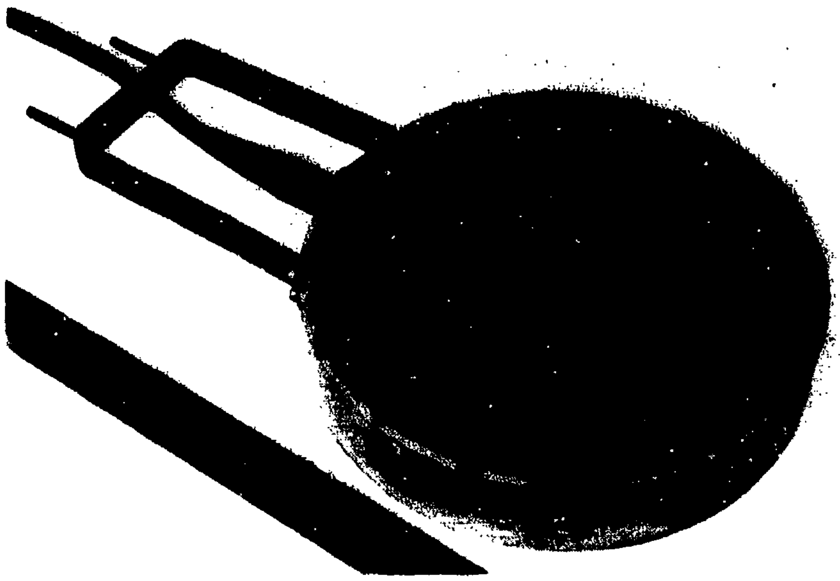


Fig. F1. USRD type F33 transducer.

The sensitive element consists of two piezoelectric ceramic arrays mounted coaxially. The smaller, inner array is composed of twelve 1.27-cm-diam by 2.5-mm-thick lead zirconate-titanate elements cemented to Kennametal disks. This array is approximately 3.8 cm wide and 5 cm high; it is useful in the frequency range 15 to 150 kHz.

The larger array is constructed from 64 modified barium titanate ceramic plates 2.54 cm long by 1.9 cm wide by 6.35 mm thick. Each plate is cemented to a steel backing plate embedded in butyl rubber to form an array approximately 20.3 cm wide by 21.6 cm high. When the two arrays are driven simultaneously, the transducer is useful in the frequency range 1 to 50 kHz. Normally, the transducer is calibrated unbalanced, with the shield and the low-output lead connected to ground.

The transducer is provided with 30 m of vinyl-sheathed cable. The leads to each array section are individually shielded, as shown in the circuitry of Fig. F2. A 30-cm length of cable provided with mating connectors serves to connect the inner and the outer sections in parallel. The entire transducer then can be driven by a signal applied to pins A and B of the AN adapter. The shields are accessible at pin E.

Pressure-release Corprene is used between the individual ceramic elements. Both sections are sealed in transparent polyurethane; castor oil provides the coupling medium between the polyurethane potting material and the butyl-rubber acoustic window.

Specifications

Frequency range:	both sections, 1 to 50 kHz inner section, 15 to 150 kHz
Transmitting voltage response:	128 dB re 1 μPa/V at 10 kHz (both) 133 dB re 1 μPa/V at 50 kHz (inner)
Maximum driving voltage:	200 V rms
Nominal capacitance at end of 30-m cable:	outer section, 54500 pF inner section, 12000 pF both sections, 66500 pF
D-c resistance:	greater than 500 MΩ
Maximum hydrostatic pressure:	3.4 MPa (340-m depth)
Operating temperature range:	0 to 35°C
Weight with 30-m cable:	17.3 kg
Shipping weight:	25 kg

Electroacoustic Characteristics

Figure F3 shows both the *transmitting current and voltage responses* of both sections in parallel and of the inner section alone. No significant changes have been observed in the operating characteristics at hydrostatic pressures to 3.4 MPa (340-m depth) and temperatures between 5 and 30°C.

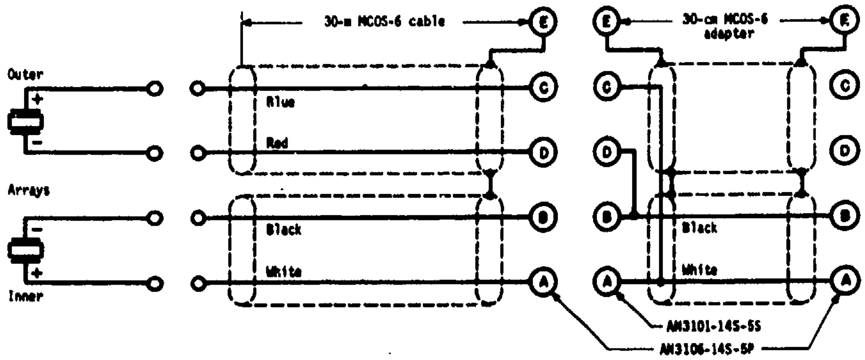
Typical *equivalent series impedance* is shown in Fig. F4.

With both sections operating, the total beam width at the 3-dB-down points is 7.5 deg at 50 kHz. The minor lobes are down at least 14 dB with respect to the major lobe. When only the inner section is used, the total beam width at 150 kHz is 12 deg. Typical *directivity patterns* in the horizontal (XY) plane for both sections in parallel and for the inner section only are presented in Figs. F5 and F6.

Preparation for Use

Attach a fixture to the mounting bracket provided. Do not support the transducer by the cable. To remove air bubbles as completely as possible and thus avoid erroneous results, wash the entire transducer with a wetting agent as it is lowered into the water. Permit the temperature of the transducer to stabilize with that of the water before making any measurements. Figure F7 is a dimensioned outline drawing showing the orientation of the transducer.

Fig. F2. (Right) Schematic diagram of cable, type F33 transducer.



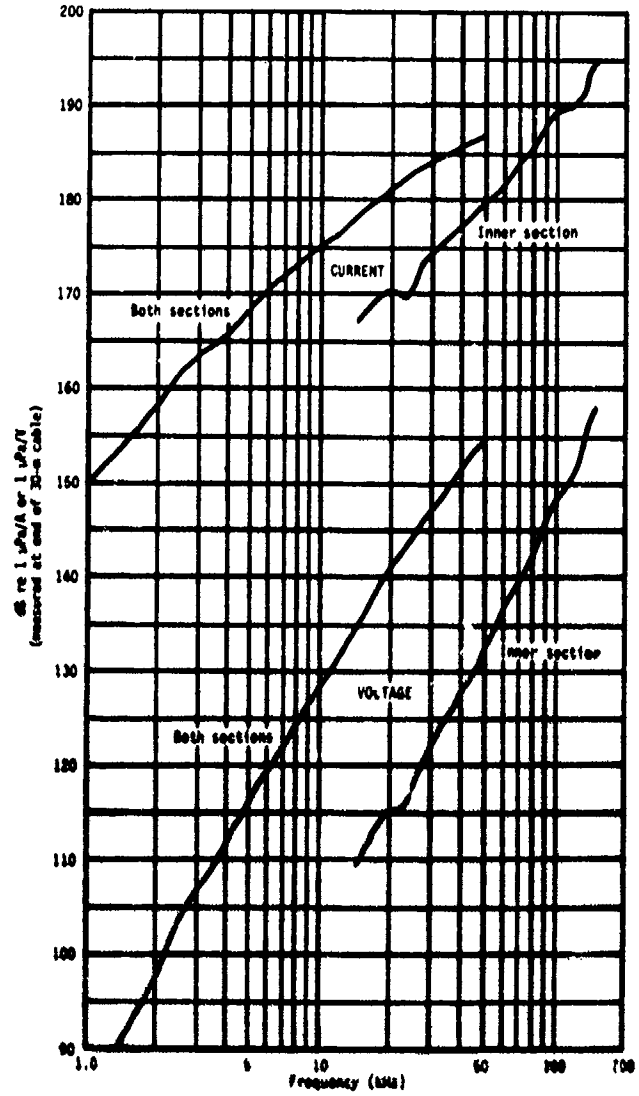
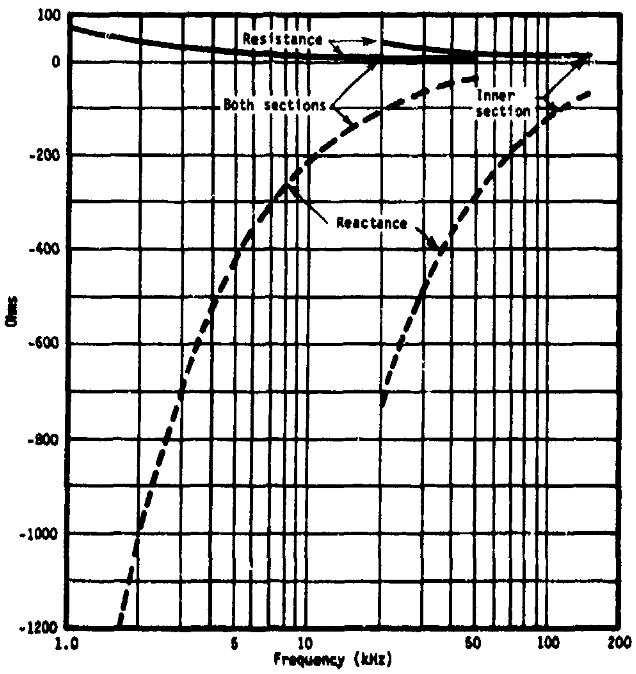


Fig. F3. (Left) Transmitting current and voltage responses, type F33 transducer.

Fig. F4. (Right) Typical equivalent series impedance, type F33 transducer.



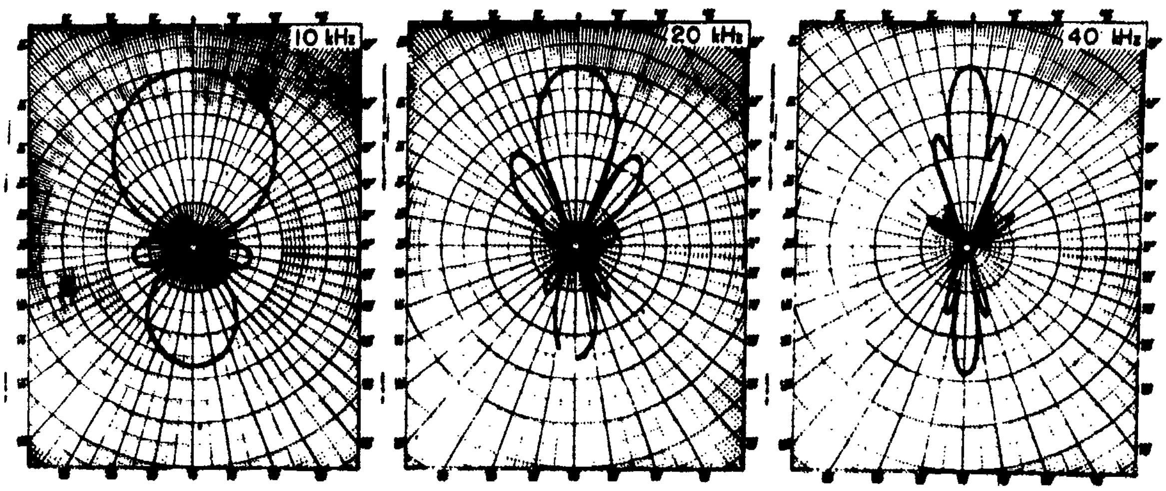


Fig. F5. Typical directivity patterns in the horizontal (XY) plane, type F33 transducer, both sections in parallel. Scale: Center to top of grid, each pattern, equals 50 dB.

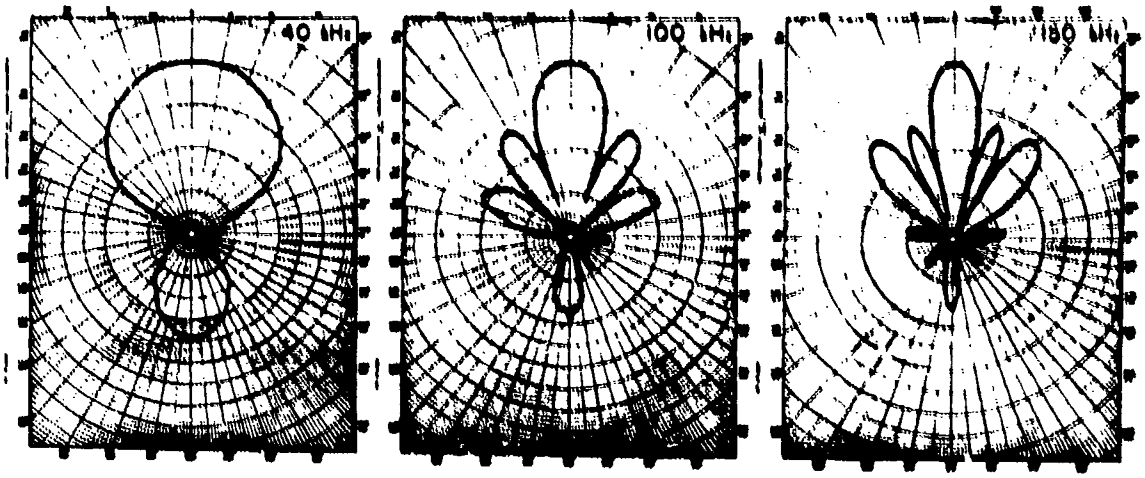


Fig. F6. Typical directivity patterns in the horizontal (XY) plane, type F33 transducer, inner section only. Scale: Center to top of grid, each pattern, equals 50 dB.

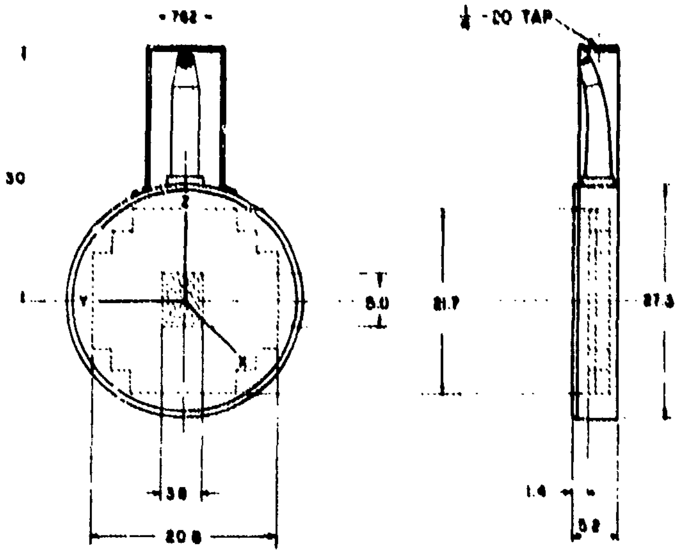


Fig. F7. (Right) Dimensions (in centimeters) and orientation of type F33 transducer (tap: UNC).

Type F36
TRANSDUCER

General Description

The USRD type F36 transducer is designed to provide smooth response in the frequency range 10 Hz to 20 kHz when used as a hydrophone. It is useful also as a sound source in the range 1 to 20 kHz. Figure G1 is a photograph of the transducer.

Fig. G1. USRD type F36 transducer.

The sensitive element consists of seven lead zirconate-titanate capped cylinders mounted one above the other to form a line 20.3 cm long. The elements are housed within an oil-filled butyl rubber boot over a framework of six steel rods that provide protection and support without affecting the acoustic characteristics. The transducer is supplied with 30 m of 2-conductor shielded neoprene-sheathed cable.

Specifications

Frequency range:	10 Hz to 20 kHz, as hydrophone
Free-field voltage sensitivity:	-201 dB re 1 V/μPa at end of 30-m cable
Transmitting voltage response:	124 dB re 1 μPa/V at 10 kHz
Maximum driving voltage:	150 V rms
Nominal capacitance:	60000 pF (with 30-m cable)
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	2.7 MPa (270-m depth)
Operating temperature range:	0 to 35°C
Weight with 30-m cable:	4 kg
Shipping weight:	6 kg

Electroacoustic Characteristics

Figure G2 is a typical *free-field voltage sensitivity* curve for the type F36 transducer, measured in terms of open-circuit voltage at the end of 30 m of cable. The sensitivity of each transducer is provided by the calibration curve furnished with it. Sensitivity depends on the frequency characteristics of the amplifier used and on the resistance and capacitance of the input circuit (including transducer, cable, and amplifier input impedance). The capacitance of the transducer with 30 m of cable is greater than 60 000 pF. The input impedance of the amplifier should be at least 3 MΩ to insure that its effect on the response of the transducer at low frequencies is negligible.

The sensitivity of the type F36 transducer does not vary significantly with temperature in the range 5 to 30°C. No changes have been observed in the sensitivity of the transducer with hydrostatic pressure up to 2.7 MPa (400 psi).

Additional cable can be used with the transducer; however, the added cable will increase the shunt capacitance, and the over-all sensitivity will be correspondingly lower.

The *transmitting voltage response* from 1 to 25 kHz is shown in Fig. G3. It is recommended that the transducer not be used above 20 kHz.

Directivity. The transducer is omnidirectional within ±0.5 dB in the plane (XY) normal to its longitudinal axis. The vertical (XZ plane) directivity is equivalent to that of a 20.3-cm line. Typical vertical directivity patterns are shown in Fig. G4.

Preparation for Use

Figure G5 is a dimensioned outline drawing showing the orientation of the transducer. Attach a fixture to the molded cable gland as near as possible to the transducer. When no fixture is used, a line should be attached to the lifting eyes to remove the tension from the cable and the gland. A pad eye is provided at the lower end of the transducer also, so that a weight can be attached if necessary. The weight should not be greater than 12 kg. Wash the entire transducer with a wetting agent. Air bubbles must be removed as completely as possible when the transducer is lowered into the water, to avoid erroneous results. Permit the temperature of the transducer to stabilize with that of the water before making any measurements.

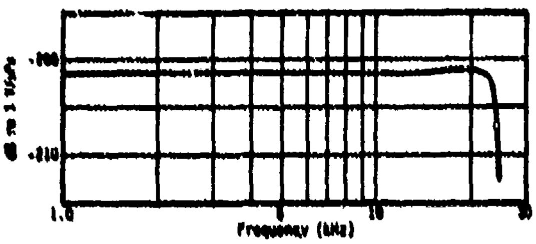


Fig. G2. Typical free-field voltage sensitivity, type F36 transducer.

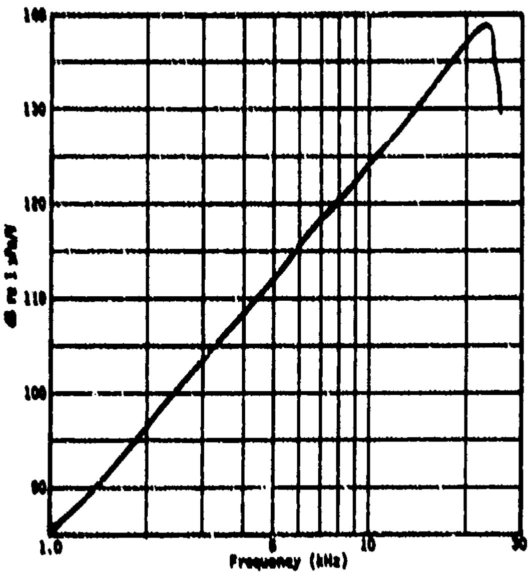


Fig. G3. Typical transmitting voltage response, type F36 transducer.

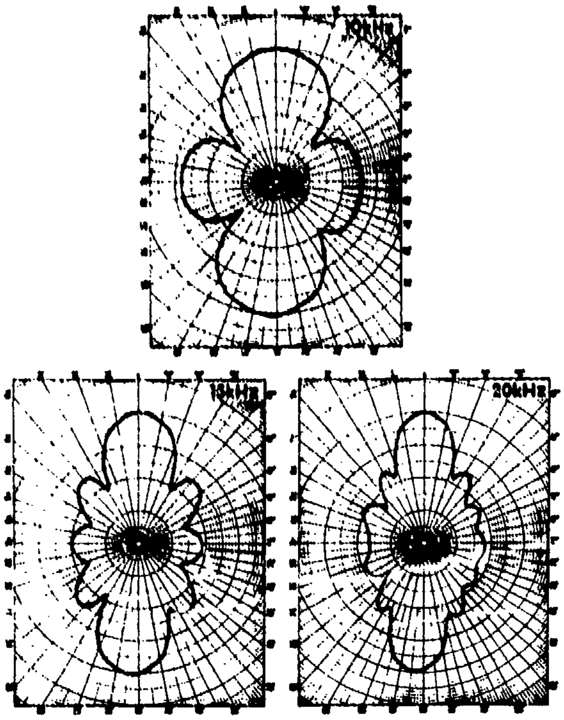


Fig. G4. Typical directivity patterns in the vertical (XZ) plane, type F36 transducer. Scale: center to top of grid, each pattern, equals 50 dB.

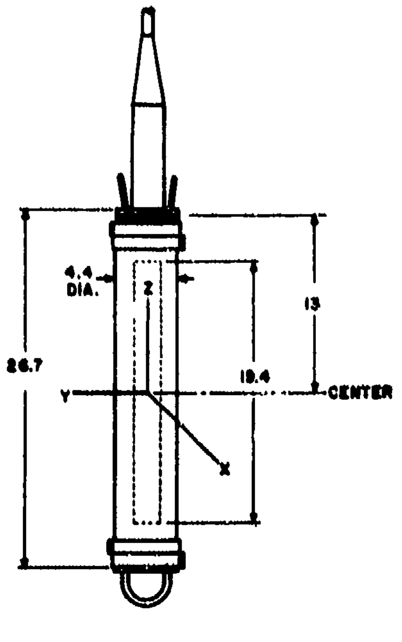


Fig. G5. (Left) Dimensions in centimeters) and orientation of type F36 transducer.

Type F37
TRANSDUCER

General Description

The USRD type F37 transducer provides a smooth response in the frequency range 10 Hz to 37 kHz when used as a hydrophone. It is useful also as a sound source in the range 1 to 37 kHz. Figure H1 is a photograph of the transducer.

Fig. H1. USRD type F37 transducer.

The sensitive element consists of eight lead zirconate-titanate cylinders mounted one above the other to form a line 16.5 cm long. The elements are housed within an oil-filled butyl-rubber boot over a framework of six steel rods that provide protection and support without affecting the acoustic characteristics. The transducer is supplied with 30 m of 2-conductor shielded Hypalon-sheathed cable.

Specifications

Frequency range:	10 Hz to 37 kHz, as hydrophone
Free-field voltage sensitivity:	-204.0 dB re 1 V/μPa at end of 30-m cable
Transmitting voltage response:	121.7 dB re 1 μPa/V at 10 kHz
Maximum driving voltage:	100 V rms
Nominal capacitance:	60000 pF (with 30.5-m cable)
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	2.75 MPa (275-m depth)
Operating temperature range:	0 to 35°C
Weight with 30-m cable:	4 kg
Shipping weight:	6 kg

Electroacoustic Characteristics

Figure H2 shows a typical *free-field voltage sensitivity* curve in terms of open-circuit voltage at the end of 30 m of cable. The sensitivity of each transducer is provided by the calibration curve furnished with the transducer. The sensitivity depends on the frequency characteristics of the amplifier used and on the resistance and capacitance of the input circuit (including transducer, cable, and amplifier input impedance). The capacitance of the transducer with 30 m of cable is greater than 50 000 pF. The input impedance of the amplifier used should be at least 3 MΩ to insure that its effect on the response of the transducer at low frequencies is negligible.

Additional cable can be used with the transducer. Because additional cable will increase the shunt capacitance, however, the over-all sensitivity will be correspondingly lower.

The *transmitting voltage response* from 1 to 40 kHz is shown in Fig. H3. It is recommended that the transducer not be used above 37 kHz.

The sensitivity of the type F37 transducer does not vary significantly with temperature in the range 5 to 30°C. No changes have been observed in the sensitivity of the transducer with hydrostatic pressures up to 2756 kPa (275 m depth).

Directivity. The type F37 transducer is omnidirectional within ±0.5 dB in the plane (XY) normal to its longitudinal axis. The vertical (XZ plane) directivity is equivalent to that of a 16.5-cm line. Typical vertical directivity patterns are shown in Fig. H4.

Preparation for Use

Figure H5 is a dimensioned outline drawing of the transducer showing its orientation. The transducer can be mounted in a fixture that can be clamped on the packing gland as near as possible to the transducer. When necessary, a weight can be attached to the pad eye provided at the lower end of the transducer. The weight should not be greater than 12 kg. The entire transducer should be washed with a wetting agent. All air bubbles must be removed as completely as possible when the transducer is lowered into the water, to avoid erroneous results. Permit the temperature of the transducer to stabilize with that of the water before making any measurements.

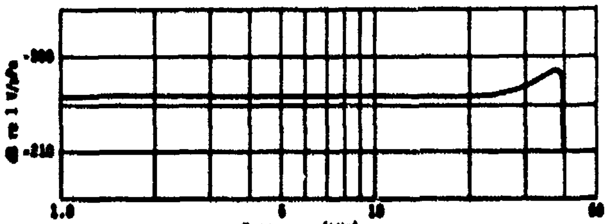


Fig. H2. Typical free-field voltage sensitivity, type F37 transducer.

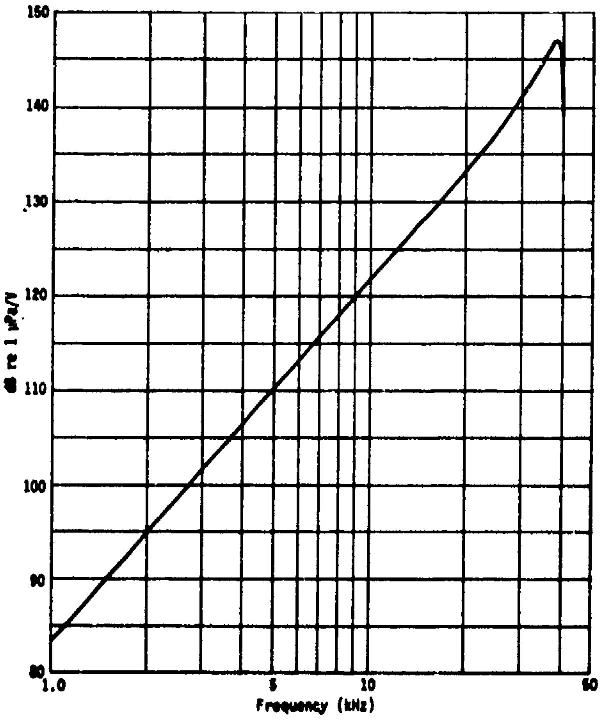


Fig. H3. Typical transmitting voltage response, type F37 transducer.

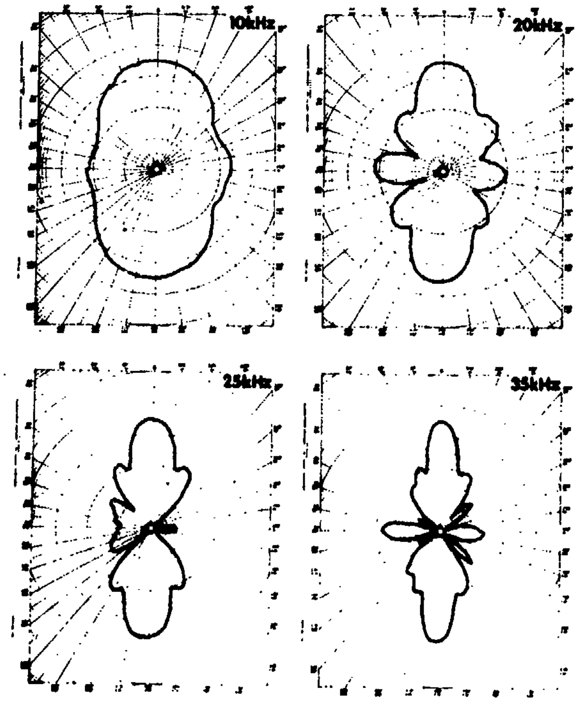
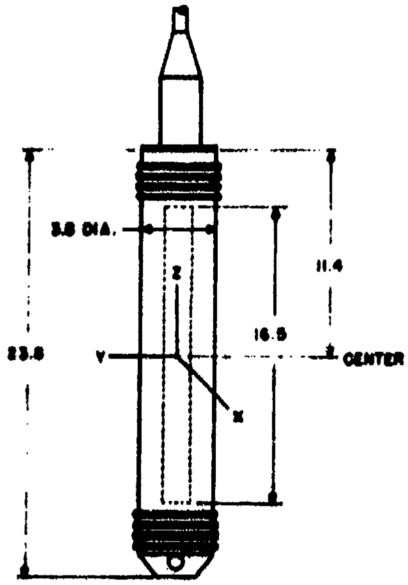


Fig. H4. Typical directivity patterns in the vertical (XZ) plane, type F37 transducer. Scale: center to top of grid, each pattern, equals 50 dB.

Fig. H5. (Right) Dimensions (in centimeters) and orientation of type F37 transducer.



Type F40
TRANSDUCER

General Description

The USRD type F40 transducer is primarily a high-power sound source. It can be used as such in the frequency range 1 kHz to 30 kHz, or as a receiver (hydrophone) in the range 1 Hz to 30 kHz. Figure I1 is a photograph of the transducer.

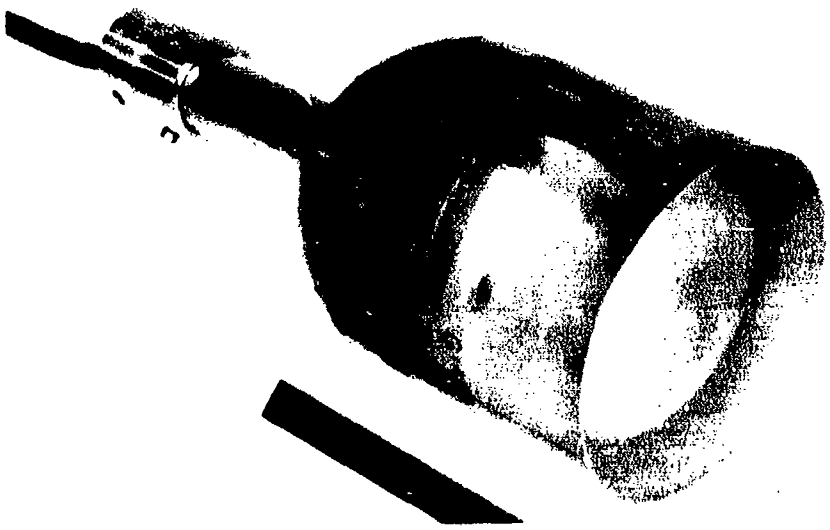


Fig. I1. USRD type F40 transducer.

The sensitive element is a 10-cm-diam piezoelectric, lead zirconate-titanate, hollow sphere with a wall 6.35 mm thick. A 1.9-cm-diam access hole permits soldering a lead to the inside silver electrode before the opening is covered with a glass-to-metal seal. The entire sphere is encapsulated in polyurethane; type DSS-2 cable enters the access hole through a short length of stainless steel tube that is molded in place. The transducer can be supplied with a 30-m cable or a 1-m cable with a waterproof connector. The wiring diagram is shown in Fig. I2.

Specifications

Frequency range:	1 to 30 kHz as source
Free-field voltage sensitivity (nominal):	-187 dB re 1 V/μPa at end of 30-m cable
Transmitting voltage response:	128.5 dB re 1 μPa/V at 5 kHz

Maximum driving voltage:	400 V rms
Nominal capacitance:	47000 pF with 30-m cable
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Weight with 1-m cable:	4 kg
Shipping weight:	9 kg

Electroacoustic Characteristics

Figure I3 shows typical *transmitting voltage response*. The transducer will produce an undistorted signal that is linear with driving voltage up to 400 V rms in the frequency range 1 to 20 kHz.

Figure I4 gives the *equivalent series impedance*.

Figure I5 provides typical *free-field voltage sensitivity* at the end of 30 m of cable. A calibration curve is provided with each transducer. The sensitivity depends on the frequency characteristics of the amplifier used and on the resistance and capacitance of the input circuit (including transducer, cable, and amplifier input impedance). The input impedance of the receive amplifier should be at least 3 MΩ to insure negligible effect on transducer sensitivity at low frequency. Additional cable can be used with the transducer, but the shunt capacitance will be increased and the over-all sensitivity will be reduced correspondingly.

Measurements on the type F40 transducer show that neither the transmitting response nor the receiving sensitivity change within the temperature range 0 to 30°C or the pressure range 0 to 6.9 MPa.

Directivity. The type F40 transducer is omnidirectional within ±0.5 dB in the horizontal (XY) and vertical (XZ) planes to 25 kHz. The horizontal plane is that passing through the center of the spherical element perpendicular to the axis of symmetry of the transducer.

Preparation for Use

Mount the transducer rigidly in a fixture attached by screws in the tapped 10-32 holes in the cable gland tube. Before submerging it, wash the entire transducer thoroughly with a detergent to eliminate bubbles that cling to its outer surface. Permit the temperature of the transducer to stabilize with that of the water before making any measurements. Figure I6 is a dimensioned outline drawing showing the orientation of the transducer.

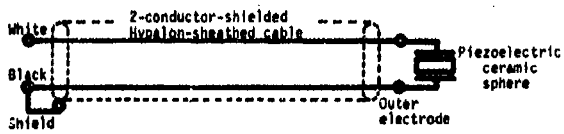


Fig. I2. Wiring diagram, type F40 transducer.

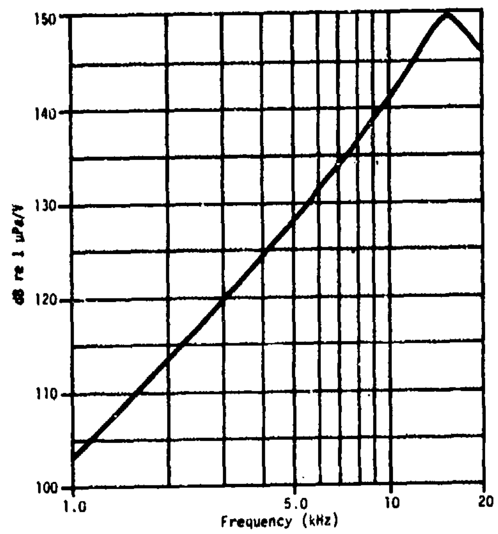


Fig. I3. Typical transmitting voltage response, type F40 transducer, unbalanced, black lead and shield grounded, 30-m cable.

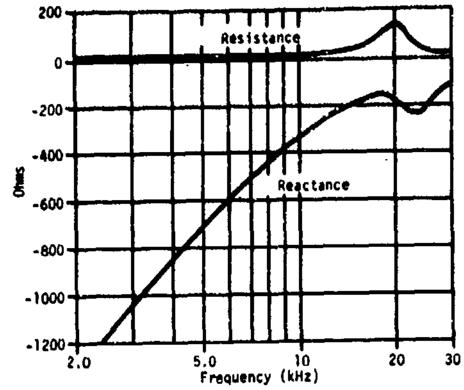


Fig. I4. Typical equivalent series impedance, type F40 transducer, unbalanced, black lead and shield grounded, 30-m cable.

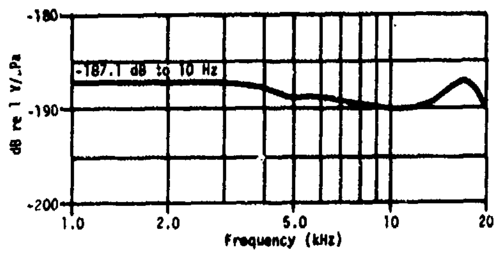


Fig. I5. Typical free-field voltage sensitivity, type F40 transducer; open-circuit voltage at end of 30-m cable; unbalanced, black lead and shield grounded.

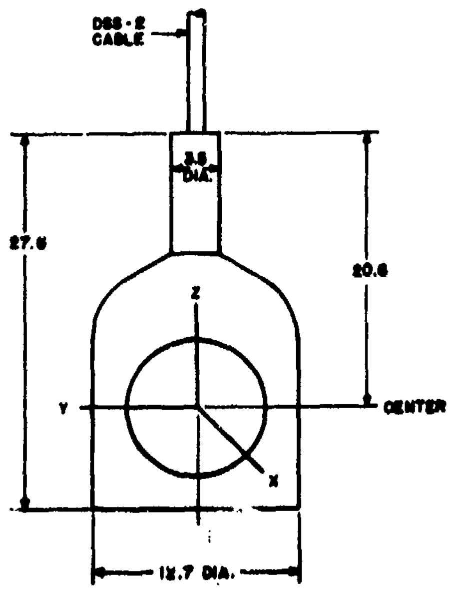


Fig. I6. Dimensions (in centimeters) and orientation of type F40 transducer.

Type F40A TRANSDUCER

General Description

The USRD type F40A transducer is primarily a high-power sound source. It can be used as such in the frequency range 1 kHz to 20 kHz, or as a receiver (hydrophone) in the range 1 Hz to 20 kHz. Figure J1 is a photograph of the transducer.

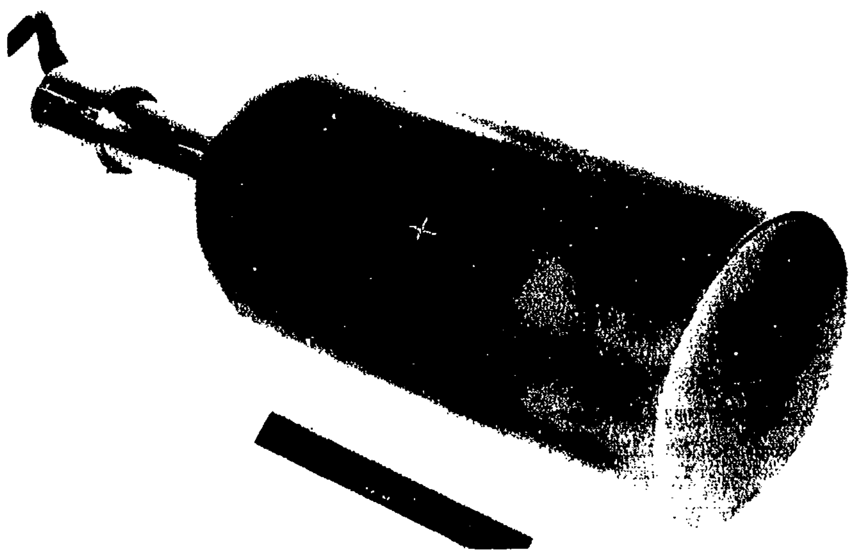


Fig. J1. USRD type F40A transducer.

The sensitive element consists of two 10-cm-diam piezoelectric, lead zirconate-titanate, hollow spheres with a wall 6.35 mm thick. A 1.9-cm-diam access hole permits soldering a lead to the inside silver electrode before the opening is covered with a glass-to-metal seal. The spheres are encapsulated in polyurethane; the cable enters the access hole through a short length of stainless steel tube that is molded in place. The transducer is supplied with a 0.5-m cable and waterproof connector. Type DSS-2 cable with mating connector can be provided in any length up to 61 m. The wiring diagram is shown in Fig. J2.

Specifications

Frequency range:	1 to 20 kHz as source
Free-field voltage sensitivity (nominal):	-187 dB re 1 V/μPa at end of 30-m cable
Transmitting voltage response:	131.5 dB re 1 μPa/V at 5 kHz

Maximum driving voltage:	400 V rms
Nominal capacitance:	97000 pF with 0.5-m cable
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Weight with 1-m cable:	6 kg
Shipping weight:	11 kg

Electroacoustic Characteristics

Figure J3 shows typical *transmitting voltage response*. The F40A transducer will produce an undistorted signal that is linear with driving voltage up to 400 V rms in the frequency range 1 to 20 kHz.

Figure J4 provides typical *free-field voltage sensitivity* at the end of 12 m of cable. A calibration curve is provided with each transducer. The input impedance of the receive amplifier should be at least 1.5 MΩ to insure negligible effect on transducer sensitivity at low frequency. Additional cable can be used with the transducer, but this will increase shunt capacitance and reduce over-all sensitivity correspondingly.

Measurements on the type F40A transducer show that neither the transmitting response nor the receiving sensitivity change within the temperature range 0 to 30°C nor the pressure range 0 to 6895 kPa.

The *electrical impedance* of the F40A transducer, measured in water under free-field conditions, is shown on the left in Fig. J5; the locus of impedance in the region of the resonance frequency, on an expanded scale, is shown on the right.

Directivity. The type F40A transducer is omnidirectional within ±0.2 dB in the horizontal (XY) plane to 20 kHz. This horizontal plane passes between the two spherical elements perpendicular to the axis of symmetry of the transducer. Typical directivity patterns in the vertical plane (XZ) are shown in Fig. J6.

Preparation for Use

Mount the transducer rigidly in a fixture attached by screws in the tapped 10-32 holes in the cable gland tube. Before submerging it, wash the entire transducer thoroughly with a detergent to eliminate bubbles that may cling to its outer surface. Permit the temperature of the transducer to stabilize with that of the water before making any measurements. Figure J7 is a dimensioned outline drawing showing the orientation of the transducer.

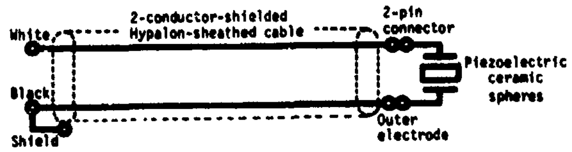


Fig. J2. (Above) Wiring diagram, type F40A transducer.

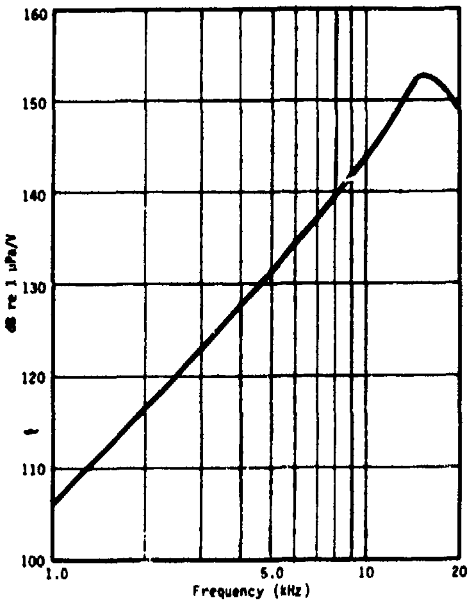


Fig. J3. (Right) Typical transmitting voltage response, type F40A transducer; unbalanced, black lead and shield grounded, 30-m cable.

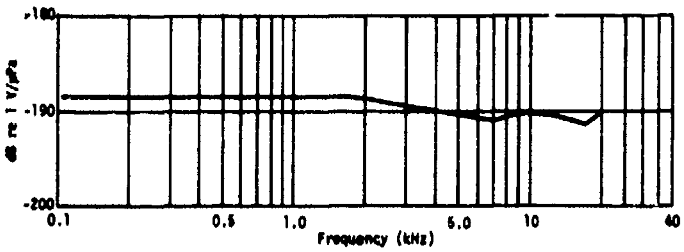


Fig. J4. (Right) Typical free-field voltage sensitivity, type F40A transducer; open-circuit voltage at end of 30-m cable; unbalanced, black lead and shield grounded.

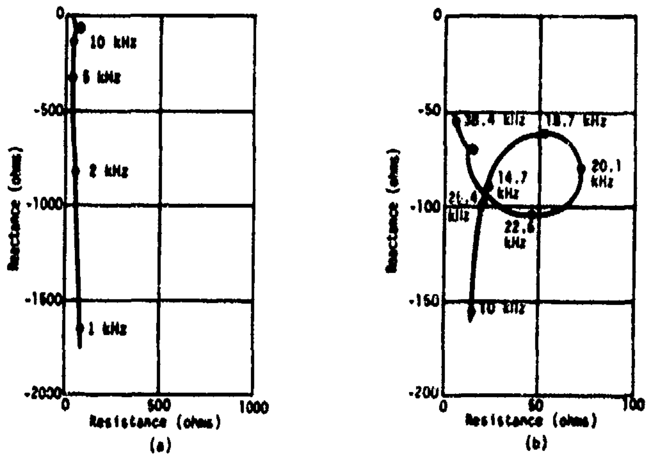


Fig. J5. (Right)
(a) Typical electrical impedance of F40A transducer under free-field conditions; (b) locus of impedance in the region of the resonance frequency.

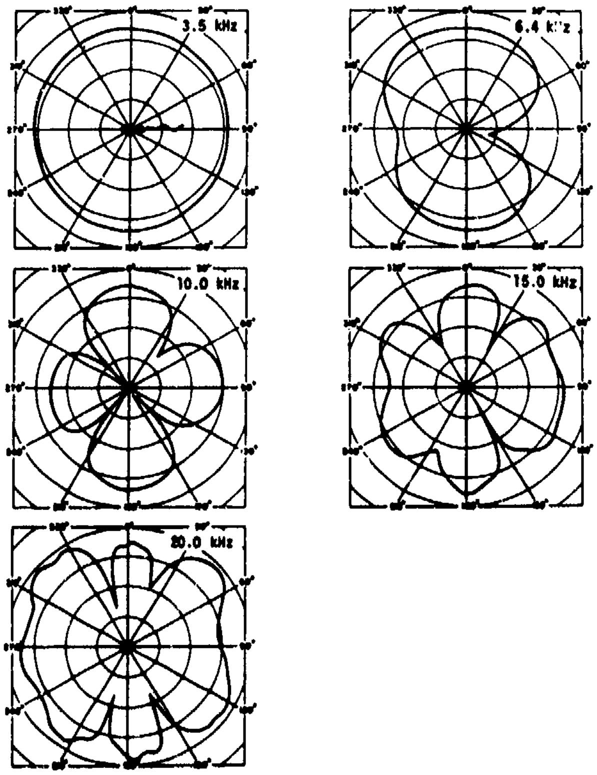


Fig. J6. (Left) Typical directivity patterns in the vertical (XZ) plane, type F40A transducer. Scale: center to top of grid, each pattern, equals 40 dB.

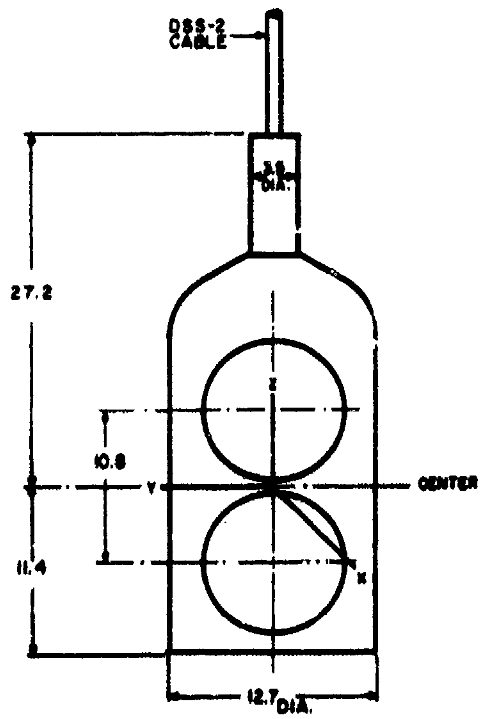


Fig. J7. (Right) Dimensions (in centimeters) and orientation, type F40A transducer.

Type F41
TRANSDUCER

General Description

The USRD type F41 transducer is a laboratory standard for use in underwater sound reciprocity calibrations in the frequency range 15 to 150 kHz. Figure K1 is a photograph of the transducer.

Fig. K1. USRD type F41 transducer.

The sensitive element consists of twelve 1.27-cm-diam by 0.254-cm-thick lead zirconate-titanate elements cemented to high-density Kennametal disks. The array is approximately 3.8 cm wide and 5 cm high.

Corprene is used as the pressure-release material around each of the twelve ceramic elements, which are sealed in transparent polyurethane; castor oil is the acoustic coupling medium between the polyurethane potting compound and the butyl-rubber acoustic window. A thin expanded metal sheet connected to the metal housing affords electrical shielding for the active array.

A 30-m, 2-conductor, shielded, neoprene-sheathed cable is provided. The transducer can be used balanced or unbalanced; for the USRD calibration, the shield is connected to one lead, as shown in Fig. K2.

Specifications

Frequency range:	15 to 150 kHz
Transmitting voltage response:	131 dB re 1 μPa/V at 50 kHz
Maximum driving voltage:	200 V rms
Nominal capacitance:	12000 pF
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	3.4 MPa (340-m depth)
Operating temperature range:	0 to 35°C

Weight with 30-m cable: 4 kg

Shipping weight: 9 kg

Electroacoustic Characteristics

Figure K3 shows typical transmitting current and voltage responses. The *free-field* voltage sensitivity is presented in Fig. K4 and the equivalent series impedance in Fig. K5.

The response changes less than ±0.75 dB with pressure to 3.4 MPa. In the frequency range 20 to 150 kHz, the response varies less than ±0.75 dB in the temperature range 3 to 25°C.

The directivity in the horizontal plane is broader than in the vertical because of the dimensions of the crystal array. The patterns are symmetrical and, at frequencies above 25 kHz, the back radiation is 19 to 22 dB below the front radiation. Typical directivity patterns in the XY (horizontal) and XZ (vertical) planes are shown in Fig. K6.

Preparation for Use

Figure K7 is a dimensioned outline drawing showing the orientation of the transducer. In normal operation, the 4.4-cm-diam housing extends vertically above the transducer case. Clamp a bracket around the steel case near the molded cable gland to support the transducer. Wash the entire transducer with a suitable wetting agent to remove air bubbles as completely as possible and thus avoid erroneous results. Permit the temperature of the transducer to stabilize with that of the water before making any measurements.

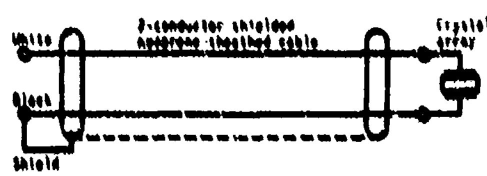


Fig. K2. Schematic circuit diagram, type F41 transducer.

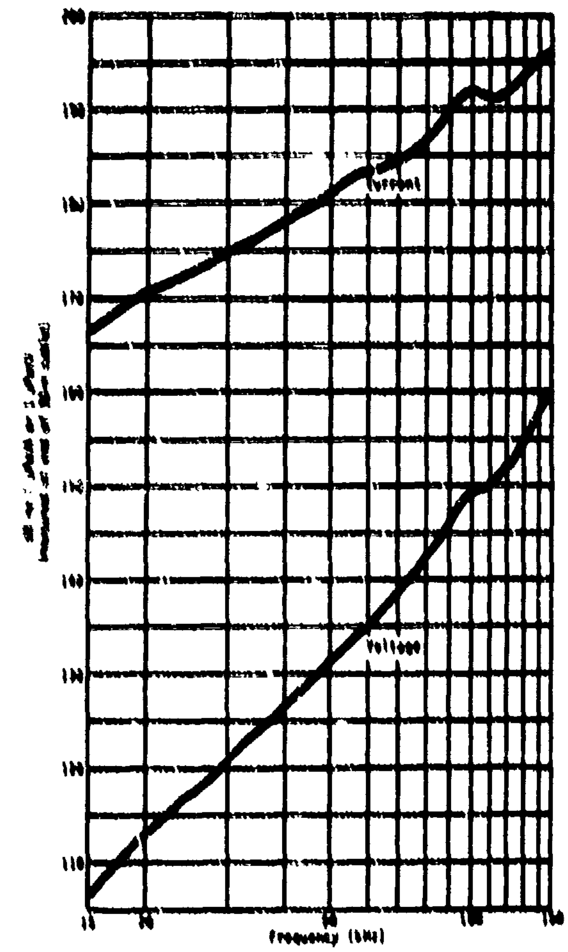


Fig. K3. Typical transmitting current and voltage responses, type F41 transducer.

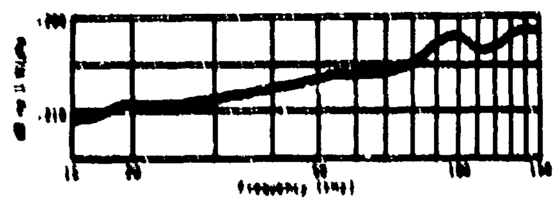


Fig. K4. Typical free-field voltage sensitivity, type F41 transducer.

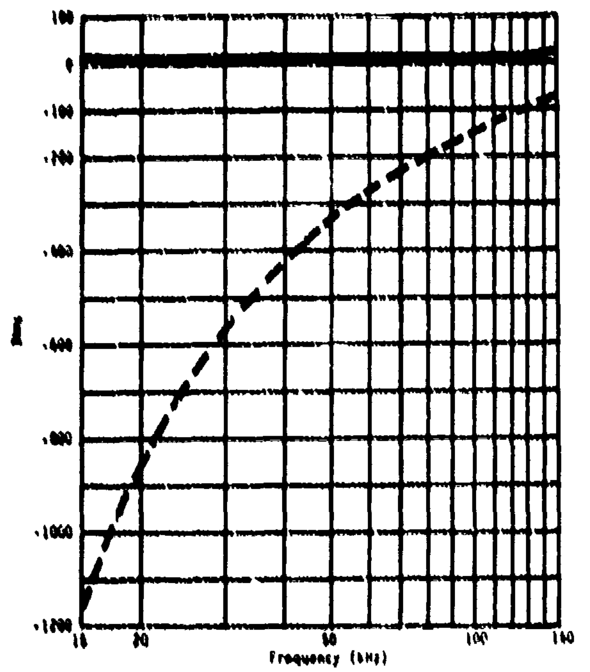


Fig. K5. Typical equivalent series impedance, type F41 transducer.

Fig. K6a. Typical directivity patterns in the XY (horizontal) plane, type F41 transducer. Scale: center to top of grid, each pattern, equals 50 dB.

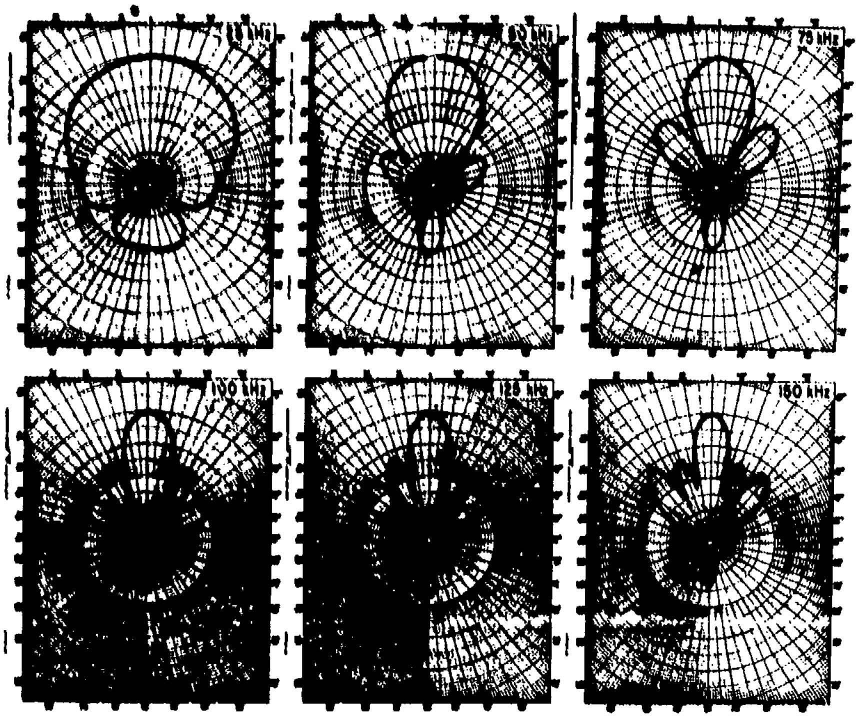
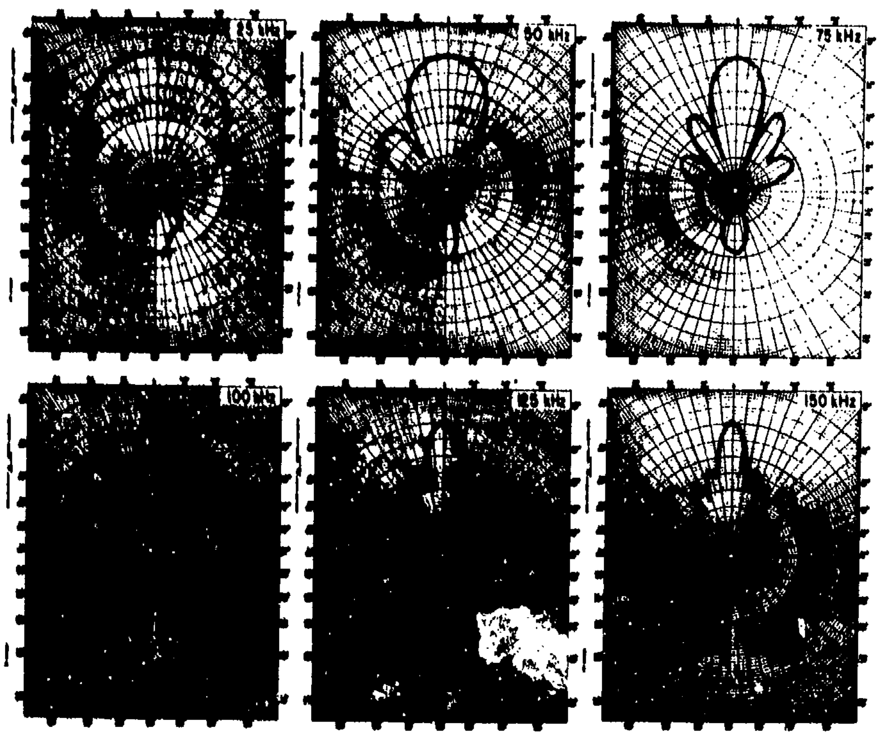


Fig. K6b. Typical directivity patterns in the XZ (vertical) plane, type F41 transducer. Scale: center to top of grid, each pattern, equals 50 dB.



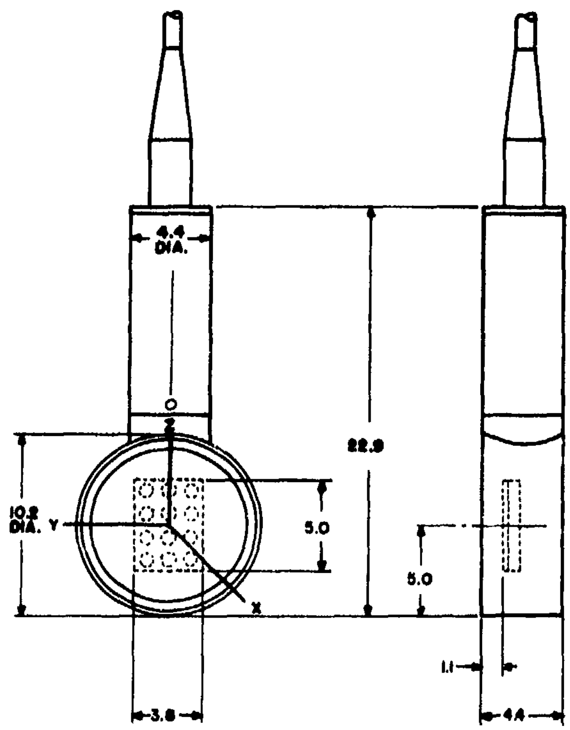


Fig. K7. Dimensions (in centimeters) and orientation of type F41 transducer.

Type F42
TRANSDUCER

General Description

The USRD type F42 transducer is primarily a sound source. It can be used as such in the frequency range 2 to 45 kHz, or as a receiver (hydrophone) in the range 1 Hz to 45 kHz. Figure L1 is a photograph of the transducer.

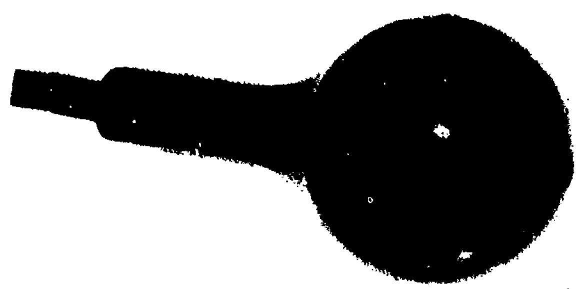


Fig. L1. USRD type F42 transducer.

The sensitive element is a 5.0-cm-diam piezoelectric, lead zirconate-titanate, hollow sphere with a wall 3.2 mm thick. An access hole permits soldering a lead to the inside silver electrode before the opening is covered with a glass-to-metal seal. The entire sphere is encapsulated in polyurethane; the cable enters the access hole through a short length of swaged copper tubing that is molded in place. The transducer is supplied with a 1-m cable with a waterproof connector. Additional cable up to 45 m long can be attached. The wiring diagram is shown in Fig. L2.

Specifications

Frequency range:	1 to 45 kHz as source
Free-field voltage sensitivity (nominal):	-192.5 dB re 1 V/μPa at end of 11-m cable
Transmitting voltage response:	110.5 dB re 1 μPa/V at 5 kHz
Maximum driving voltage:	400 V rms
Nominal capacitance:	31000 pF with 1-m cable
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C

Weight with 30-m cable: 4 kg

Shipping weight: 9 kg

Electroacoustic Characteristics

Figure L3 shows typical *transmitting voltage response*. The transducer will produce an undistorted source level that is linear with driving voltage up to 400 V rms in the frequency range 1 to 30 kHz. Figure L4 gives the *impedance* of the F42 transducer.

Figure L5 provides typical *free-field voltage sensitivity* at the end of 11 m of cable. A calibration curve is provided with each transducer. The sensitivity depends on the frequency characteristics of the amplifier used and on the resistance and capacitance of the input circuit (including transducer, cable, and amplifier input impedance). The input impedance of the receive amplifier should be at least 3 MΩ to insure negligible effect on transducer sensitivity at low frequency. Additional cable can be used with the transducer, but the shunt capacitance will be increased and the over-all sensitivity will be reduced correspondingly.

Measurements on the type F42 transducer show that neither the transmitting response nor the receiving sensitivity change within the temperature range 0 to 30°C or the pressure range 0 to 6900 kPa (equivalent to 685-m water depth).

Directivity. The type F42 transducer is omnidirectional within ±0.5 dB in the horizontal (XY) and vertical (XZ) planes to 45 kHz. The horizontal plane is that passing through the center of the spherical element perpendicular to the axis of symmetry of the transducer.

Preparation for Use

Figure L6 is a dimensioned outline drawing showing the orientation of the transducer. Mount the transducer rigidly in a fixture. Before submerging it, wash the entire transducer thoroughly with a detergent to eliminate bubbles that cling to its outer surface. Permit the temperature of the transducer to stabilize with that of the water before making any measurements.

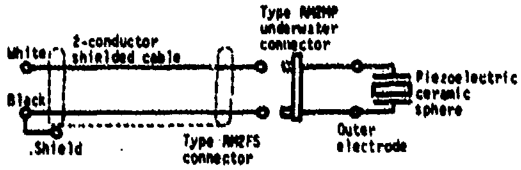


Fig. L2. Wiring diagram, type F42 transducer.

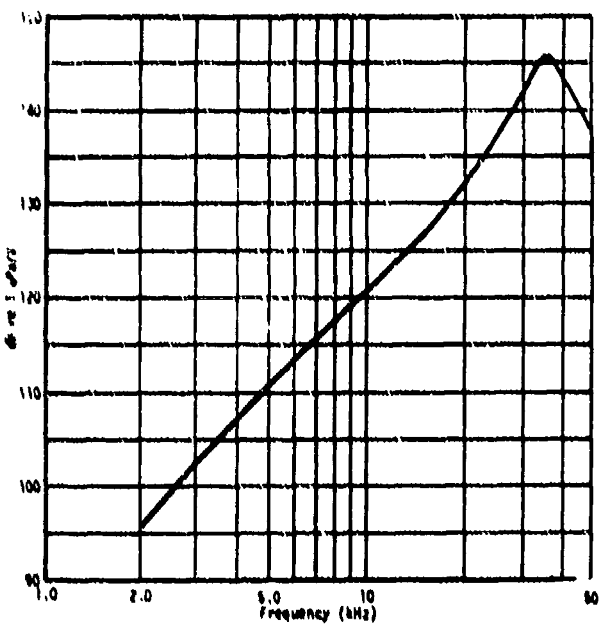


Fig. L3. Typical transmitting voltage response, type F42 transducer, unbalanced, black lead and shield grounded, 16-m cable.

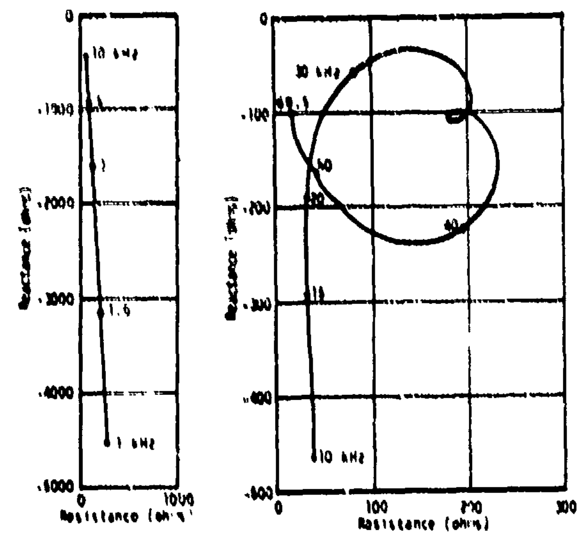


Fig. L4. Typical impedance, type F42 transducer, unbalanced, black lead and shield grounded, 11-m cable.

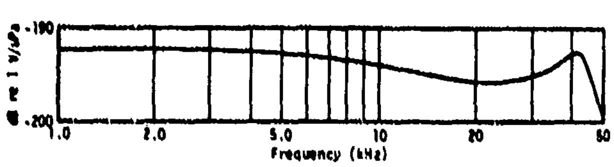


Fig. L5. Typical free-field voltage sensitivity, type F42 transducer, open-circuit voltage at end of 11-m cable; unbalanced, black lead and shield grounded.

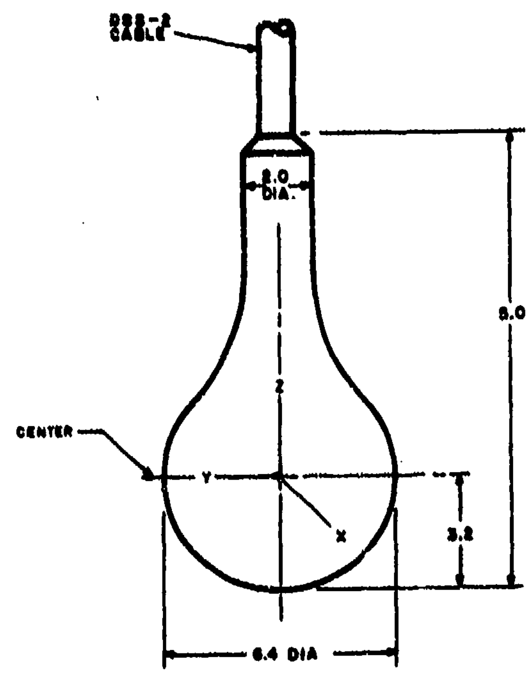


Fig. L6. (Right) Dimensions (in centimeters) and orientation, type F42 transducer.

Type F50
TRANSDUCER

General Description

The USRD type F50 transducer was designed for use primarily as an underwater sound receiver in the frequency range 1 Hz to 70 kHz; however, it can be used as a sound source in the frequency range 10 to 70 kHz. The active sensor element consists of lead zirconate-titanate cylinders mounted coaxially and mechanically isolated from each other in an oil-filled, butyl boot. Normally, these transducers are supplied with a 23-m 2-conductor shielded cable. Figure M1 is a photograph of the transducer.

Fig. M1. USRD type F50 transducer.

Specifications

Frequency range:	1 Hz to 70 kHz
Free-field voltage sensitivity (nominal):	-205 dB re 1 V/μPa at end of 23-m cable, below 10 kHz
Transmitting voltage response:	117.5 dB re 1 μPa/V at 20 kHz
Maximum driving voltage:	200 V rms (300 V pulse, 30% duty cycle)
Nominal capacitance:	0.015 μF at end of 23-m cable
D-c resistance:	greater than 1000 MΩ
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Weight with 23-m cable:	4.3 kg
Shipping weight:	8.6 kg

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type F50 transducer is determined by comparison with standard hydrophones in free-field measurements, or by the reciprocity method. Figure M2 shows a typical free-field voltage sensitivity curve in terms of open-circuit voltage at the end of a 23-m cable. A calibration curve is provided with each transducer.

Figure M3 shows a typical *transmitting voltage response* curve. The transducer will produce an undistorted source level that is linear with driving voltage up to 200 V rms or 300 V pulse, 30% duty cycle, in the frequency range 10 to 70 kHz.

Measurement indicate that the open-circuit voltage sensitivity of the transducer is independent of temperature in the frequency range 1 Hz to 70 kHz at temperatures between 3 and 30°C. The sensitivity changes by approximately 1 dB at 70 kHz because of a slight shift in the resonance frequency as the temperature changes.

Measurements made at hydrostatic pressures to 6895 kPa in a closed tank under controlled pressure and tempeature conditions indicate that at this pressure the sensitivity decreases approximately 0.8 dB uniformly over the frequency spectrum.

Typical *impedance* values for the F50 at 25°C are shown in Fig. M4.

Directivity. The F50 transducer is omnidirectional within ±0.5 dB at frequencies below 70 kHz in the horizontal (XY) plane--that is, in the plane normal to the longitudinal axis of the transducer. The vertical directivity approximates that of a 4-cm line. Typical directivity patterns in the vertical plane are shown in Fig. M5.

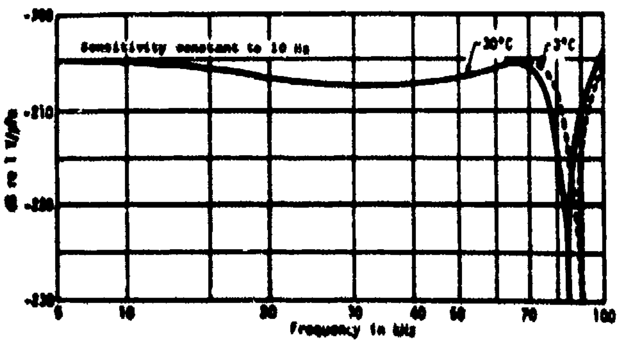
Preparation for Use

Figure M6 is a dimensioned outline drawing showing the orientation of the transducer. Mount the transducer in a fixture that can be clamped around the stainless-steel mounting sleeve near the cable. Wash the entire transducer with a wetting agent or detergent to remove all air bubbles. Permit the temperature of the transducer to stabilize with that of the water before making any measurements.

Reference

A. C. Tims, "A New Capped-Cylinder Design for an Underwater Sound Transducer (USRD Type F50)," J. Acoust. Soc. Amer. 51, 1751-1758 (1972).

Fig. M2. Typical free-field voltage sensitivity, type F50 transducer, open-circuit voltage at end of a 23-m coaxial cable.



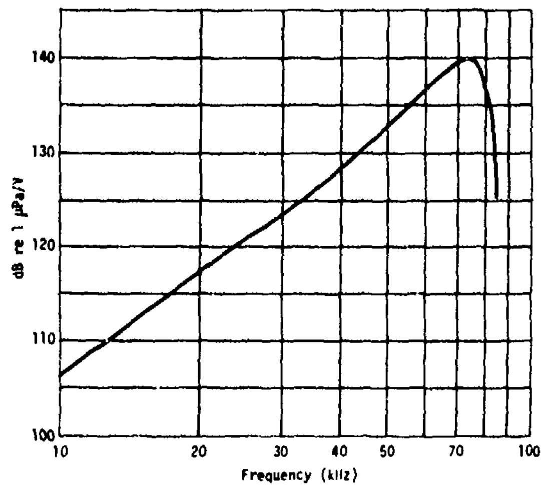
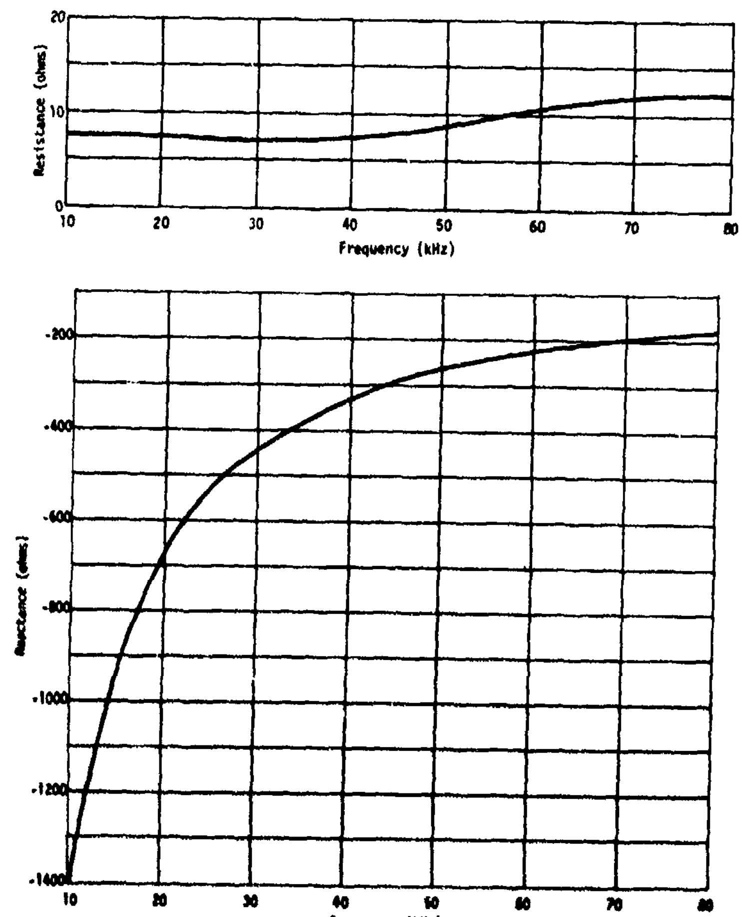


Fig. M3. (Left) Typical transmitting voltage response, type F50 transducer.

Fig. M4. (Right) Typical impedance at 25°C, type F50 transducer.



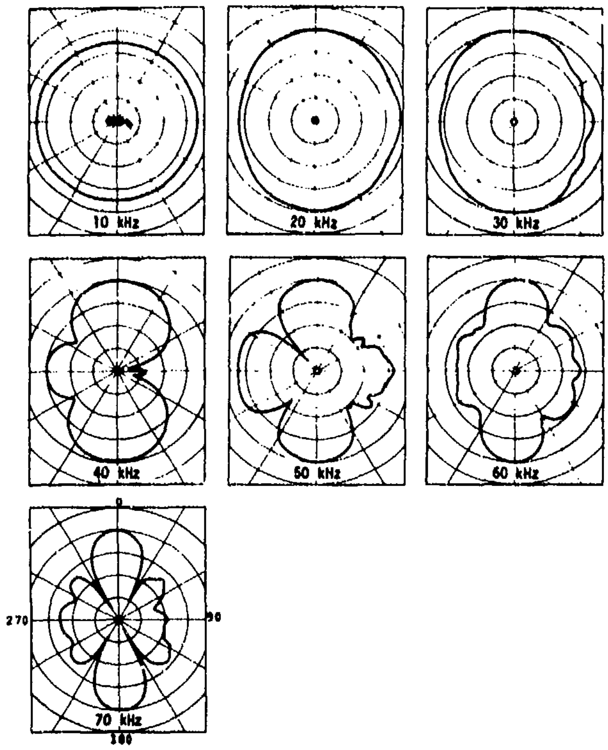
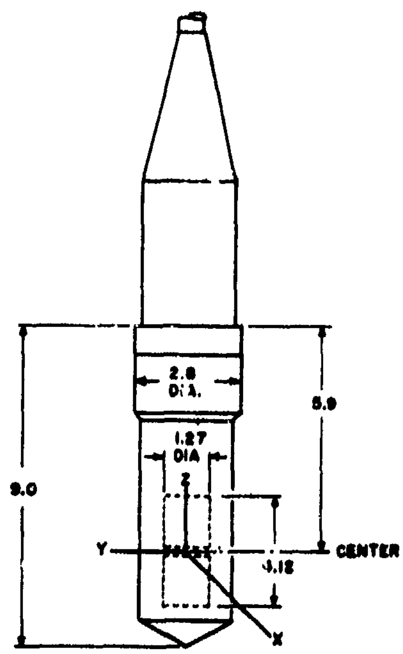


Fig. M5. (Left) Typical directivity patterns in the vertical (XZ) plane, type F50 transducer. Scale: center to top of grid, each pattern, equals 50 dB.

Fig. M6. (Right) Dimensions (in centimeters) and orientation of type F50 transducer.



Type G19
CALIBRATOR

Introduction

The calibrator provides a rapid, economical, and reliable acoustic bench test for small hydrophones in the frequency range 100 to 1000 kHz. Its primary function is to calibrate hydrophones by the comparison method; however, the theory of operation is given here to enable the user to adapt the system to his particular needs. Figure N1 is a photograph and Fig. N2 is a dimensioned outline drawing.

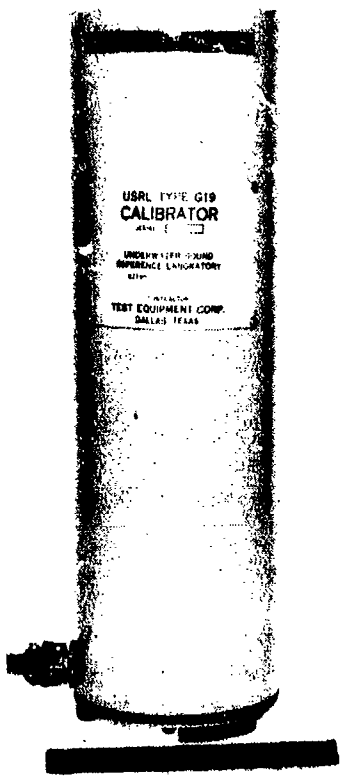


Fig. N1. (Left) USRD type G19 calibrator.

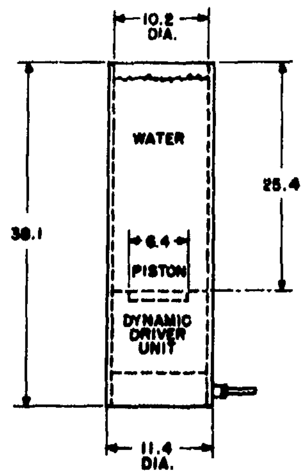


Fig. N2. Dimensions (in centimeters), type G19 calibrator.

Theory

The calibrator consists of an open-ended column of water that is excited by an electrodynamic driver. A cross section is shown in Fig. N3. The driver consists of a 5-cm-diam magnesium piston suspended by two sheets of rubber with silicone oil at the periphery between the rubber supports. This method of suspending the diaphragm permits considerable motion yet retains a high acoustic shunt impedance at the periphery of the piston.

The equivalent circuit of the system is shown in Fig. N4. For simplicity, only the mechanical circuit is given; it is assumed that the electrodynamic transducer is a constant-force generator when driven with a constant electrical current.

When the system operates in the region where the stiffness of the suspension is negligible and the impedance of the slit around the piston is high, the circuit reduces to that shown on the left in Fig. N5; the result is a simple division of force between the mass of the diaphragm and that of the water. Conversion to acoustic parameters gives the circuit shown at the right, where the pressure on the hydrophone is represented as appearing across the hydrophone stiffness (assumed very high). The mass of water on the diaphragm side causes the pressure to decrease as a probe moves upward away from the diaphragm (or the arrow in Fig. N5 moves downward). This reasoning predicts a linear pressure gradient in the tube, as would be expected in the region where the water impedance is all inertial. The longer the column of water, the less steep is the pressure gradient. Increasing the length, of course, lowers the high-frequency cutoff because of the length resonance of the water column. The diaphragm suspension must also be made stiffer to support the static head.

Substituting numbers for the $B\ell$ factor and the mass of the diaphragm yields a calculated rms pressure level of about 2×10^9 μPa at 2 cm from the diaphragm for a driving current of approximately 0.25 A. The measured pressure for the experimental unit was within 1 dB of this value in the mass-controlled frequency range. This pressure can be increased, if necessary. A maximum of one ampere can be used.

Both the radial and the axial distribution of pressure in the tube have been investigated. The vertical gradient is linear from about 2 cm above the diaphragm to the top of the water column. There was no horizontal gradient at low frequencies.

Measurement Technique

Figure N6 shows the output of a constant-sensitivity hydrophone whose acoustic center is 11.4 cm from the driving piston of the calibrator. The hydrophone has an active element that is approximately 2.5 cm long and a boot 5 cm in diameter. The low-frequency peak results from the calibrator diaphragm and water mass in resonance with the suspension stiffness; the high-frequency peak is at the resonance of the water column.

Comparison measurements can be made at and through the frequencies of the peaks if care is taken to avoid extraneous resonances of supporting stands at low frequencies and unstable conditions at high frequencies caused by air in the water. The presence of air will lower the high-frequency resonance. It is recommended that comparison measurements be made in the frequency range 100 to 1000 Hz for greatest accuracy.

Procedure

Fill the calibration tube with clean, fresh water so that, with the hydrophone submerged, the water level will be within 1.5 cm of the top. After filling, dislodge any clinging air bubbles with a bottle brush or some similar device. Next, immerse the reference hydrophone in the tube so that the center of its active element is approximately 11 to 12 cm from the driving piston. Take care to insure that no air bubbles are trapped under the hydrophone. After reading the output of the reference hydrophone, immerse the hydrophone to be calibrated so that its acoustic center is at exactly the same distance from the driving piston and the water level is the same as for the reference reading. A difference of 6 mm in distance from the piston or in water level will result in a 0.3 to 0.4 dB difference in sound pressure level.

Limitations

The limitations of the method are: (1) When dimensionally different hydrophones are to be compared, the locations of the sensitive elements of the hydrophones must be known. (2) The vertical position of the acoustic center of the hydrophone in the tube must be known with reasonable accuracy. (3) The acoustic impedance of the hydrophone must be high in comparison with the impedances of the tube system. (4) The frequency range is limited.

Advantages

The advantages of the method are: (1) Instruments can be easily inserted and removed from the tank. (2) There is no coupling problem as occurs with closed air chambers. (3) The equipment is rugged. (4) It is easily handled and portable. (5) It is virtually unaffected by temperature. (6) Because of the high acoustic pressure available, only a voltmeter and a signal generator are required; no power amplifier or voltage amplifier is needed.

Absolute calibrations are possible if the various parameters are measured carefully enough. *Absolute calibration is not the intent*, however, because much more sophisticated methods are available for this purpose. A comparison calibration wherein an unknown is compared with a standard is the most practical and convenient application of the calibrator.

Reference

C. C. Sims, "Hydrophone Calibrator," USRL Research Report No. 60, 12 Apr 1962 (AD-279 904).

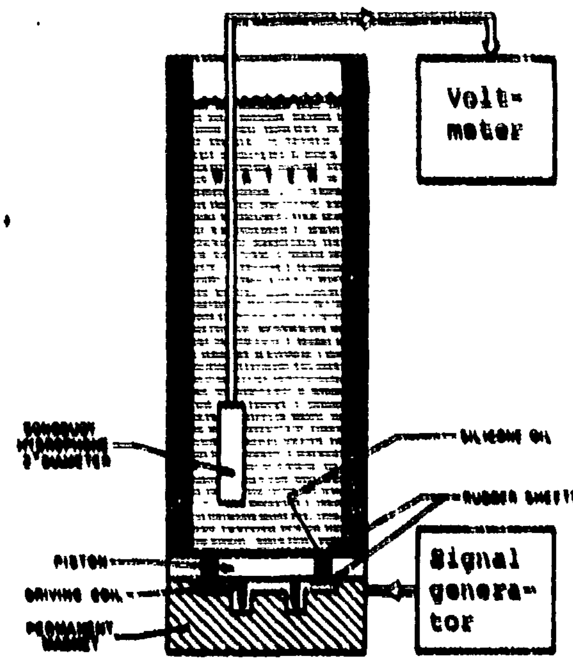
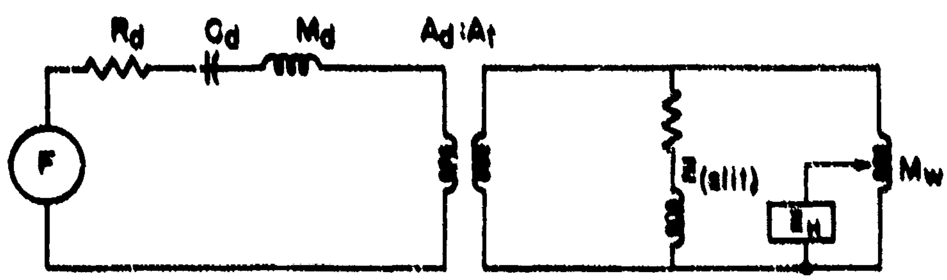


Fig. N3. (Right) Cross section, type G19 calibrator.



F = Bli
M_d = MASS OF PISTON
R_d = RESISTANCE OF SUSPENSION
C_d = COMPLIANCE OF SUSPENSION
A_d = AREA OF PISTON
A_t = CROSS-SECTIONAL AREA OF TUBE
M_w = LUMPED MASS OF WATER
$Z_{(slit)}$ = IMPEDANCE OF OIL-FILLED SLIT AROUND EDGE OF DIAPHRAGM
Z_H = HYDROPHONE IMPEDANCE

Fig. N4. Equivalent circuit, type G19 calibrator.

Fig. N5. Simplified equivalent mechanical (left) and acoustical (right) circuits, type G19 calibrator.

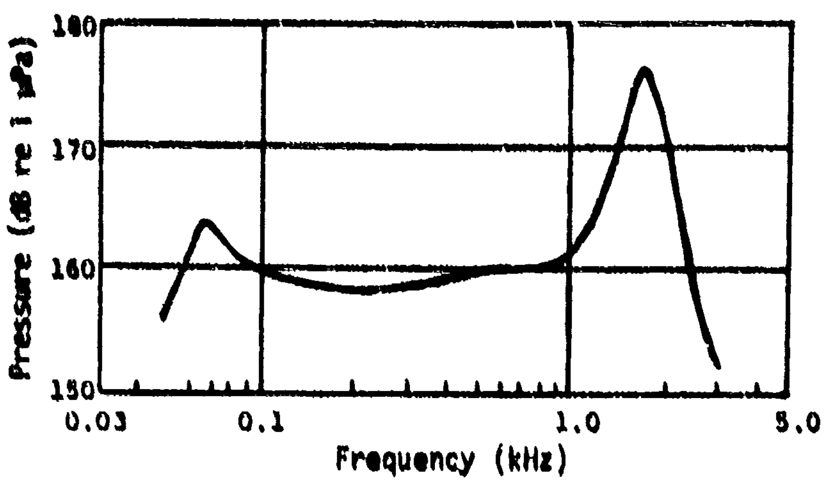


Fig. N6. Typical sound pressure in type G19 calibrator as measured by a constant-sensitivity hydrophone for a 5-V input to calibrator.

Type G34
TRANSDUCER

General Description

The USRD type G34 transducer is primarily a sound source for the frequency range 200 Hz to 3 kHz, but it may also be used as a receiver. Figure O1 is a photograph of the transducer.

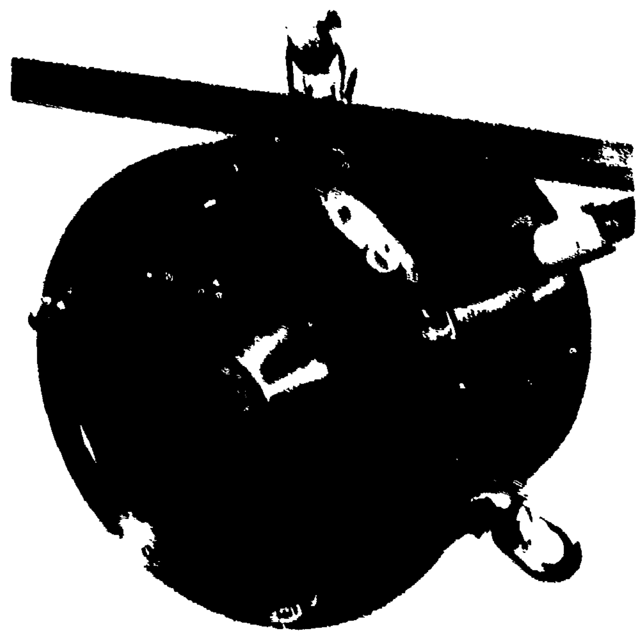


Fig. O1. USRD type G34 transducer.

The transducer consists of two aluminum pistons 28.5 cm in diameter driven by seven stacks of lead zirconate-titanate disks 5 cm in diameter by 0.635 cm thick. This piezoelectric ceramic piston assembly is mounted in a cylindrical housing made of aluminum, steel, or beryllium-copper, depending upon the serial number. The housing of the latest model is of beryllium-copper, which has low corrosion and high strength characteristics. The aluminum pistons of this model are covered with butyl rubber, and a bias bolt is used through the center of the piston. The electrical cable is attached by a plug-in underwater bulkhead connector. Figure O2 shows the electrical circuit.

Specifications

Frequency range: 200 Hz to 3 kHz

Free-field voltage sensitivity: -180.7 dB re 1 V/μPa at end of 30-m cable

Transmitting voltage response:	123 dB re 1 μPa/V at 1 kHz at end of 30-m cable
Maximum driving voltage:	1000 V rms
Nominal capacitance:	0.48 μF
D-c resistance:	200 MΩ
Operating temperature range:	0 to 35°C
Maximum operating depth:	depends on housing material: steel (serials 1-5), 345 m; aluminum (serials 6-9), 241 m; Be-Cu (serials 10 and up), 1379 m
Weight:	depends on housing material: steel (serials 1-5), 41 kg; aluminum (serials 6-9), 26 kg; Be-Cu (serials 10 and up), 60 kg

Electroacoustic Characteristics

Figure O3 shows typical *transmitting voltage response*. The G34 transducer will produce an undistorted source level that is linear with driving voltage up to 1000 V rms in the frequency range 200 Hz to 3 kHz. Typical transmitting current response is shown in Fig. O4.

Figure O5 shows typical *free-field voltage sensitivity* at the end of a 76-m, 2-conductor, shielded cable.

The type G34 transducer has been calibrated in the temperature range 22 to 27°C, but it has not been calibrated at depths greater than 15 m. It may be operated to the depth indicated under "Specifications" for the three different housing materials.

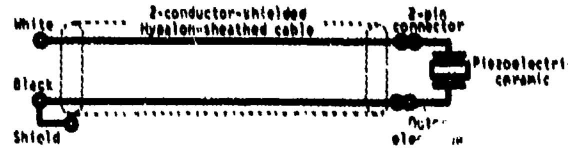
The *electrical impedance* of the G34 transducer, measured in water under free-field conditions, is shown in Fig. O6.

Directivity. The type G34 transducer is omnidirectional within ±1 dB in the plane of the acoustic center (YZ) up to 3 kHz. Typical directivity patterns in the vertical (XZ) plane are shown in Fig. O7.

Preparation for Use

Figure O8 is a dimensioned outline drawing showing the orientation of the transducer. Mount the transducer by using the attached lugs or by applying a clamp around the cylindrical housing. Do not use an eye bolt in either piston for mounting or lifting. Before submerging it, wash the entire transducer thoroughly with water and detergent to eliminate bubbles that may cling to the outer surface. Permit the temperature of the transducer to stabilize with that of the water before making any measurements.

Fig. 02. (Right) Wiring diagram, type G34 transducer.



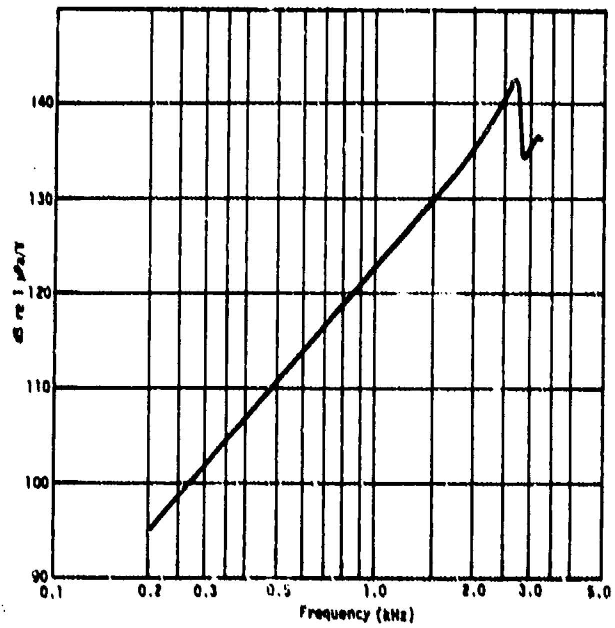


Fig. 03. (Left) Typical transmitting voltage response, type G34 transducer, unbalanced, black lead and shield grounded, 76-m cable. Serials 10 and higher operate satisfactorily above 3 kHz.

Fig. 04. (Right) Typical transmitting current response, type G34 transducer, unbalanced, black lead and shield grounded, 76-m cable.

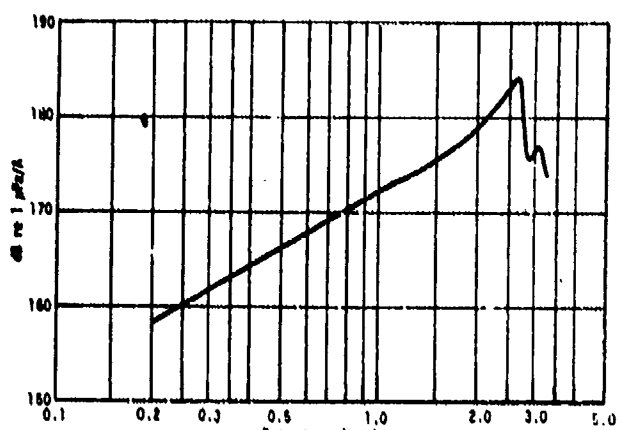
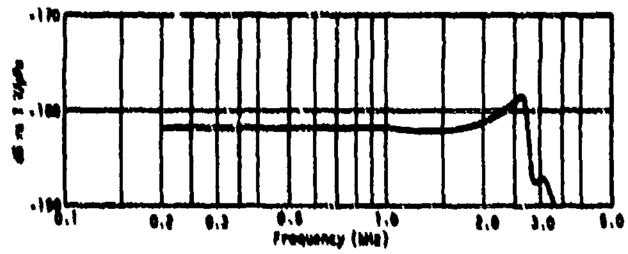


Fig. 05. (Right) Typical free-field voltage sensitivity, type G34 transducer; open-circuit voltage at end of 76-m cable, unbalanced, black lead and shield grounded.



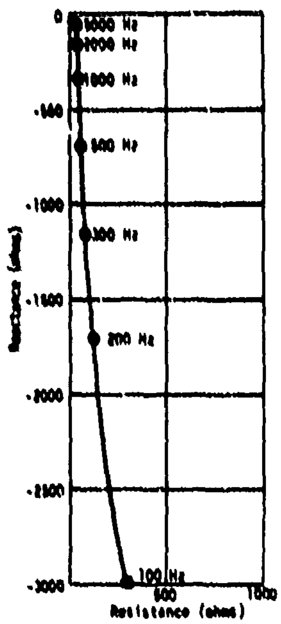
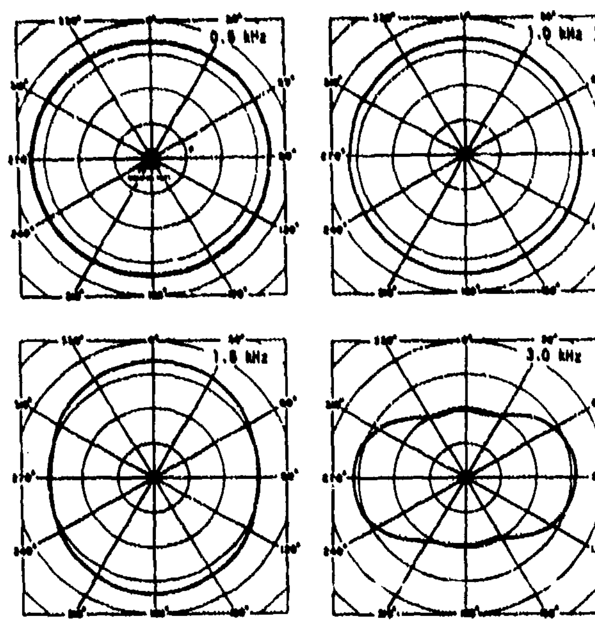


Fig. 06. (Left) Typical impedance of type G34 transducer under free-field conditions in water.

Fig. 07. (Right) Typical directivity patterns in the vertical (XZ) plane, type G34 transducer. Scale: center to top of grid, each pattern, equals 50 dB.



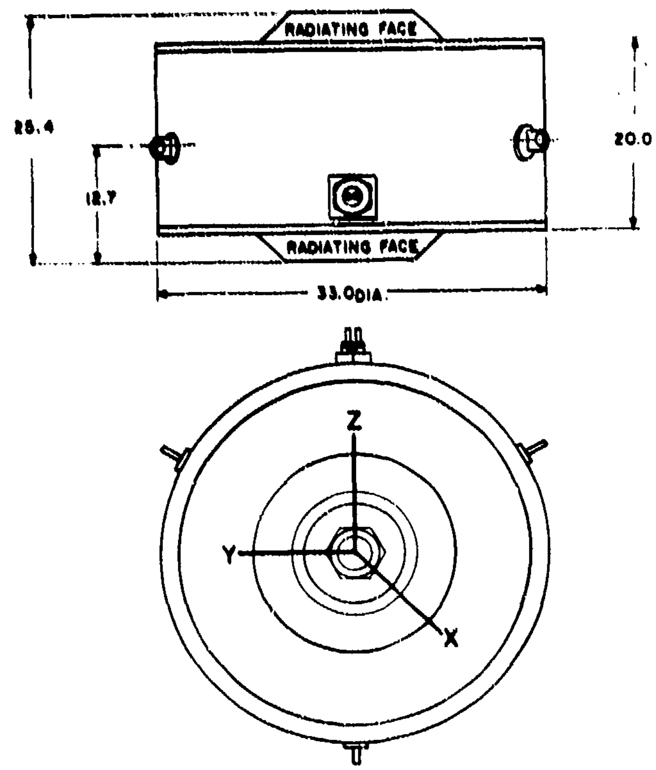


Fig. 08. Dimensions (in centimeters) and orientation, type G34 transducer.

Type H11
HYDROPHONE

General Description

The USRD type H11 hydrophone is designed for use in the frequency range 3 Hz to 2 kHz. The hydrophone is usable down to 0.3 Hz; however the loss in the preamplifier increases by approximately 6 dB per octave below 3 Hz. Figure P1 is a photograph of the hydrophone.

Fig. P1. USRD type H11 hydrophone.

The hydrophone consists of a piezoelectric sensor element and an associated preamplifier assembled into a single unit. The sensor element consists of six Y-cut lithium sulfate crystals 2.54 cm in diameter and 0.305 cm thick (the crystals in serials 131 to 145 are 0.228 cm thick). The crystals with their electrodes are cemented together into a single stack and are connected electrically in parallel. The acoustic window is Teflon, which has low water permeability and greatly increases the life of the hydrophone. The preamplifier is a cathode-follower circuit that offers a high input impedance to the crystal transducer and an output impedance of approximately 600 Ω. A transistor preamplifier can be provided if required. A 12-m, 2-pair, shielded, 6-conductor cable is connected to the hydrophone through a watertight seal.

Specifications

Frequency range:	0.3 Hz to 2 kHz
Free-field voltage sensitivity (nominal):	-188 dB re 1 V/μPa at 1 kHz at end of 12-m cable
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Preamplifier:	cathode follower
Preamplifier output impedance:	approximately 600Ω

Power requirements:	B-supply, 135 V, 3-4 mA A-supply, 6 V, 150 mA
Weight with 12-m cable:	6.4 kg
Shipping weight:	14 kg

Preamplifier

The over-all response of the hydrophone consists of (1) the open-circuit crystal voltage, (2) the voltage loss due to coupling the crystal to the preamplifier, and (3) the voltage loss or gain of the preamplifier. When these three quantities, expressed in decibels, are totaled, the sum represents the over-all response of the hydrophone. The sum of the coupling loss and the preamplifier gain or loss is called the "preamplifier-coupling characteristic." The crystal-to-amplifier voltage loss, or coupling characteristic, and the preamplifier gain or loss are collectively measured by inserting a known calibrating voltage (not greater than 0.1 V) across a precision 10-Ω resistor in series with the crystal and preamplifier input. The typical preamplifier coupling characteristic for the type H11 hydrophone is shown in Fig. P2.

The power supply and output connections of the hydrophones are shown in the schematic circuit, Fig. P3. For the lowest loss in the preamplifier, the hydrophone output should be terminated by a load greater than 10 000 Ω. The output is unbalanced.

The A-supply battery voltage may vary from +0.5 V to -1.0 v from the nominal 6.0 V, and the B-supply battery voltage may vary by ±10 V from the nominal 135 V. If a long extension cable is used, due allowance should be made to maintain these voltages at the end of the extension cable.

The type 9002 triode tube in the preamplifier is selected and aged. Hydrophones serials 131 to 145, and a few of the hydrophones with a lower serial number that have been modified, contain the type Raytheon CK6533 tube.

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type H11 hydrophone is established by comparison with standard hydrophones in free-field open-water measurements or by the reciprocity method in a closed-chamber low-frequency system. The typical free-field voltage sensitivity of the type H11 hydrophone is shown in Fig. P4. The sensitivity of the type H11 hydrophone does not change more than 1.5 dB with temperature from 5 to 35°C. The sensitivity does not change with hydrostatic pressure up to 6.9 Pa.

Equivalent noise pressure of the type H11 hydrophone is shown in Fig. P5. These values were determined from measurements made with a 20-Hz filter in the electronic measuring system and were verified by measurements with a low-noise transistor amplifier and a General Radio type 1554-A sound and vibration analyzer.

Preparation for Use

Figure P6 is a dimensioned outline drawing showing the orientation of the hydrophone. Mount the hydrophone in a fixture that clamps the body. It may be used in any position desired. Wash the diagram with a wetting agent, and stir the instrument under water; this will help to free most of the trapped air bubbles. Do not hang the instrument by the cable because the strength of the packing gland is not sufficient to support the weight.

Reference

I. D. Groves, "The USRL Infrasonic Hydrophone Type H11," Navy Underwater Sound Reference Laboratory Report No. 37, 3 Jan 1956 (AD-88 170).

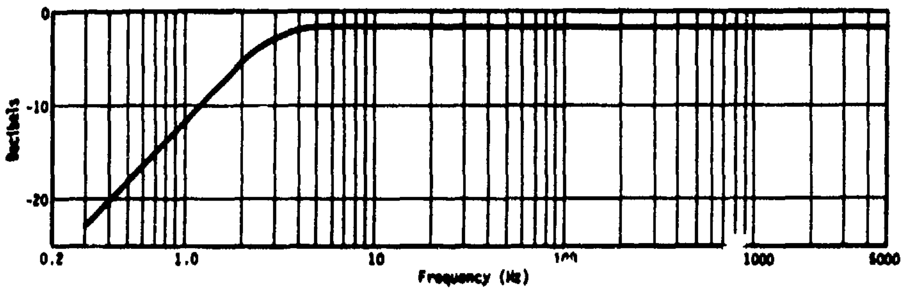


Fig. P2. (Above) Typical preamplifier coupling characteristic, type H11 hydrophone (ratio in decibels of open-circuit voltage at preamplifier output to open-circuit crystal voltage).

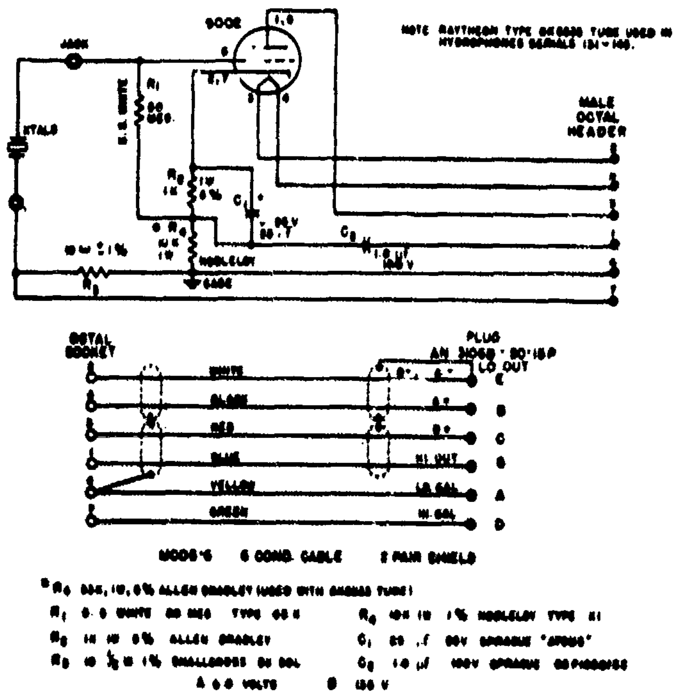


Fig. P3. (Right) Preamplifier circuit diagram, type H11 hydrophone. A transistor preamplifier can be provided if required.

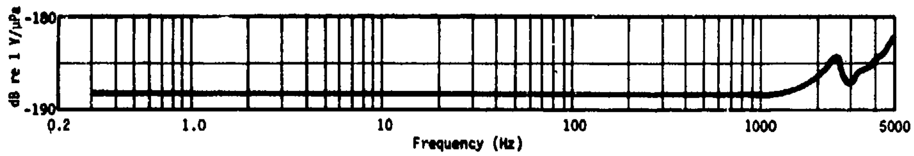


Fig. P4. Typical free-field voltage sensitivity, type H11 hydrophon , in terms of open-circuit voltage at end of 12-m cable.

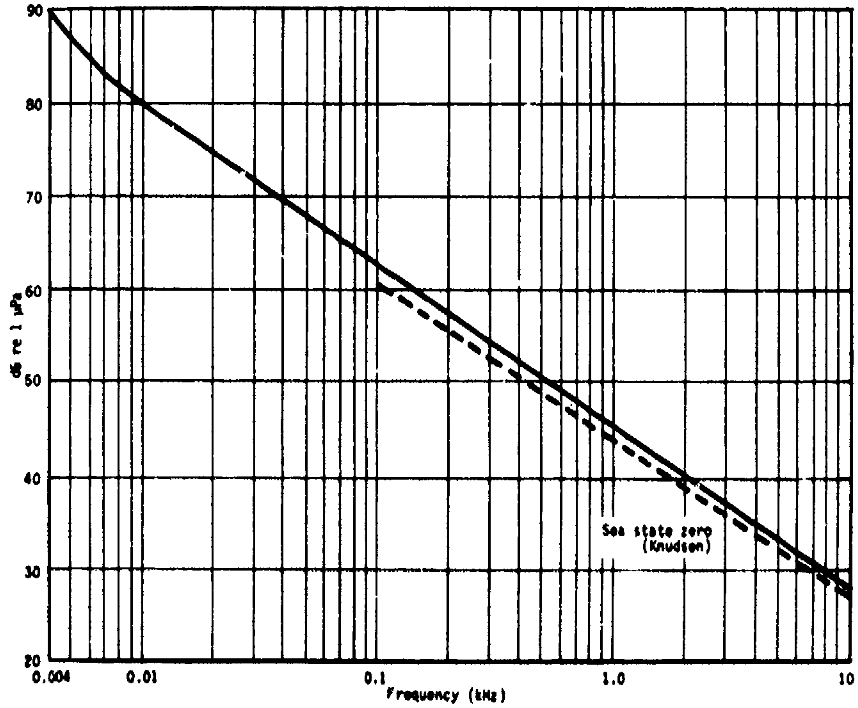


Fig. P5. (Above) Typical equivalent noise pressure computed from noise voltage at end of cable, type H11 hydrophone.

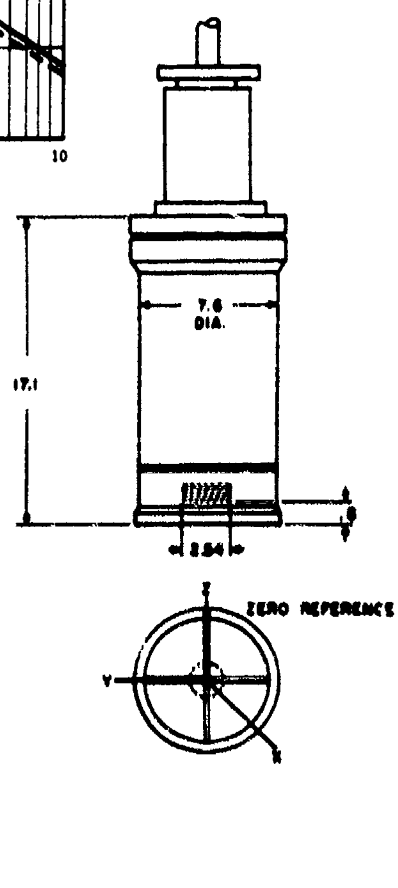


Fig. P6. (Right) Dimensions (in centimeters) and orientation of H11 hydrophone.

Type H17
HYDROPHONE

General Description

The USRD type H17 hydrophone is designed primarily for use as an underwater sound measurement standard for the frequency range 50 Hz to 150 kHz and for use at hydrostatic pressures up to 6.9 MPa. The hydrophone consists of an active element of four lithium sulfate crystals mounted in a symmetrical-drive arrangement that is surrounded by castor oil in a butyl rubber boot and a high-impedance cathode-follower type preamplifier with a 600-Ω output impedance.

The hydrophone normally is furnished with 12 m of 5-conductor, shielded neoprene-covered cable with a type AN3106-20-15P connector at the free end. Figure Q1 is a photograph of the hydrophone.

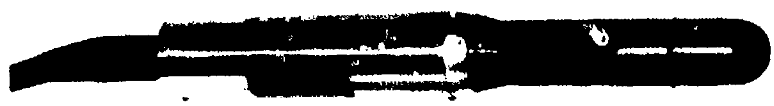


Fig. Q1. USRD type H17 hydrophone.

Specifications

Frequency range:	20 Hz to 150 kHz
Free-field voltage sensitivity (nominal):	-201 dB re 1 V/μPa at end of 12-m cable
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Preamplifier:	cathode follower
Preamplifier output impedance:	approximately 600Ω
Power requirements:	B-supply, 135 V, 2 mA A-supply, 6 V, 200 mA
Weight with cable:	3.9 kg
Shipping weight:	9 kg

Preamplifier

The over-all response of a hydrophone consists of (1) the voltage generated by the crystal on open circuit, (2) the voltage loss due to coupling the crystal to the preamplifier, and (3) the voltage loss or gain of the preamplifier. When these three quantities are expressed in decibels, they add up to the over-all response of the hydrophone.

Figure Q2 shows typical coupling loss and preamplifier characteristic of the type H17 hydrophone. A precision 10-Ω resistor is contained in the hydrophone for determining the loss of each individual hydrophone. The calibration voltage across the resistor should not exceed 0.1 V when the coupling loss measurement is made.

The power supply requirements and the schematic circuit of the preamplifier are shown in Fig. Q3. For the least loss in the preamplifier, the hydrophone output should be terminated by a load greater than 10 kΩ. The output is unbalanced; that is, one terminal is normally at ground potential. The output is connected to a low-capacitance coaxial cable.

The A supply battery voltage may vary by +0.5 V to -1.0 V from the nominal 6.0 V, and the B supply voltage may be ±10 V from the nominal 135 V. If an extension cable is used, allowance should be made to maintain these voltages at the output end of the 12-m cable.

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type H17 hydrophone is established by comparison with standard hydrophones in free-field measurements or by the reciprocity method. Figure Q4 shows a typical free-field voltage sensitivity curve for the type H17 hydrophone, measured in terms of open-circuit crystal voltage.

The *effect of temperature* on the sensitivity of the type H17 hydrophone was determined in a low-frequency closed tank and in an anechoic closed tank in which the temperature of the water was controlled from 5 to 25°C. The voltage sensitivity in the frequency ranges 10 to 500 Hz and 2 to 150 kHz was measured at a sufficient number of discrete temperatures to define any trend. The open-circuit voltage sensitivity of the hydrophone was stable within ±0.5 dB in the frequency range 10 Hz to 15 kHz and temperature range 5 to 25°C, and within ±2.0 dB from 15 to 150 kHz in the same temperature range.

The *effect of hydrostatic pressure* on the sensitivity was determined in the same closed tanks in which the temperature characteristics were determined. Free-field voltage sensitivity measurements were made in the frequency ranges 10 to 500 Hz and 2 to 150 kHz at the hydrostatic pressure 6.9 MPa. The open-circuit voltage sensitivity of the hydrophone remained the same within ±1.0 dB from 10 Hz to 50 kHz, and within ±1.5 dB from 50 to 150 kHz at pressures from 0 to 6.9 MPa.

The *equivalent noise pressure* of the type H17 hydrophone is shown in Fig. Q5. This curve agrees well with the theoretical values. These measurements, made with a 10-Hz filter in the electronic calibration system, were verified by laboratory measurements with a low-noise-level transistorized amplifier and a General Radio type 1554-A sound and vibration analyzer.

Directivity. The type H17 hydrophone is omnidirectional within ±1.0 dB at frequencies below 50 kHz in the horizontal (XY) plane; that is, the plane normal to the vertical axis of the preamplifier housing. The hydrophone is bidirectional in the same plane at the 0 and 180-deg orientations within ±1.0 dB in the frequency range 50 Hz to 150 kHz. Directivity patterns of the hydrophone for the XY, XZ, and YZ planes are shown in Figs. Q6, Q7, and Q8. A steel-stamped "O" on the metal housing immediately above the rubber boot is the zero reference for the hydrophone.

The *maximum sound pressure* that can be measured with the type H17 hydrophone is limited by the highest voltage that can be impressed on the input of the preamplifier without distortion. The type H17 hydrophone can be used at sound pressures up to 210 dB re 1 μPa without overloading the preamplifier.

Preparation of the Hydrophone for Use

Figure Q9 is a dimensioned outline drawing showing the orientation of the hydrophone. Mount the hydrophone in a fixture that clamps around the case near the cable gland. Do not support it by the cable. Wash the rubber boot with a wetting agent. Completely remove all air bubbles from the boot to avoid erroneous results.

Reference

I. D. Groves, "The USRL Broadband Hydrophone Type H17," Navy Underwater Sound Reference Laboratory Research Report No. 59, 15 Feb 1962 (AD-271 910).

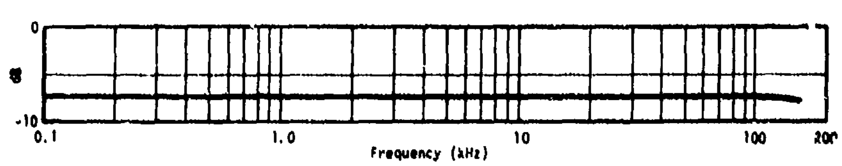
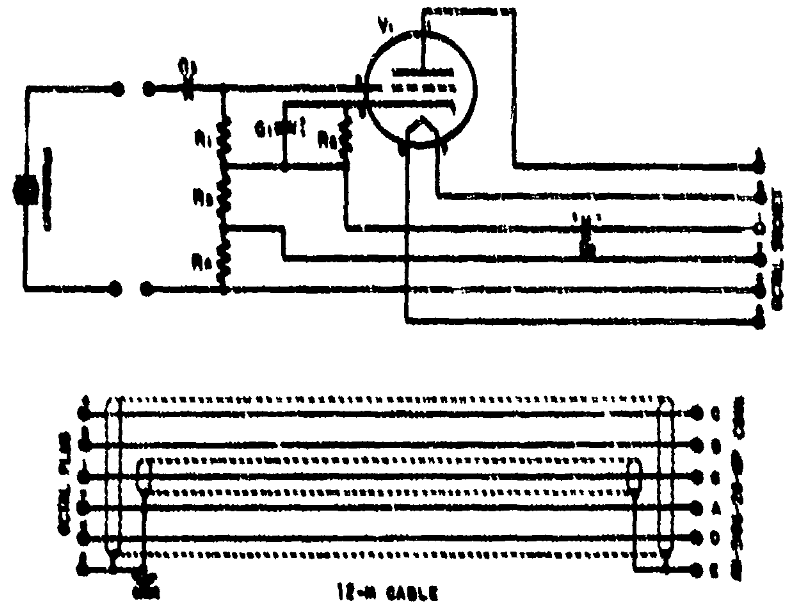


Fig. Q2. Typical preamplifier coupling characteristic, type H17 hydrophone (ratio in decibels of open-circuit voltage at preamplifier output to open-circuit crystal voltage).



PIN	FUNCTION	WIRE COLOR
A	LO CALIBRATE	[illegible]
B	A+6 VOLTS	WHITE
C	B+135 VOLTS	RED
D	HI CALIBRATE	GREEN
E	A-, B-, GND, LO SIG	SHIELD
F	NOT USED	
G	HI SIG OUT	BLACK

R_1 20 MEG 1W. ALLEN-BRADLEY
R_2 1K. ½W DEPOSITED CARBON
R_3 33K. ½W DEPOSITED CARBON
R_4 10Ω 1% 0.5 W DEPOSITED CARBON
C_1 10 μF 16V. OHMITE TANTALUM
C_2 1.0 μF 60V. OHMITE TANTALUM
C_3 500 pF 600V. CERAMIC
V_1 CK 6533 RAYTHEON

Fig. Q3. Schematic circuit of preamplifier, type H17 hydrophone.

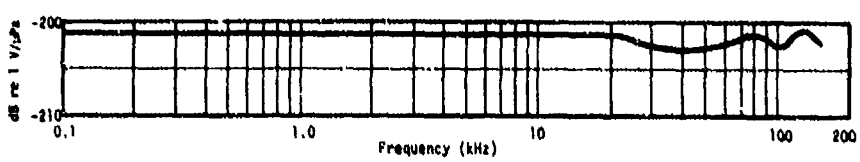


Fig. Q4. Typical free-field voltage sensitivity, type H17 hydrophone (open-circuit voltage at end of 12-m cable).

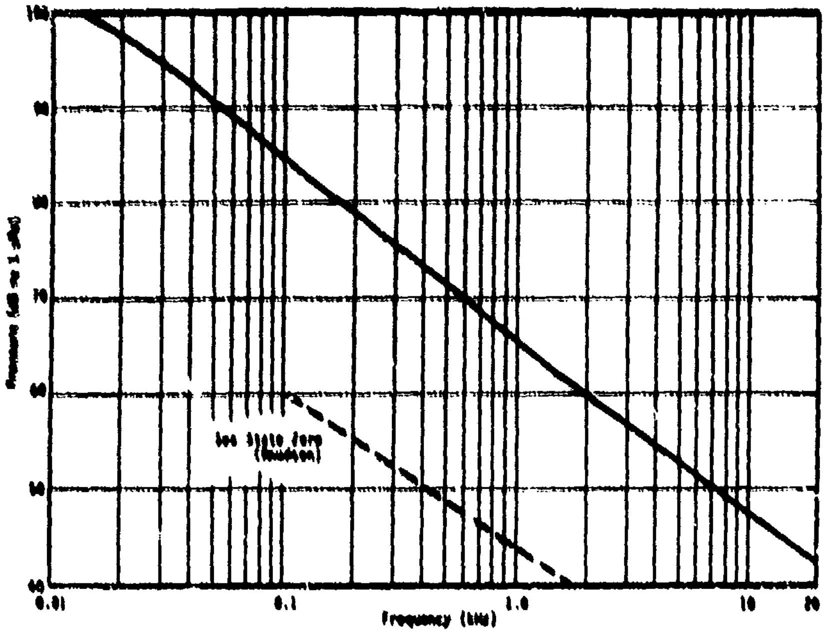


Fig. Q5. Equivalent noise pressure, type H17 hydrophone (computed from noise voltage measured at end of 12-m cable).

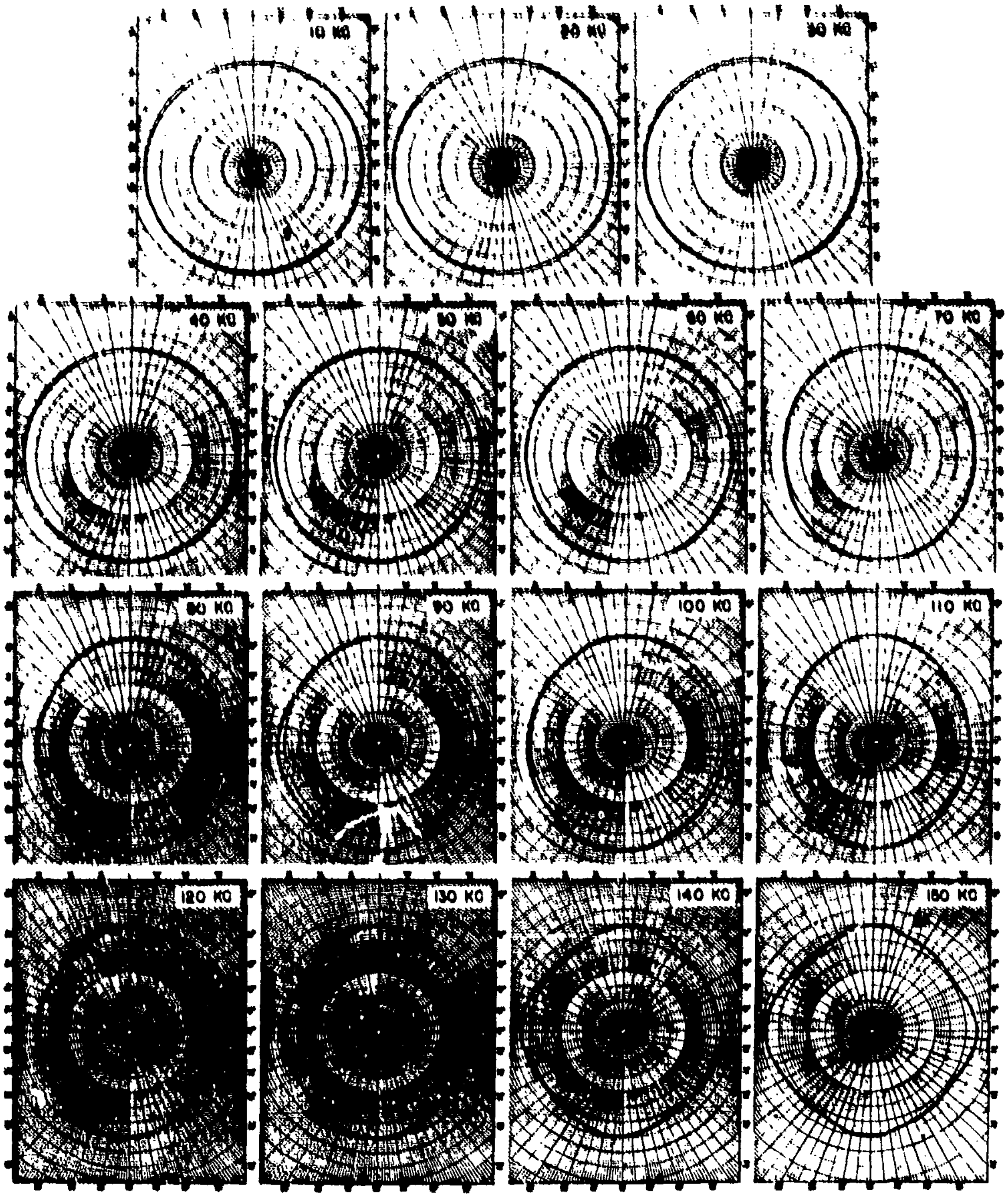


Fig. Q6. Typical directivity patterns in the XY plane, type H17 hydrophone. Scale: Center to top of grid, each pattern, equals 50 dB.

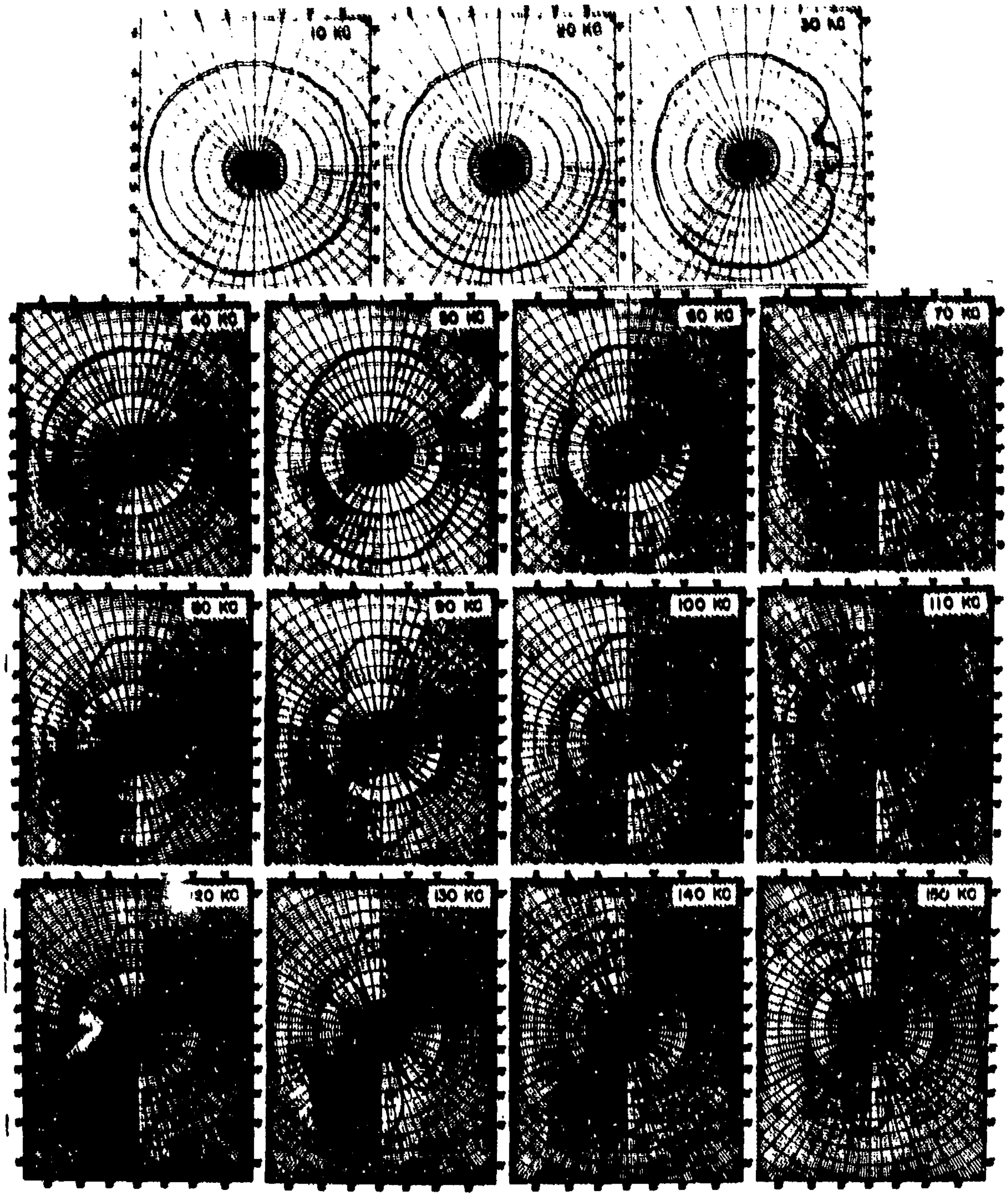


Fig. Q7. Typical directivity patterns in the XZ plane, type H17 hydrophone. Scale: Center to top of grid, each pattern, equals 50 dB.

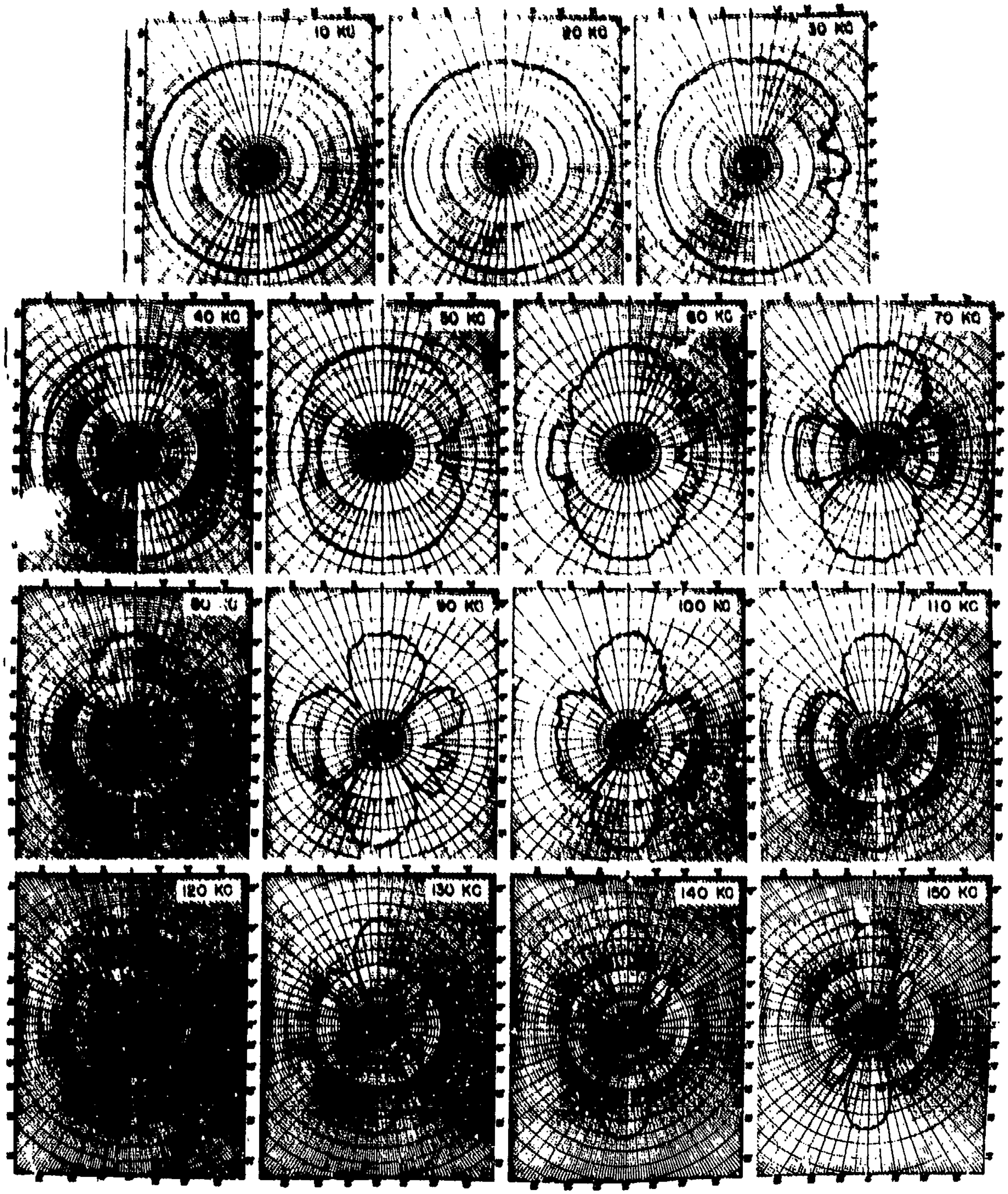


Fig. Q8. Typical directivity patterns in the YZ plane, type H17 hydrophone. Scale: Center to top of grid, each pattern, equals 50 dB.

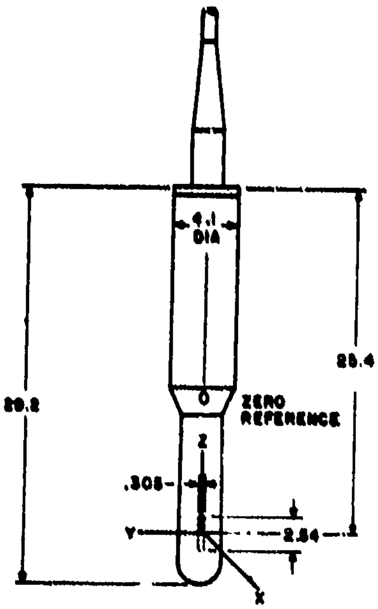


Fig. Q9. Dimensions (in centimeters) and orientation of type H17 hydrophone.

Type H17M
HYDROPHONE

General Description

The USRD type H17M (modified) hydrophone is designed primarily for use as an underwater sound measurement standard in the frequency range 20 Hz to 150 kHz. The sensitive element consists of four lithium sulfate crystals mounted on rubber supports in a castor-oil-filled butyl rubber boot. A solid-state preamplifier provides high input impedance and low output impedance through the use of field-effect transistors in a circuit stabilized by feedback. The voltage gain is 10 dB.

Normally, the hydrophone is supplied with a 12-m, 5-conductor, shielded, neoprene-covered cable with a type AN3106-20-15P connector at the free end. Longer cables (300 to 600 m) can be used, however, with reduction in the dynamic range.

Figure R1 is a photograph of the hydrophone.

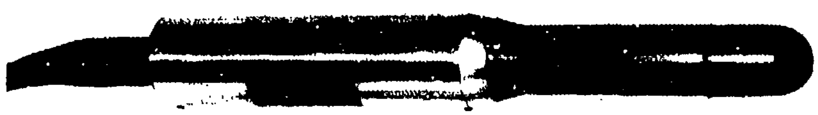


Fig. R1. USRD type H71M hydrophone.

Specifications

Frequency range:	20 Hz to 150 kHz
Free-field voltage sensitivity (nominal):	-191 dB re 1 V/μPa to 150 kHz at end of 12-m cable
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 35°C
Preamplifier:	transistorized, 10-dB gain
Preamplifier output impedance:	less than 35 Ω in series with 100 μF
Power requirements:	12 V, 5.0 mA
Weight with 12-m cable:	3.9 kg
Shipping weight:	9 kg

Preamplifier

Figure R2 shows the wiring diagram of the cable and calibration circuit of the type H17M hydrophone. The transistorized preamplifier provides a hydrophone output impedance of 35 Ω in series with 100 μF. The unbalanced output is connected to an RG188/U coaxial cable that is part of the five-conductor hydrophone cable.

The over-all voltage sensitivity of a hydrophone consists of the sum in decibels of (1) the open-circuit voltage generated by the crystal, (2) the voltage loss due to coupling of the crystal to the preamplifier, and (3) the voltage loss or gain of the preamplifier operating into its normal load. The typical hydrophone preamplifier coupling gain, which is the ratio in decibels of the open-circuit voltage at the preamplifier output to the open-circuit crystal voltage, is 4.0 ± 0.5 dB. Each hydrophone contains a precision 10-Ω resistor for use in determining the preamplifier coupling gain. *Do not apply more than 0.1 V across this resistor when making these measurements.*

When a 12-m cable is used, the dynamic range of the preamplifier is such that sound pressures of 3200 Pa (190 dB re 1 μPa) can be measured at frequencies below 30 kHz without preamplifier overload. For undistorted output signal at higher frequencies, the sound pressure limit is lower.

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type H17M hydrophone is determined by comparison with standard hydrophones in free-field measurements, or by the reciprocity method. Figure R3 shows the typical free-field voltage sensitivity in terms of open-circuit voltage at the end of a 12-m cable.

The *effect of temperature and hydrostatic pressure* on the sensitivity of the H17M hydrophone has been determined in closed tanks under controlled conditions of temperature and pressure. Measurements indicate that the free-field voltage sensitivity in the frequency range 20 Hz to 150 kHz changes by less than 1.5 dB with temperature from 10 to 25°C. No greater change would be expected in the range 5 to 35°C. The sensitivity is not affected by hydrostatic pressure to 6900 kPa.

Figure R4 shows the *equivalent noise pressure* of the type H17M hydrophone These measurements were made with a 1/3-octave filter, an 80-dB-gain, low-noise, transistorized amplifier, and a General Radio 1554A sound and vibration analyzer.

Directivity. The hydrophone is omnidirectional within ±1 dB in the plane (XY) normal to the longitudinal axis at frequencies below 40 kHz. It is bidirectional within ±1 dB in the XY plane at the 0- and 180-deg orientations in the frequency range 20 Hz to 150 kHz. The vertical (XZ plane) directivity is equivalent to that of a 2.54-cm line. Horizontal and vertical patterns are shown in Figs. R5 and R6, respectively.

Preparation for Use

Figure R7 is a dimensioned outline drawing of the hydrophone showing its orientation. Mount the hydrophone in a fixture that can be clamped around the case near the cable gland. Do not support the hydrophone by the cable. Wash the hydrophone thoroughly with a wetting agent or a detergent to remove all air bubbles from the boot and reduce the possibility of erroneous results. Permit the temperature of the hydrophone to stabilize with that of the water before making any measurements.

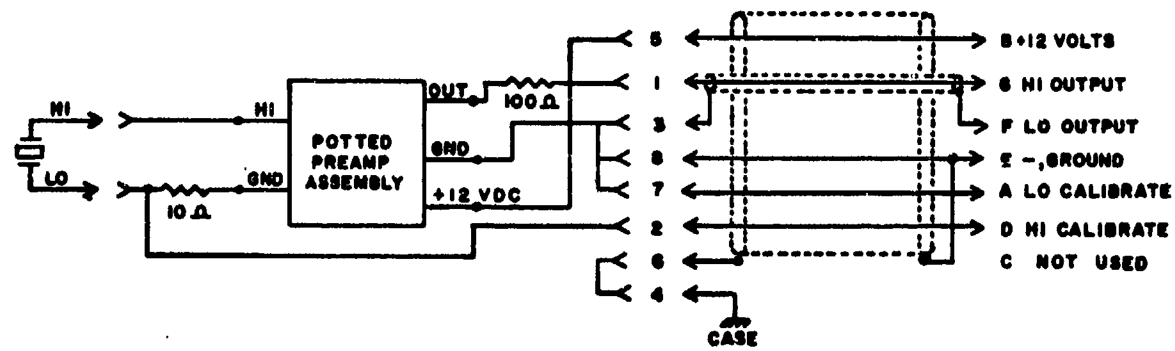


Fig. R2. Wiring diagram, type H17M hydrophone.

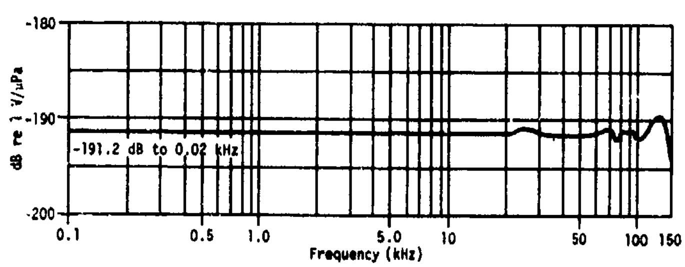


Fig. R3. (Left) typical free-field voltage sensitivity, type H17M hydrophone; open-circuit voltage at end of 12-m cable.

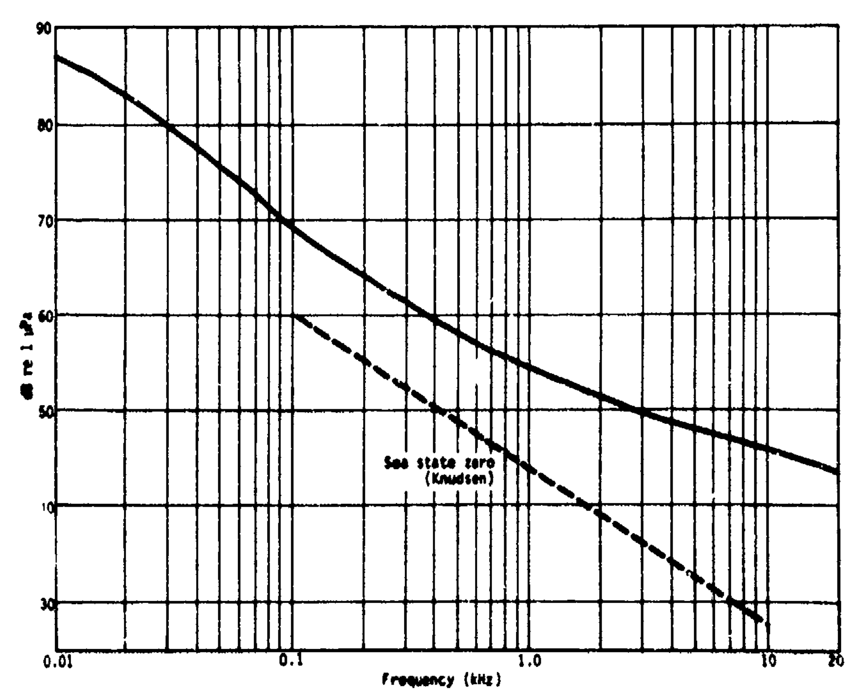


Fig. R4. (Right) Typical equivalent noise pressure measured at end of 12-m cable, type H17M hydrophone.

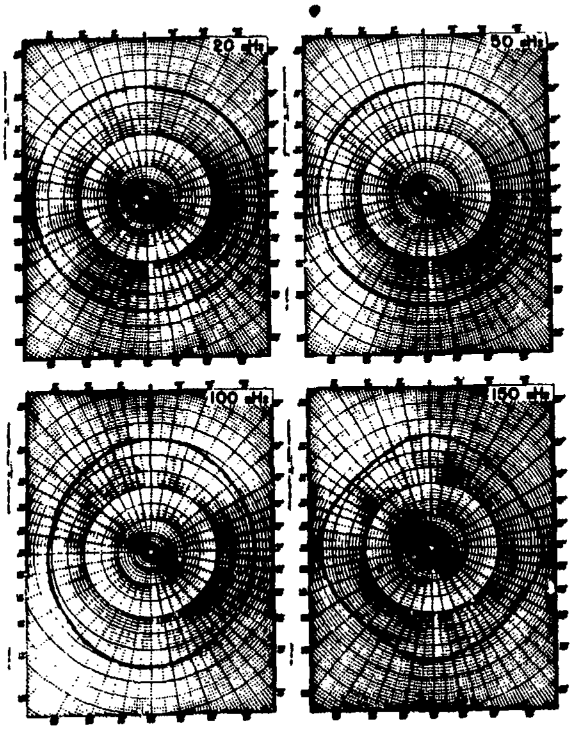


Fig. R5. Typical directivity patterns in the horizontal (XY) plane, type H17M hydrophone. Scale: center to top of grid, each pattern, equals 50 dB.

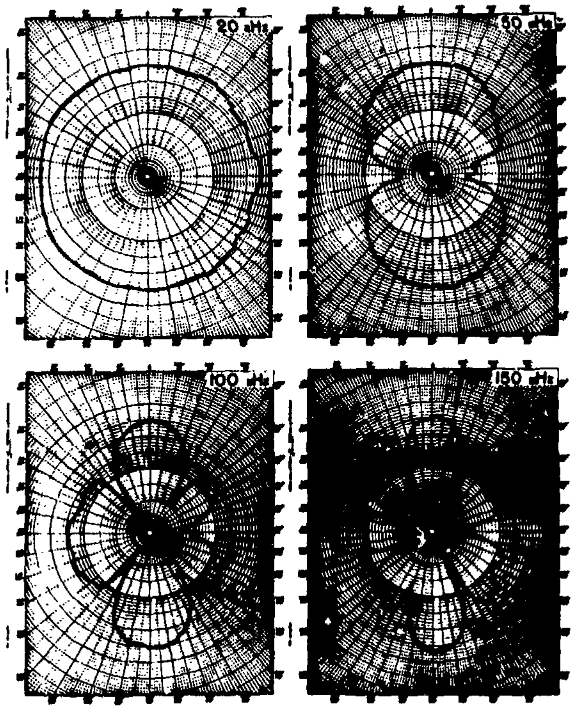
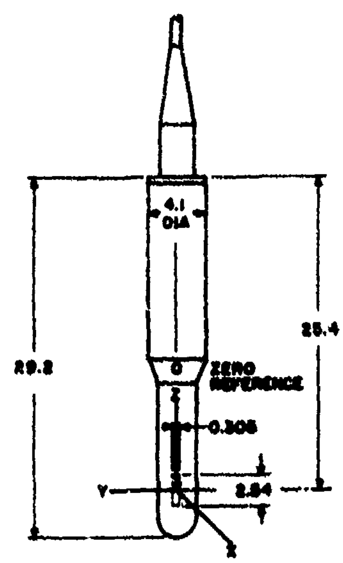


Fig. R6. Typical directivity patterns in the vertical (XZ) plane, type H17M hydrophone. Scale: center to top of grid, each pattern, equals 50 dB.

Fig. R7. (Right) Dimensions (in centimeters) and orientation, type H17M hydrophone.



Type H23
HYDROPHONE

General Description

The USRD type H23 hydrophone is designed primarily for use as an underwater sound measurement standard in the frequency range 20 Hz to 150 kHz. Figure S1 is a photograph of the hydrophone.

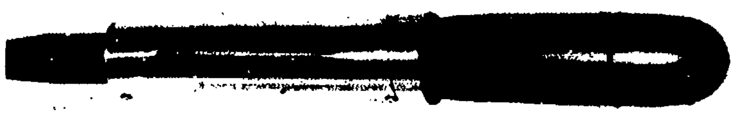


Fig. S1. USRD type H23 hydrophone.

The sensitive element consists of eight lithium sulfate crystals mounted on rubber supports in a castor-oil-filled butyl rubber boot. A solid-state preamplifier provides high input impedance and low output impedance through the use of field-effect transistors in a circuit stabilized by feedback. The voltage gain is 10 dB.

Normally, the hydrophone is supplied with 23 m of 5-conductor shielded neoprene-covered cable with a type AN3106-20-15P connector at the free end. Longer cables (300 to 600 m) can be used with a resultant loss in sensitivity, particularly at the higher frequencies, and with a reduction in dynamic range.

Specifications

Frequency range:	20 Hz to 150 kHz
Free-field voltage sensitivity (nominal):	-188 dB re 1 V/μPa to 20 kHz at end of 23-m cable; above 20 kHz, the average end-of-cable sensitivity is approximately -191 dB re 1 V/μPa
Maximum hydrostatic pressure:	17 MPa (1700-m depth)
Operating temperature range:	0 to 35°C
Preamplifier:	transistorized, 10-dB gain
Preamplifier output impedance:	less than 35 Ω in series with 100 μF
Power requirements:	12 V, 5.0 mA
Weight with 23-m cable:	6 kg
Shipping weight:	13 kg

Preamplifier

The over-all sensitivity of a hydrophone consists of (1) the voltage generated by the crystal on open circuit, (2) the voltage loss due to coupling of the crystal to the preamplifier, and (3) the voltage loss or gain of the preamplifier operating into its normal load. The sum of these three quantities expressed in decibels in the over-all sensitivity of the hydrophone.

Figure S2 shows the typical coupling loss characteristic of the transistorized preamplifier. The associated circuitry is shown in Fig. S3. Each hydrophone contains a precision 10-Ω resistor for use in determining the preamplifier coupling characteristic. *Do not apply more than 0.1 V across the precision resistor when making the coupling measurement.*

The nominal output impedance is less than 35 Ω in series with 100 μF. The unbalanced output is connected to an RG188/U coaxial cable that is part of the 5-conductor cable. When 23 m of cable are used, the dynamic range of the preamplifier is such that sound pressures of 3.2 kPa (190 dB re 1 μPa) can be measured without overload below 30 kHz. For undistorted output signal at higher frequencies, the sound pressure limit is lower.

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type H23 hydrophone is determined by comparison with standard hydrophones in free-field measurements, or by the reciprocity method. Figure S4 shows typical free-field voltage sensitivity in terms of open-circuit voltage at the end of the 23-m cable.

The *effect of temperature and hydrostatic pressure* on the sensitivity of the H23 hydrophone has been determined in closed tanks under controlled conditions of temperature and pressure. Measurements indicate that the free-field voltage sensitivity in the frequency range 20 Hz to 150 kHz changes less than 1.5 dB with temperature from 5 to 25°C. The sensitivity is not affected by hydrostatic pressure to 7 MPa. Little or no change has been found at pressures to and including the maximum design pressure 17 MPa in the frequency range 100 to 4000 Hz. Measurements have not been made above 4000 Hz at pressure greater than 7 MPa.

Figure S5 shows the *typical equivalent noise pressure,* which is the sound pressure that is equivalent to the open-circuit noise voltage generated by the hydrophone. Equivalent noise pressure can be computed from the relation $p_{en} = e_n - M_e$, where p_{en} is the equivalent noise pressure, e_n is the noise voltage per hertz, and M_e is the free-field voltage sensitivity.

Directivity. The hydrophone is omnidirectional within ±1 dB in the plane (XY) normal to the longitudinal axis at frequencies below 50 kHz. It is bidirectional within ±1 dB in the XY plane at the 0- and 180-deg orientations in the frequency range 20 Hz to 150 kHz. The vertical (XZ plane) directivity is equivalent to that of a 5-cm line. Horizontal and vertical patterns are shown in Figs. S6 and S7, respectively.

Preparation and Use

Figure S8 is a dimensioned outline drawing showing the orientation of the hydrophone. Mount the hydrophone in a fixture that can be clamped around the case near the cable gland. Do not support the hydrophone by the cable. Wash the hydrophone thoroughly with a wetting agent or a detergent to remove completely all air bubbles from the boot and reduce the possibility of erroneous results.

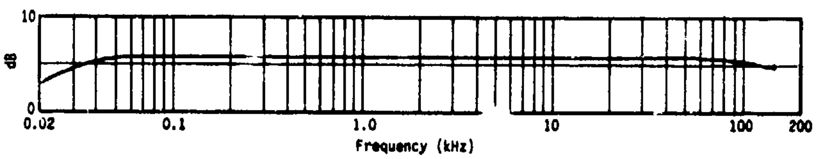


Fig. S2. Typical coupling loss, transistorized preamplifier of type H23 hydrophone (ratio in decibels of open-circuit voltage at preamplifier output to open-circuit crystal voltage).

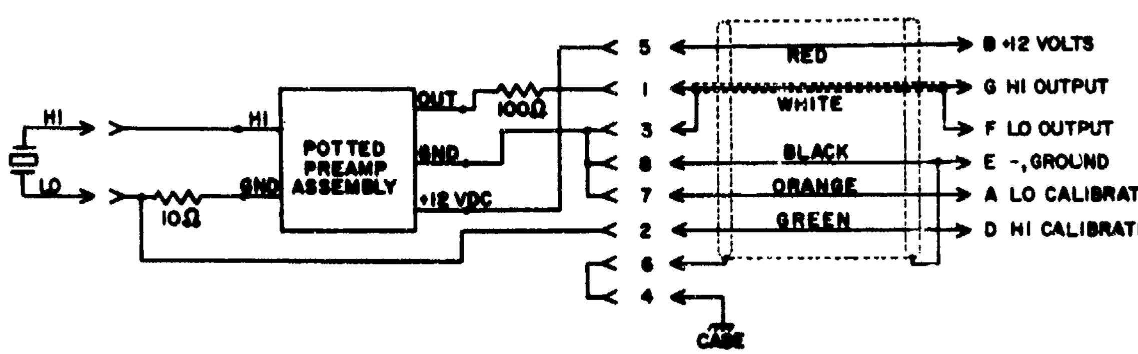


Fig. S3. Wiring diagram, type H23 hydrophone.

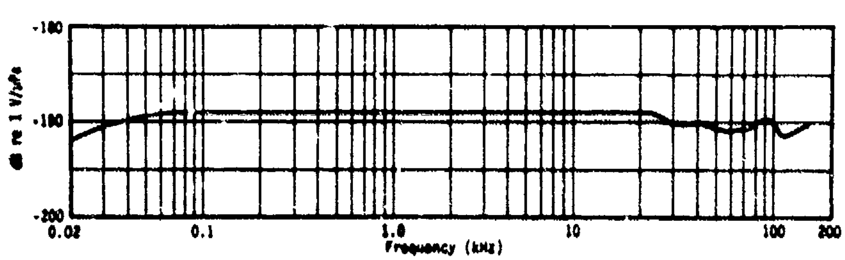


Fig. S4. Typical free-field voltage sensitivity, type H23 hydrophone (open-circuit voltage at end of 23-m cable).

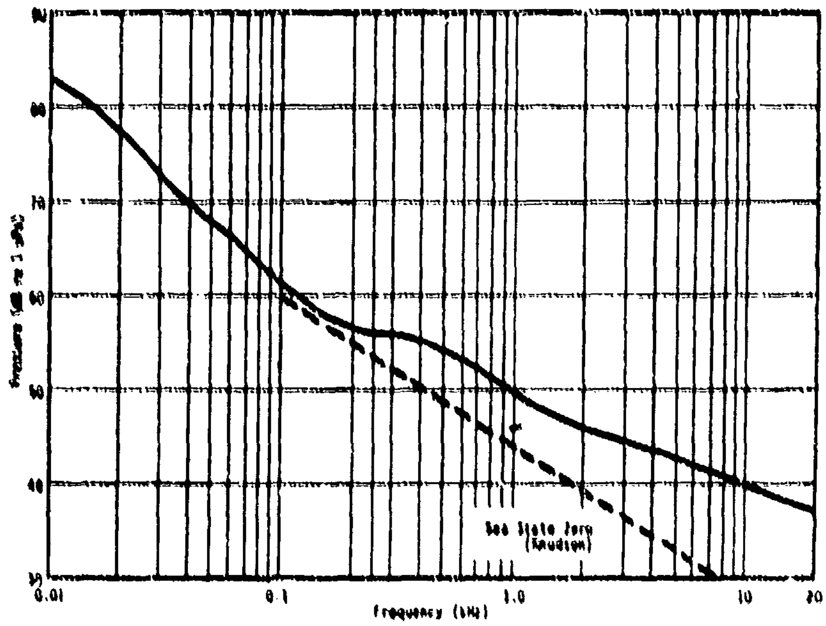
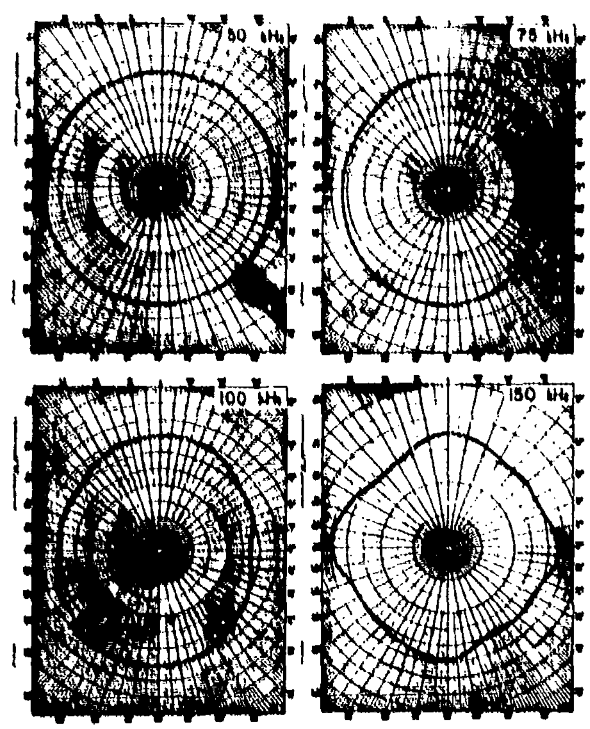


Fig. S5. Typical equivalent noise pressure, type H23 hydrophone.

Fig. S6. (Right) Typical directivity patterns in the horizontal (XY) plane, type H23 hydrophone. Scale: center to top of grid, each pattern, equals 50 dB.



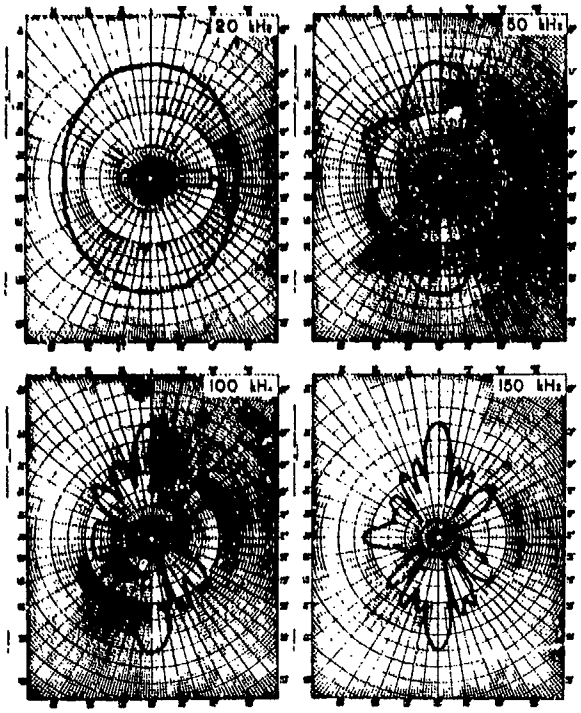


Fig. S7. (Right) Typical directivity patterns in the vertical (XZ) plane, type H23 hydrophone. Scale: center to top of grid, each pattern, equals 50 dB.

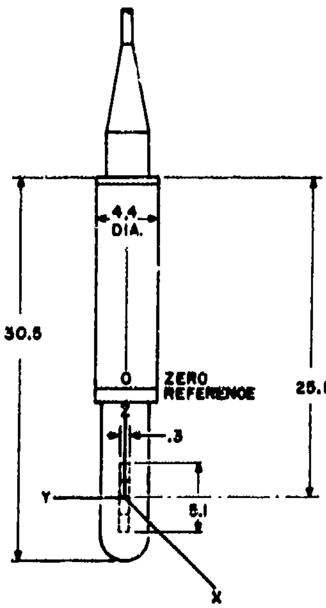


Fig. S8. (Right) Dimensions (in centimeters) and orientation of type H23 hydrophone.

Type H52
HYDROPHONE

General Description

The USRD type H52 hydrophone is an underwater sound measurement standard for use in the frequency range 20 Hz to 150 kHz. It can be used to a depth of 5200 m. Figure T1 is a photograph of the hydrophone.

Fig. T1. USRD type H52 hydrophone.

The sensitive element consists of eight lithium sulfate crystals mounted on rubber supports in a castor-oil-filled butyl-rubber boot. A solid-state preamplifier within the transducer housing provides high input impedance, low output impedance, and a 10-dB voltage gain.

Normally, the hydrophone is supplied with 23 m of multiconductor, shielded, neoprene-covered cable bonded to the transducer and terminated by a type AN3106-20-15P connector. Longer cables can be used, however, with a reduction in the dynamic range.

Specifications

Frequency range:	20 Hz to 150 kHz
Free-field voltage sensitivity (nominal):	-187 dB re 1 V/μPa to 150 kHz at end of 23-m cable
Maximum hydrostatic pressure:	52 MPa (5200-m depth)
Operating temperature range:	0 to 35°C
Preamplifier:	transistorized, 10-dB gain
Preamplifier output impedance:	less than 35 Ω in series with 100 μF
Power requirement:	12 V d-c, 10 mA
Weight with 23-m cable:	4.3 kg
Shipping weight:	12 kg

Preamplifier

The wiring diagram of circuitry associated with the integral preamplifier is shown in Fig. T2. The unbalanced output is connected to an RG174/U coaxial cable that is part of the hydrophone cable.

The over-all voltage sensitivity of a hydrophone consists of the sum in decibels of (1) the voltage generated by the crystal on open circuit, (2) the voltage loss due to coupling of the crystal to the preamplifier, and (3) the voltage loss or gain of the preamplifier operating into its normal load. The typical H52 hydrophone voltage coupling gain--the ratio in decibels of the open-circuit voltage at the preamplifier output to the open-circuit crystal voltage--is 8.0 ± 0.5 dB from 20 Hz to 150 kHz. Each hydropone contains a precision 10-Ω resistor for use in determining the hydrophone voltage coupling gain. Do not apply more than 0.1 V across this resistor when making the coupling measurement.

To prevent excessive input voltage to the preamplifier, the maximum sound pressure to which the hydrophone is subjected with 23 m of cable should be limited to 5600 Pa (195 dB re 1 μPa).

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type H52 hydrophone is determined by comparison with standard hydrophone in free-field measurements, or by the reciprocity method. Figure T3 shows the typical free-field voltage sensitivity.

The *effect of temperature and hydrostatic pressure* on the sensitivity of the H52 hydrophone has been determined in closed tanks under controlled conditions of temperature and pressure. The free-field voltage sensitivity in the frequency range 20 Hz to 100 kHz changes less than 1.0 dB with temperature from 3 to 25°C at pressure to 6.9 MPa. From 100 to 150 kHz, the variation in sensitivity with temperature is caused by changes in the characteristic impedance of the butyl rubber boot. No change in sensitivity with temperature has been observed up to 51.7 MPa in the frequency range 20 Hz to 4 kHz. Measurements have not been made above 4 kHz at pressure greater than 6.9 MPa.

Figure T4 shows the typical *equivalent noise pressure,* which is the sound pressure equivalent to the open-circuit noise voltage generated by the hydrophone. These measurements were made with a 1/3-octave filter, an 80-dB-gain, low-noise, transistorized amplifier, and a General Radio 1554-A sound and vibration analyzer.

Directivity. The hydrophone is omnidirectional within ±1 dB in the plane (XY) normal to the longitudinal axis at frequencies below 50 kHz. The vertical (XZ plane) directivity is equivalent to that of a 5-cm line.

Above 50 kHz, the hydrophone protective guard affects directivity in the XY plane. These variations can be seen in Fig. T5, which shows typical directional characteristics in the XY plane, with and without the guard. Figure T6 shows patterns in the vertical (XZ) plane.

Preparation for Use

Figure T7 is a dimensioned outline drawing showing the orientation of the hydrophone. Mount the hydrophone in a rigid fixture that can be clamped around the case near the cable gland. Do not support the hydrophone by its cable. Wash the hydrophone thoroughly with a wetting agent or a detergent to remove completely all air bubbles from the boot and reduce the possibility of erroneous results. The protective guard can be removed to improve directional characteristics, but should be replaced before transporting or storing the hydrophone. Permit the temperature of the hydrophone to stabilize with that of the water before making any measurements.

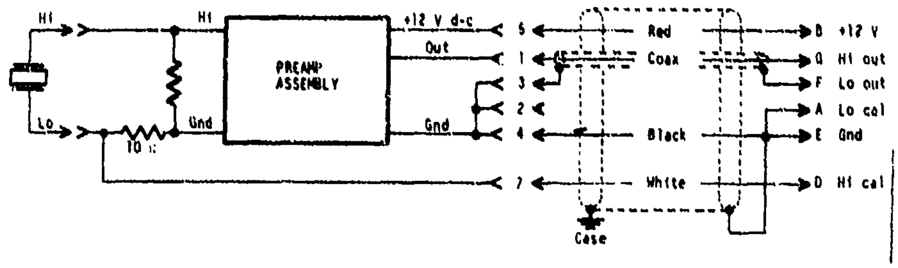


Fig. T2. Wiring diagram, type H52 hydrophone.

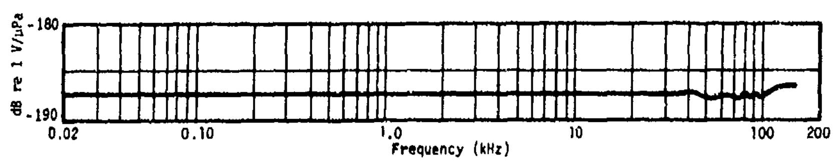


Fig. T3. Typical free-field voltage sensitivity, type H52 hydrophone; open-circuit voltage at end of 23-m cable.

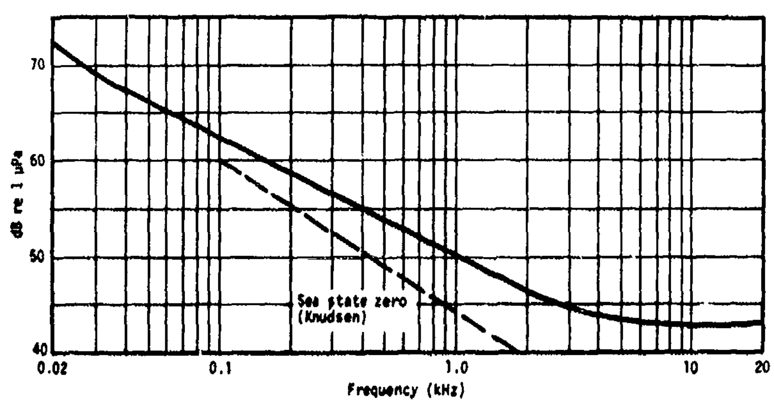


Fig. T4. Typical equivalent noise pressure, type H52 hydrophone.

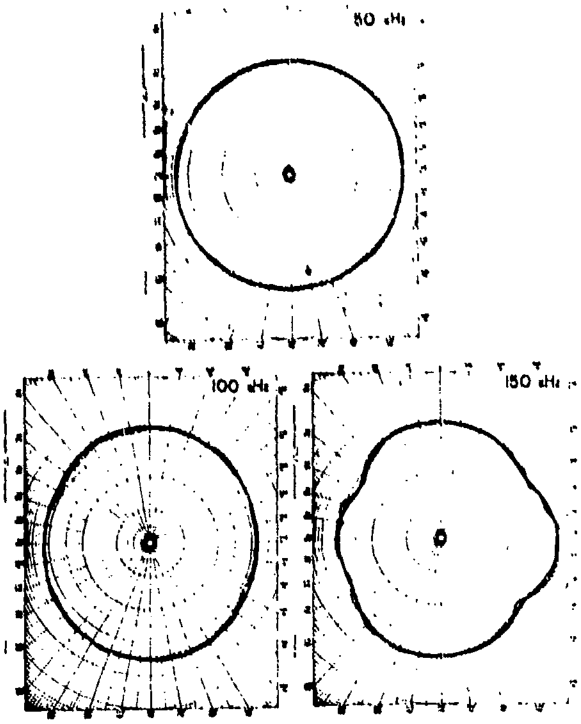


Fig. T5. Typical directivity patterns in the horizontal (XY) plane, type H52 hydrophone; dashed lines show effect of protective wire guard around hydrophone. Scale: center to top of grid, each pattern, equals 50 dB.

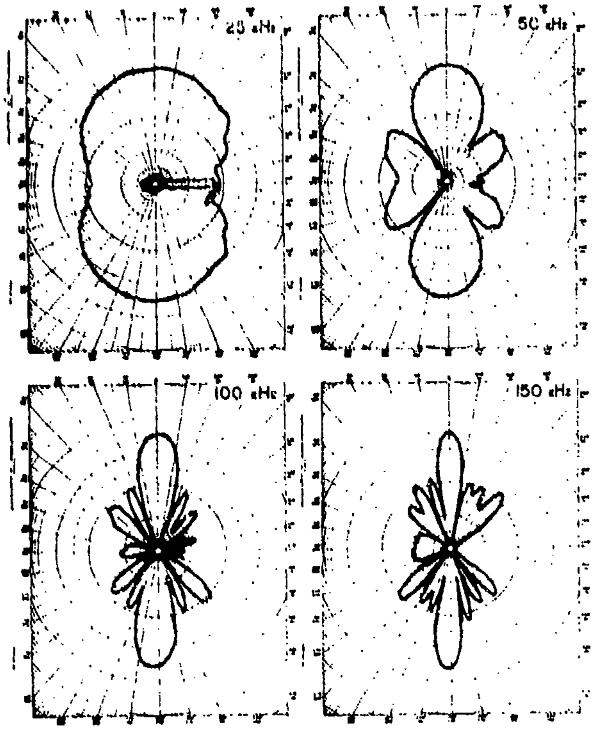
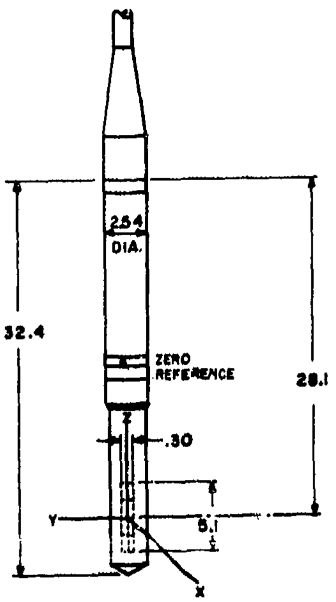


Fig. T6. Typical directivity patterns in the vertical (XZ) plane, type H52 hydrophone. Scale: center to top of grid, each pattern, equals 50 dB.

Fig. T7. (Right) Dimensions (in centimeters) and orientation of type H52 hydrophone.



Type H56
HYDROPHONE

General Description

The USRD type H56 hydrophone is an underwater sound measurement standard for use in the frequency range 10 Hz to 65 kHz. It was designed to provide high sensitivity and low self noise and thus permit the measurement of low signal levels. Figure U1 is a photograph of the hydrophone.

Fig. U1. USRD type H56 hydrophone.

The sensor element normally supplied consists of a capped length-polarized tube with the area ratio 3:1 of end caps to ceramic tube. This ratio provides the maximum sensitivity at the lowest impedance for operation independent of hydrostatic pressure to approximately 6.9 MPa. The upper frequency limit of operation for this design is about 65 kHz. When operation to 100 kHz is required, a hydrophone containing circumferentially poled striped lead zirconate-titanate cylinders can be supplied on special request (subject to availability). The 3:1-area-ratio model provides better reproducibility from unit to unit and better temperature independence than does the striped-cylinder model.

The hydrophone usually is supplied with 23 m of multiconductor, shielded, neoprene-jacketed cable terminated by a type AN-3106-20-15P or a Marsh & Marine underwater connector. Longer cables can be used, however, with a reduction in the dynamic range. The hydrophone is fully rubber covered to insulate all metal parts from the water. A solid-state preamplifier within the transducer housing provides high input impedance, low output impedance, and approximately 11 dB voltage gain.

Specifications

Frequency range:	10 Hz to 65 kHz (100 kHz for striped cylinder)
Free-field voltage sensitivity (nominal, at 10 kHz):	-173 dB re 1 V/μPa at the end of 23-m cable
Maximum hydrostatic pressure:	6.9 MPa (690-m depth)
Operating temperature range:	0 to 30°C
Preamplifier:	transistorized, 11-dB gain

Preamplifier output impedance:	less than 35 Ω in series with 100 μF
Power requirement:	24 V, 7 mA
Weight with 23-m cable:	6 kg
Shipping weight:	14 kg

Preamplifier

The wiring diagram for the circuitry associated with the integral preamplifier is shown in Fig. U2. The unbalanced output is connected to a coaxial cable that is part of the hydrophone cable. The typical H56 hydrophone voltage coupling gain (the ratio in decibels of the open-circuit voltage at the preamplifier output to the open-circuit crystal voltage) is 11.0 ± 1.0 dB from 30 Hz to 100 kHz. Each hydrophone contains a precision 10-Ω resistor in series with the sensor element for use in determining the hydrophone voltage coupling gain. *Do not apply more than 0.1 V across this resistor when making the coupling measurement.*

To prevent excess input voltage to the preamplifier and keep the distortion less than 1% at frequencies below 30 kHz, do not subject the hydrophone to sound pressure greater than 636 μPa (176 dB re 1 μPa).

Electroacoustic Characteristics

The *free-field voltage sensitivity* of the type H56 hydrophone is determined by comparison with standard hydrophones in free-field measurements or by the reciprocity method. The typical free-field voltage sensitivity for the 3:1-area-ratio capped-tube model is shown in Fig. U3. Individual calibration curves are provided for each hydrophone at the time of issue.

The *effect of temperature and hydrostatic pressure* on the sensitivity of the H56 hydrophone has been determined in closed tanks under controlled conditions of temperature and pressure. Figure U4 shows the effect of temperature on the sensitivity of the striped ceramic tube sensor element. The sensitivity does not change more than 1.3 dB at pressures to 6.9 MPa. Temperature and pressure effects on the 3:1-area-ratio capped-tube sensor element is less than 0.75 dB at pressures to 6.9 MPa and for temperatures in the range 6-29°C.

Figure U5 shows typical *equivalent noise pressure* for the type H56 hydrophone with a 100-pF sensor element and an open-circuit crystal voltage sensitivity of -183 dB re 1 V/μPa. The equivalent noise pressure is the rms sound pressure of a sinusoidal plane progressive wave which, if propagated parallel to the principal axis of the hydrophone, would produce an open-circuit signal voltage equal to the rms value of the inherent open-circuit noise voltage of the hydrophone in a transmission band having a bandwidth of 1 Hz and centered on the frequency of the plane sound wave (see ANSI standards S1.1-1960 and S1.20-1972).

The data presented in Fig. U5 were obtained from measurements made with a 1/3-octave filter, a low-noise transistorized amplifier, and a

General Radio 1554-A sound and vibration analyzer. The hydrophone was shock mounted within a vacuum bell that was isolated from building vibrations by air shock mounts.

Directivity. Both models of the hydrophone are omnidirectional within ±1 dB in the plane (XY) normal to the longitudinal axis at frequencies below 60 kHz. The vertical (XZ) plane directivity patterns are shown in Fig. U6 for the 3:1-area-ratio capped-tube sensor.

Preparation for Use

Mount the hydrophone in a fixture that can be clamped around the case near the cable gland. The hydrophone normally is used with its length axis coincident with the Z axis. Wash the hydrophone thoroughly with a wetting agent or a detergent to remove all air bubbles from the boot. Permit the temperature of the hydrophone to stabilize with that of the water for best calibration accuracy. Figure U7 is a dimensioned outline drawing showing the hydrophone orientation.

Reference

T. A. Henriquez, "An Extended-Range Hydrophone for Measuring Ocean Noise," J. Acoust. Soc. Amer. 52, 1450-1455 (1972).

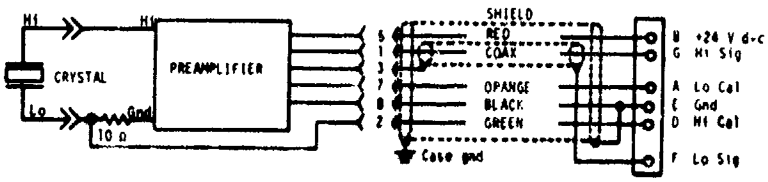


Fig. U2. Wiring diagram of circuitry associated with the integral preamplifier of type H56 hydrophone.

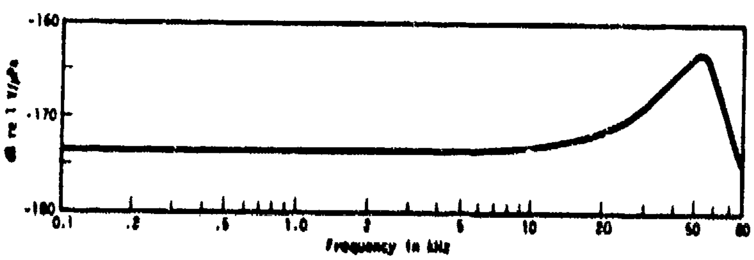
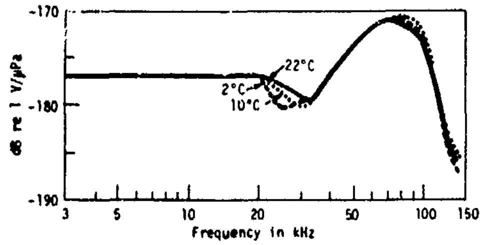


Fig. U3. Typical free-field voltage sensitivity, type H56 hydrophone, 3:1-area-ratio capped-tube model; open-circuit crystal voltage at the end of a 23-m cable.

Fig. U4. (Right) Effect of temperature on the free-field voltage sensitivity of the striped ceramic tube model, type H56 hydrophone.



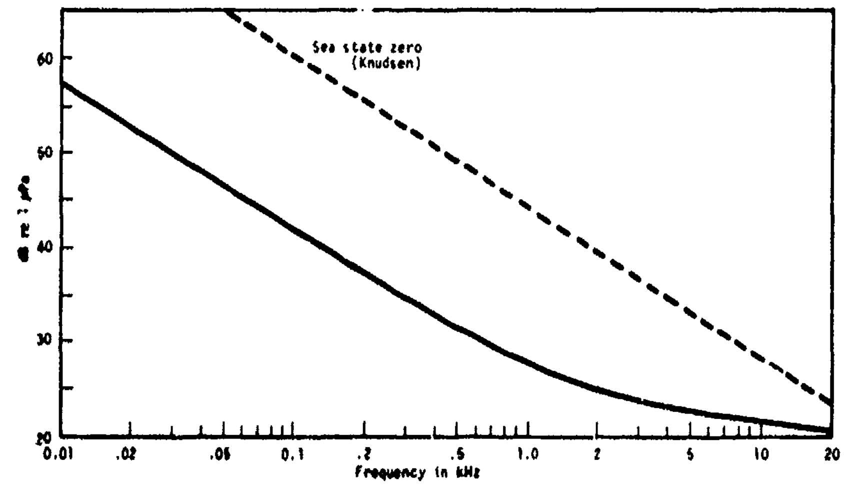


Fig. U5. Equivalent noise pressure of type H56 hydrophone (computed from noise voltage measured at the end of a 12-m cable).

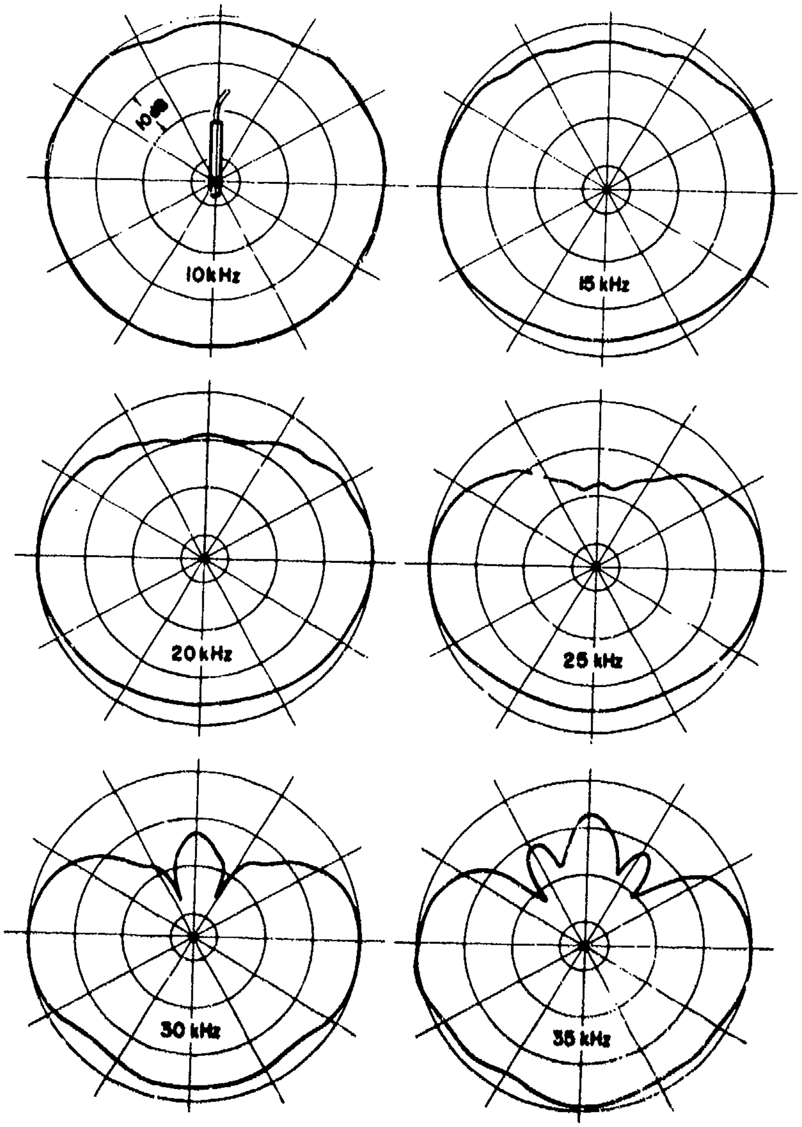


Fig. U6. Directivity patterns in the vertical (XZ) plane of type H56 hydrophone, 3:1-area-ratio capped-tube model.

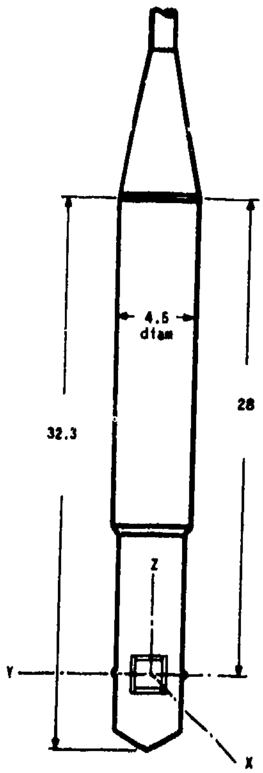


Fig. U7. Dimensions (in centimeters) and orientation of type H56 hydrophone.

Type J9
TRANSDUCER

General Description

The USRD type J9 transducer is a laboratory standard underwater sound projector for use in reciprocity calibrations or as a sound source for the audio-frequency range 40 Hz to 20 kHz. Figure V1 is a photograph of the transducer.

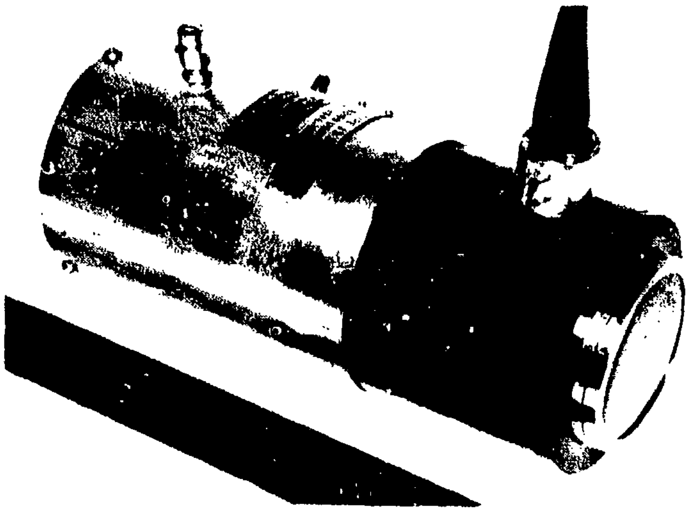


Fig. V1. USRD type J9 transducer.

The 4.7-cm-diam diaphragm is supported by a novel rubber suspension system that permits large linear movement of the diaphragm, but offers a high acoustic impedance to the region around it.

When the transducer is submerged, water enters the rear compensation chamber and compresses the butyl rubber compensation bag until the internal air pressure is equal to the external water pressure on the face of the diaphragm, which does not then undergo any static displacement when the depth is changed.

Each J9 transducer normally is supplied with either 12 or 30 m of shielded 2-conductor rubber-covered cable. The electrical connections for the cable are shown in Fig. V2.

Specifications

Operating range:	40 Hz to 20 kHz
Reciprocity range:	40 Hz to 20 kHz
Maximum power input:	20 W above 100 Hz

Efficiency:	approximately -32.5 dB re ideal
Driving impedance:	23 Ω at 1 kHz
Maximum depth:	24 m
Weight with 18-m cable:	9.1 kg
Shipping weight:	16.8 kg

Electroacoustic Characteristics

Typical *transmitting current and voltage response data* for the J9 transducer are shown in Fig. V3.

Typical *impedance* data are shown in Fig. V4.

The acoustic output of the J9 transducer is linear with driving power up to 20 W.

Power Limitation

The transducer should not be driven with more than 20 V or 1.25 A at frequencies above 100 Hz. The displacement of the diaphragm limits the driving power below this frequency. Monitor the waveform to prevent overdriving at frequencies below 100 Hz and reduce the driving voltage to maintain a good wave form.

Hydrostatic Pressure Compensation

The transducer will operate at depths to 24 m with increasing resonance frequency; below 200 Hz, the response characteristics change as a function of depth.

Inflate the compensation bag with air as dry as possible; *do not inflate by mouth.* Open the small valve located on the compensation housing and, with the aid of a small rubber or plastic tube and a squeeze bulb, gently fill the bag with air; do not overinflate. The bag should feel limp to the touch. After inflating the bag, close the valve and tighten it with the small key provided for this purpose.

Preparation and Use

Figure V5 is a dimensioned outline drawing showing orientation of the transducer.

Support the transducer by the mounting lugs provided.

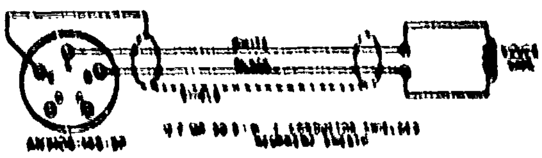
Wash the transducer thoroughly with a wetting agent to aid in the removal of air on or around the diaphragm and housing. While the transducer is submerged in the water, move it briskly from side to side and forward and backward a few times to help dislodge air bubbles.

Examine the compensation bag after a few hours of operation and occasionally thereafter to insure that no air leaks exist.

Reference

C. C. Sims, "High-Fidelity Underwater Sound Transducers," Proc. IRE 47, 866-871 (1959).

Fig. V2. (Right) Cable connections for type J9 transducer.



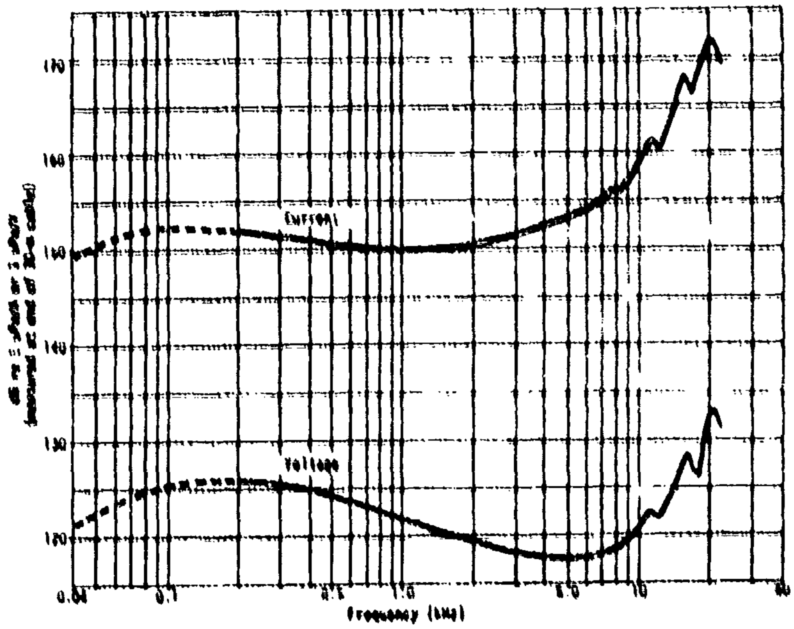


Fig. V3. Typical transmitting current and voltage responses, type J9 transducer. Response below 0.2 kHz is a function of depth.

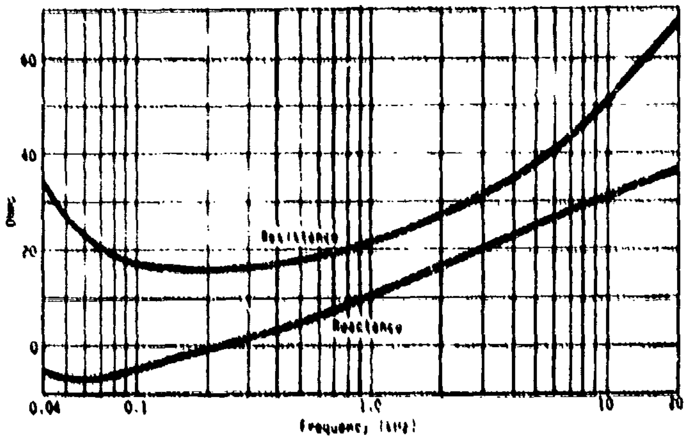


Fig. V4. Typical equivalent series impedance, type J9 transducer.

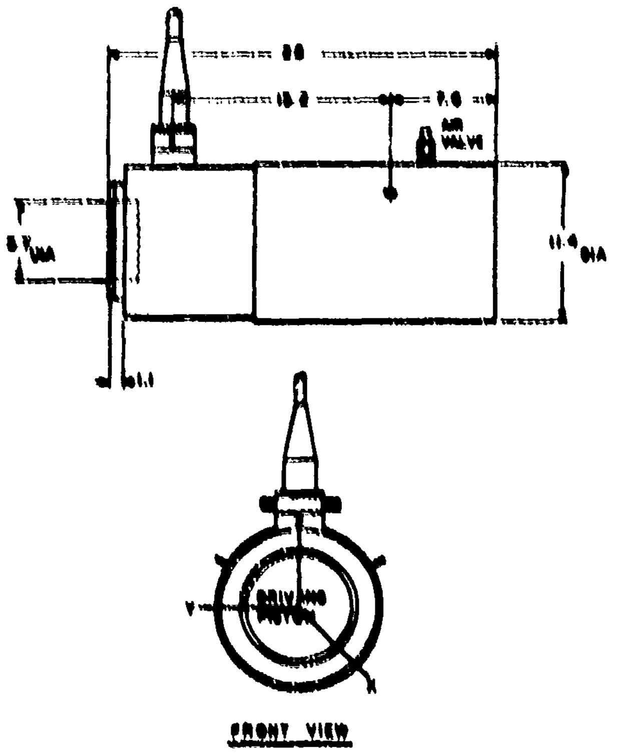


Fig. V5. Dimensions (in centimeters) and orientation of type J9 transducer.

Type J9S
TRANSDUCER
WITH DEEP-SUBMERGENCE COMPENSATOR Mod II

General Description:

The USRD type J9S transducer with deep-submergence compensator Mod II is acoustically identical with the standard J9 at shallow depths. With increasing depth, however, the stiffness of the gas in the type J9 transducer causes the transmitting response to drop off slightly at frequencies below 300 Hz. The deep-submergence feature of the type J9S allows the transducer to be used to depths as great as 180 m. Figure W1 is a photograph of the J9S transducer.

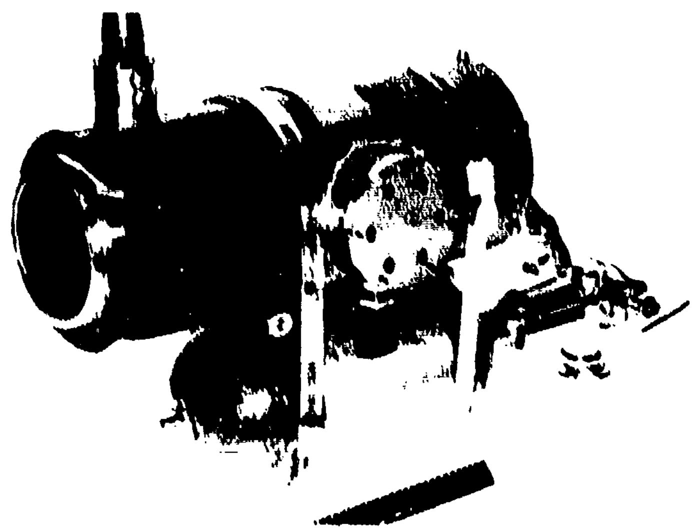


Fig. W1. USRD type J9S transducer.

The compensator consists of a 1-liter compressed-gas cylinder, a first-stage pressure regulator, a second-stage pressure regulator, and a pressure-relief valve. The compressed gas may be either dry nitrogen or dry air. Dry nitrogen gas is preferred.

The transducer is delivered with the deep-submergence device attached and ready for use.

Instructions

Figure W2 is a dimensioned outline drawing showing orientation of the transducer.

Check to see that the compressed-gas cylinder as supplied is fully charged with nitrogen at 12.4 MPa (1800 psig) pressure. Before lowering the transducer into the water, *open the valve at the compressed-gas cylinder* approximately one turn counterclockwise. Lower the transducer into the water to a depth of 5 or 6 m. Should bubbles rise for more than a minute, retrieve the transducer, determine the cause of the malfunction, and make the repair indicated. When properly operating, the transducer should not discharge air until a depth of 20 to 24 m has been reached. Failure to compensate will cause flooding of the transducer and mechanical damage.

Recharge the compressed-gas cylinder after each retrieval to insure that an adequate supply of gas is available for subsequent use. The cylinder can be recharged by a compressor or a cylinder of dry air or dry nitrogen. A charging hose is supplied, along with an adapter. The fitting on the hose mates with a standard compressed-air cylinder; the adapter is used with compressed-nitrogen cylinders. The maximum pressure to be used is 12.4 MPa (1800 psig).

Operation

The operation of the compensation system is similar to that described for the J11 transducer in NRL Report 6981 (see Reference).

Figure W3 shows the flow of gas in the system. The bladder permits compensation of the transducer at depth even for changes in depth of several meters without calling for additional gas from the high-pressure bottle. This feature extends the useful working time at depth and eliminates the frequency discharge of overpressure into the water.

Reference

G. D. Hugus III, "Pressure-Compensating System for Gas-Filled Transducers," NRL Report 6981, 25 Sep 1969 (AD-693 451).

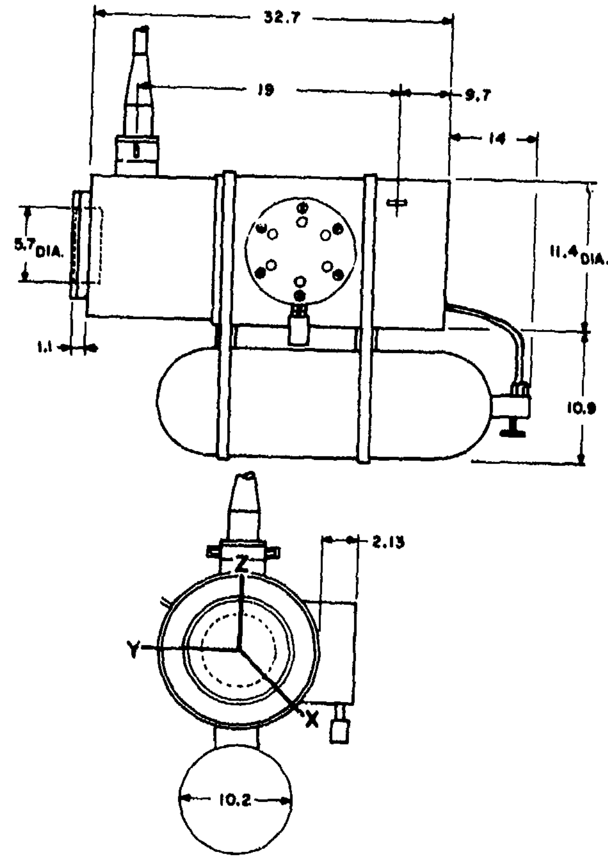


Fig. W2. Dimensions (in centimeters) and orientation of type J9S transducer.

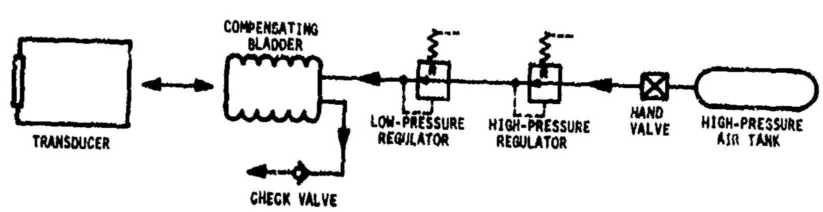


Fig. W3. Flow of gas in the system.

Type J11
TRANSDUCER

General Description

The USRD type J11 transducer is a laboratory standard underwater sound projector for use in reciprocity calibrations or as a sound source for the audio-frequency range 20 Hz to 12 kHz. Figure X1 is a photograph of the transducer.

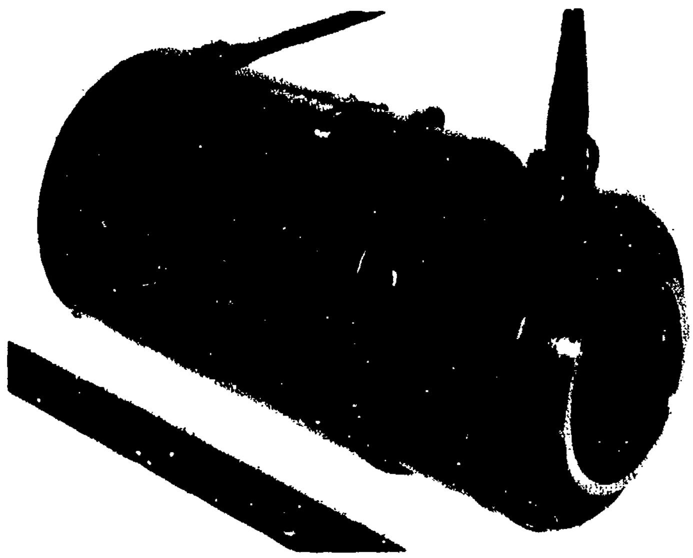


Fig. X1. USRD type J11 transducer.

The 10-cm-diam magnesium diaphragm is supported by a novel rubber suspension system that permits large linear movement of the diaphragm, but offers a high acoustic impedance to the region around it. The diaphragm is driven by a large moving coil positioned in the field of a permanent magnet.

When the transducer is submerged, water enters the rear compensation chamber and compresses the butyl rubber bag until the internal air pressure is equal to the external water pressure on the face of the diaphragm, which does not then undergo any static displacement when the depth is changed.

Each type J11 transducer is supplied with 38 m of shielded 2-conductor yellow Hypalon-covered cable. The electrical connections for the cable are shown in Fig. X2.

Specifications

Operating range:	20 Hz to 12 kHz
Reciprocity range:	20 Hz to 12 kHz
Maximum power input:	200 W above 100 Hz
Efficiency:	approximately -28 dB re ideal at 1 kHz
Driving impedance:	23 Ω at 1 kHz
Maximum depth:	23 m
Weight with 38-m cable:	57 kg
Shipping weight:	73 kg

Electroacoustic Characteristics

Typical *transmitting current and voltage response* data are shown in Fig. X3. Typical *impedance* data are shown in Fig. X4.

Power Limitation

The driving power should not exceed 200 W at frequencies above 100 Hz and must be decreased at lower frequencies. To prevent overdriving below 100 Hz, monitor the waveform and adjust the power to maintain a sine wave. This limitation at low frequencies is imposed by the displacement of the diaphragm.

Recommended maximum power for reciprocity is 50 W.

Hydrostatic Pressure Compensation

The transducer will operate at depths to 30 m with increasing resonance frequency; below 100 Hz, the response characteristics change as a function of depth.

Inflate the compensation bag with air as dry as possible; *do not inflate by mouth.* Open the small valve located on the compensation housing and, with the aid of a small rubber or plastic tube and a squeeze bulb, gently fill the bag with air; do not overinflate. The bag should feel limp to the touch. After inflating the bag, close the valve and tighten it with the small key provided for this purpose.

Preparation for Use

Figure X5 is a dimensioned outline drawing showing orientation of the transducer.

Support the transducer by the mounting lugs provided. Wash the transducer thoroughly with a wetting agent to aid in the removal of air on or around the diaphragm and housing. While the transducer is submerged in the water, move it briskly from side to side and forward and backward a few times to help dislodge air bubbles.

Examine the compensation bag after a few hours of operation and occasionally thereafter to insure that no air leaks exist.

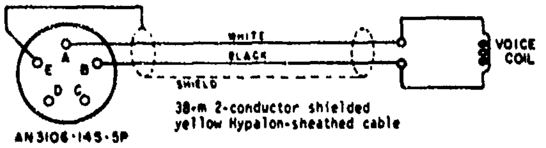


Fig. X2. (Left) Cable connections for type J11 transducer.

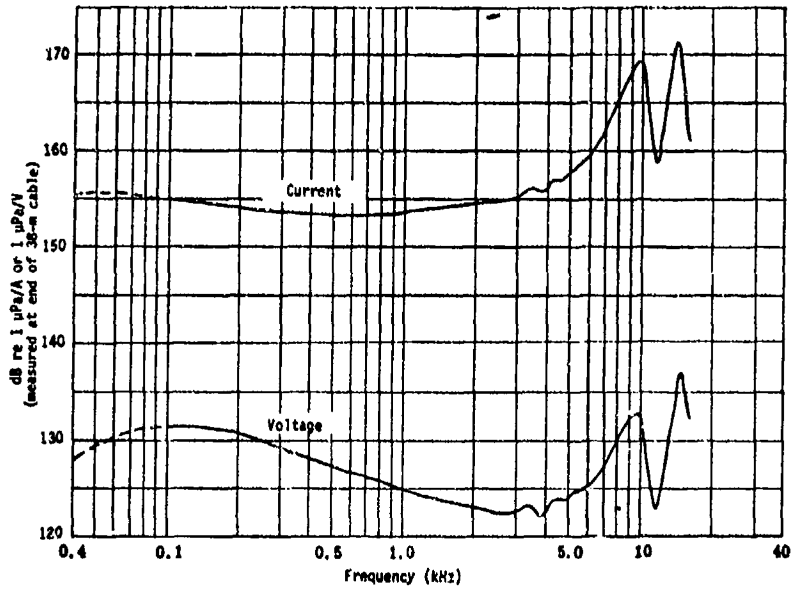
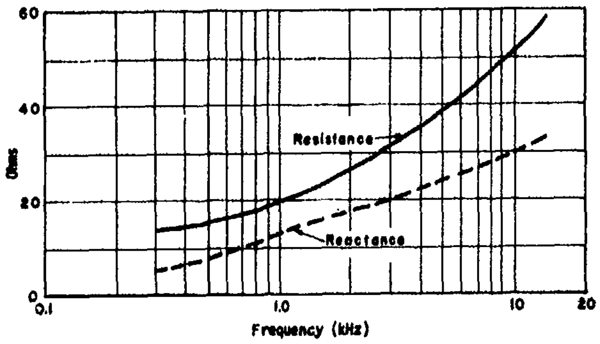


Fig. X3. Typical transmitting current and voltage responses, type J11 transducer. Response below 0.1 kHz is a function of depth.

Fig. X4. (Right) Typical impedance, type J11 transducer.



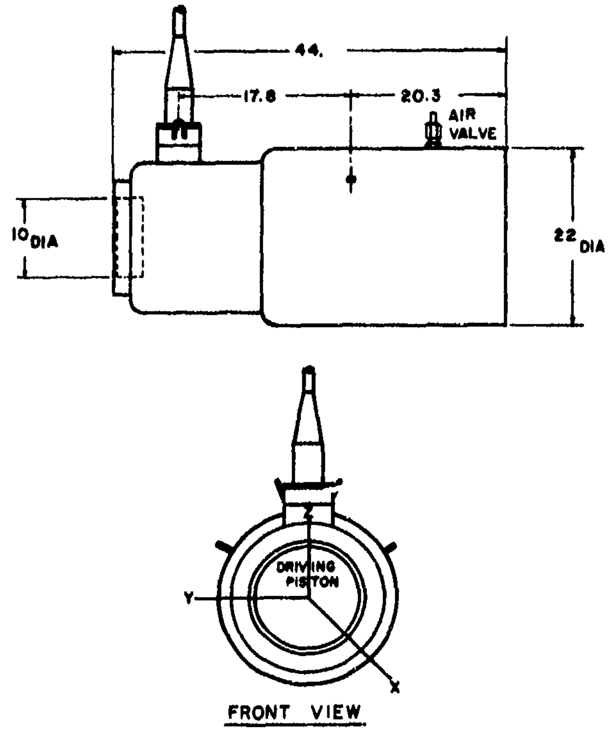


Fig. X5. Dimensions (in centimeters) and orientation of type J11 transducer.

Type J11S
TRANSDUCER
WITH DEEP-SUBMERGENCE COMPENSATOR MOD II

General Description

The USRD type J11S transducer with deep-submergence compensator Mod II is acoustically identical with the standard J11 at shallow depths. With increasing depth, however, the stiffness of the gas in the J11 transducer causes the transmitting response to drop off slightly at frequencies below 300 Hz. The deep-submergence feature of the J11S allows the transducer to be used to depths as great as 183 m. Figure Y1 is a photograph of the J11S transducer.

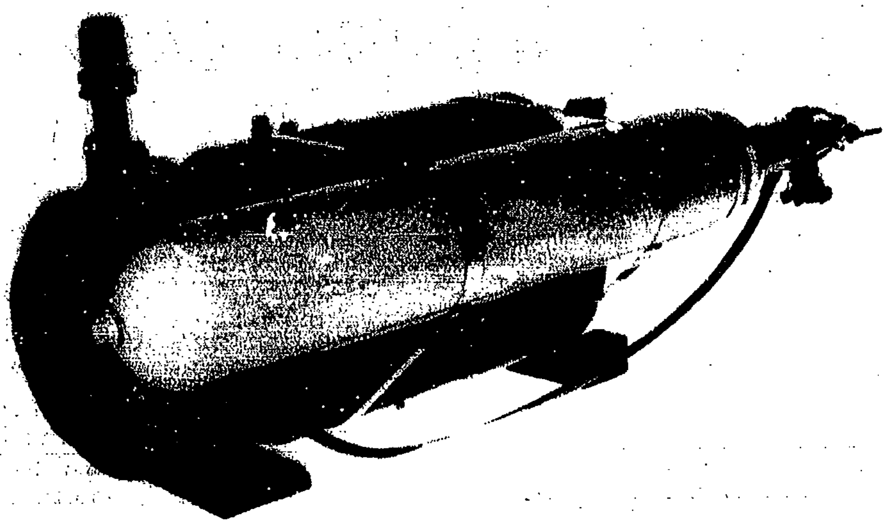


Fig Y1. USRD type J11S transducer.

The compensator consists of a 3-liter compressed-gas cylinder, a first-stage pressure regulator, a second-stage pressure regulator, and a pressure-relief valve. The compressed gas may be either dry nitrogen or dry air. Dry nitrogen gas is preferred.

The transducer is delivered with the deep-submergence device attached and ready for use.

Instructions

Figure Y2 is a dimensioned outline drawing showing orientation of the transducer.

Check to see that the compressed-gas cylinder as supplied is fully charged with nitrogen at 12.4-MPa (1800-psig) pressure. Before lowering the transducer into the water, *open the valve at the compressed-gas cylinder* approximately one turn counterclockwise. Lower the transducer into the water to a depth of 5 or 6 m. Should bubbles rise for more than a minute, retrieve the transducer, determine the cause of the malfunction and make the repair indicated. When properly operating, the transducer should not discharge air until a depth of 20 to 24 m has been reached. Failure to compensate will cause flooding of the transducer and mechanical damage.

Recharge the compressed-gas cylinder after each retrieval to insure that an adequate supply of gas is available for subsequent use. The cylinder can be recharged by a compressor or a cylinder of dry air or dry nitrogen. A charging hose is supplied, along with an adapter. The fitting on the hose mates with a standard compressed-air cylinder; the adapter is used with compressed-nitrogen cylinders. The maximum pressure to be used is 12.4 MPa (1800 psig).

Operation

The operation of the compensation system is described in NRL Report 6981 (see Reference).

Figure Y3 shows the flow of gas in the system. The bladder permits compensation of the transducer at depth, even for changes in depth of several meters, without calling for additional gas from the high-pressure bottle. This feature extends the useful working time at depth and eliminates the frequent discharge of overpressure into the water.

Conservation of Compensating Gas

Several tests were carried out to determine the amount of depth change that can be compensated by the rubber bladder alone. At the maximum depth of 183 m, the rubber bladder will provide compensation for a decrease in depth of 115 m. The amount of compensation by the bladder is reduced with decrease in operating depth as shown in Fig. Y3.

Calculations show that if the gas supply is fully charged to start with, seven excursions can be made from the surface to 183 m and back before is becomes necessary to replenish the gas supply. The amount of gas used from the bottle for each full-depth excursion is based on the drop in bottle pressure recorded during tests in a pressure tank.

The maximum pressure differential that occurred within the transducer was not measured. The maximum value would occur during rapid descent to or ascent from operating depth, when the highest demands are made on the supply regulators and the relief valve. Maximum rates of descent and ascent during the tests were recorded, however. The highest rate of descent was 2.53 m/sec; the highest ascent rate was 2.8 m/sec. These rates were experienced without structural failure of the transducer.

Reference

G. D. Hugus III, "Pressure-Compensating System for Gas-Filled Transducers," NRL Report 6981, 25 Sep 1969 (AD-693 451).

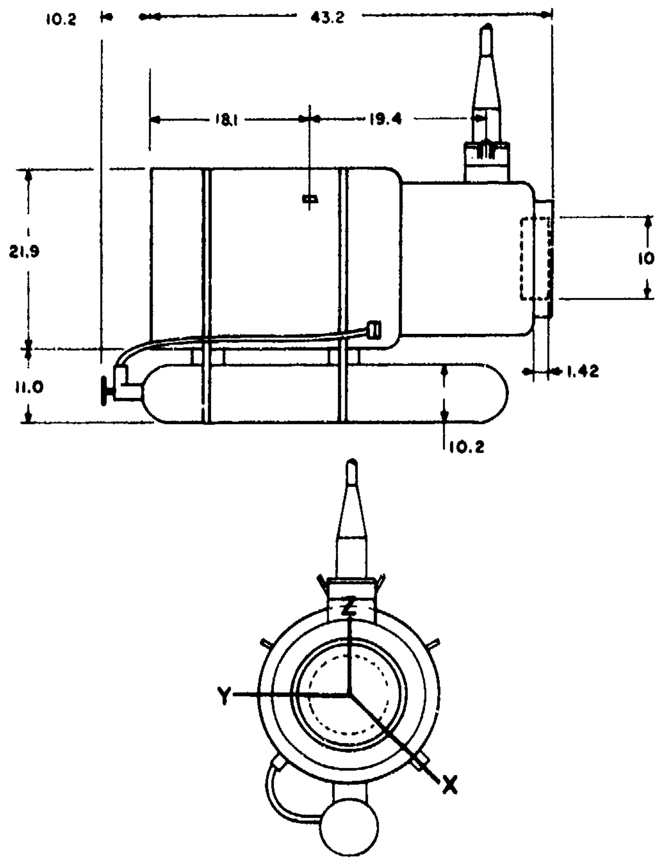


Fig. Y2. Dimensions (in centimeters) and orientation of type J11S transducer.

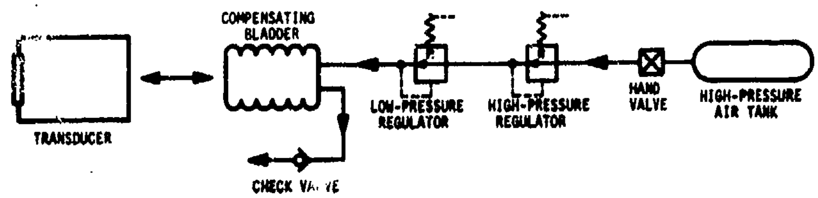


Fig. Y3. Flow of gas in the system.

Type J13
TRANSDUCER

General Description

The USRD type J13 transducer is a laboratory standard underwater sound transducer for use as a c-w source in the infrasonic and audio-frequency range 10 Hz to 3 kHz. Figure Z1 is a photograph of the transducer.

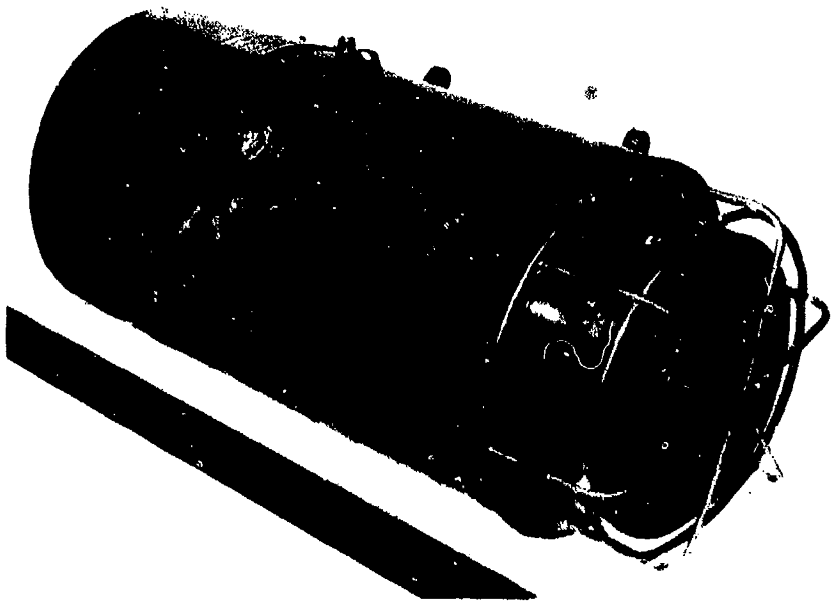


Fig. Z1. USRD type J13 transducer.

The 10-cm-diam, truncated-cone diaphragm is supported by a novel rubber suspension system that permits 1.2-cm peak-to-peak linear movement of the diaphragm, but offers high acoustic impedance to the region around it. The diaphragm is driven by a large moving coil positioned in the field of a permanent magnet.

When the transducer is submerged, water enters the rear compensation chamber and compresses the butyl rubber bag until the internal air pressure is equal to the external water pressure on the face of the diaphragm, which does not then undergo any static displacement for water depth to 22 m.

Each type J13 transducer is supplied with a 38-m length of shielded, 2-conductor cable. The electrical connections are shown in Fig. Z2.

Specifications

Operating range:	10 to 3000 Hz
Maximum input power:	250 W, continuous duty
Efficiency:	approximately -25 dB re ideal at 100 Hz
Driving impedance:	35 Ω at 100 Hz
Maximum depth:	22 m
Weight:	55 kg
Shipping weight:	88 kg

Electroacoustic Characteristics

Typical *transmitting current response* is shown in Fig. Z3; typical *impedance* data are given in Fig. Z4.

Power Limitation

Above 50 Hz, the maximum input power is limited by the rate at which the heat generated in the driving coil can be dissipated, and should not exceed 250 W for continuous use. Sufficient data have not been obtained to enable the maximum allowable continuous-duty driving power to be determined. Accordingly, it is recommended that the input power be reduced or turned off whenever possible; *do not exceed 3 A*.

At low frequencies (below 50 Hz), the power limitation is imposed by the allowable displacement of the diaphragm. To prevent overdriving below 50 Hz, observe the output of a monitoring hydrophone and adjust the power into the transducer to maintain a waveform similar to that observed at low levels. Take care to avoid transients such as those caused by switching at the input to the power amplifier when driving at or near the maximum input power.

Compensation for Hydrostatic Pressure

The transducer will operate at depth to 22 m with minor changes in response. To determine the source level accurately, therefore, a calibrated hydrophone should be used.

Inflate the compensation bag with air as dry as possible; *do not inflate by mouth*. Open the small valve located on the compensation housing and, with the aid of a small rubber or plastic tube and a squeeze bulb, gently fill the bag with air; do not overinflate. The bag is accessible through the holes in the back plate and should feel slightly firm (approximately 13 kPa, or 2 psig). After inflating the bag, close the valve and tighten it with the small key provided for this purpose.

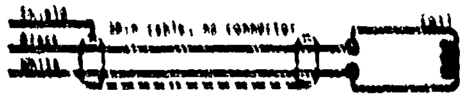
Preparation for Use

Figure Z5 is a dimensioned outline drawing showing orientation of the transducer.

Support the transducer by the mounting lugs provided. Before submerging the transducer, wash it thoroughly with a wetting agent to aid in removing air on or around the diaphragm and the housing. While the transducer is in the water, move it briskly from side to side a few times to help dislodge air bubbles.

Examine the compensation bag after a few hours of operation and occasionally thereafter, to insure that no air leaks exist.

Fig. Z2. (Right) Cable connections for type J13 transducer; d-c resistance between white and black leads: 25 Ω (approx).



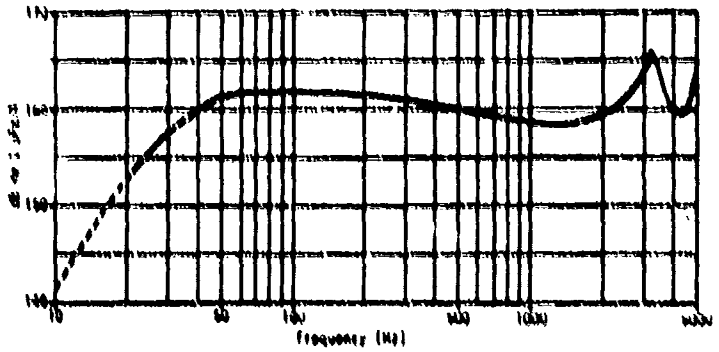


Fig. Z3. Typical transmitting current response, type J13 transducer with 30-m cable.

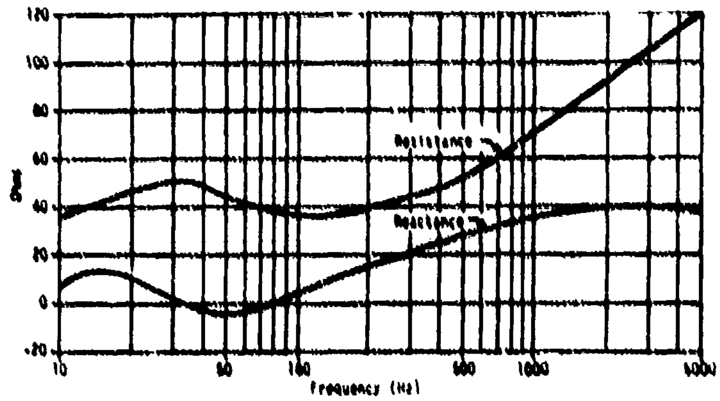


Fig. Z4. Typical impedance, type J13 transducer.

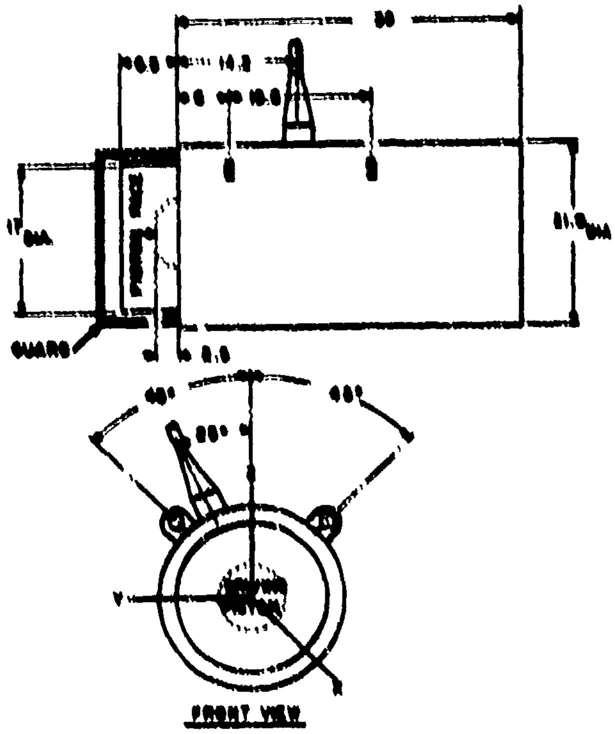


Fig. 75. Dimensions (in centimeters) and orientation of type J13 transducer.

Type J13S
TRANSDUCER
WITH DEEP-SUBMERGENCE COMPENSATOR Mod II

General Description

The USRD type J13S transducer with deep-submergence compensator Mod II is acoustically identical with the standard J13 at shallow depths. With increasing depth, however, the stiffness of the gas in the transducer causes the transmitting response to drop off at frequencies below 300 Hz. The deep-submergence feature allows the transducer to be used to depths as great as 183 m. Figure AA1 is a photograph of the J13S transducer.

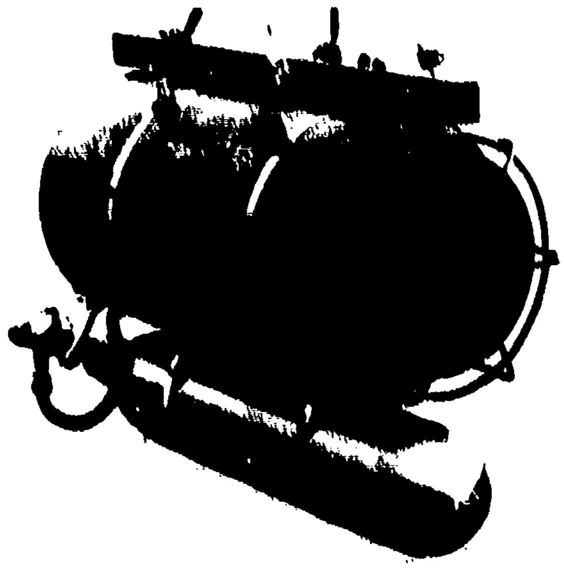


Fig. AA1. USRD type J13S transducer.

The compensator consists of a 3-liter compressed-gas cylinder, a first-stage pressure regulator, a second-stage pressure regulator, and a pressure-relief valve. The compressed gas may be either dry nitrogen or dry air. Dry nitrogen gas is preferred.

The transducer is delivered with the deep-submergence device attached and ready for use.

Figure AA2 is a dimensioned outline drawing showing the orientation of the transducer.

Instructions

Check to see that the compressed-gas cylinder as supplied is fully charged with nitrogen at 12.4 MPa (1800-psig) pressure. Before lowering the transducer into the water, *open the valve at the compressed-gas cylinder* approximately one turn counterclockwise. Lower the transducer into the water to a depth of 5 or 6 m. Should bubbles rise for more than a minute, retrieve the transducer, determine the cause of the malfunction, and make the repair indicated. When properly operating, the transducer should not discharge air until a depth of 20 to 24 m has been reached. Failure to compensate will cause flooding of the transducer and mechanical damage.

Recharge the compressed-gas cylinder after each retrieval to insure that an adequate supply of gas is available for subsequent use. The cylinder can be recharged by a compressor or a cylinder of dry air or dry nitrogen. A charging hose is supplied, along with an adapter. The fitting on the hose mates with a standard compressed-air cylinder; the adapter is used with compressed-nitrogen cylinders. The maximum pressure to be used is 12.4 MPa (1800 psig).

Operation

The operation of the compensation system is described for the J11S transducer in the reference. The compensation system used with the J13S is identical.

Figure AA3 shows the flow of gas in the system. The bladder permits compensation of the transducer at depth even for changes in depth of several meters without calling for additional gas from the high-pressure bottle. This feature extends the useful working time at depth and eliminates the frequent discharge of overpressure into the water.

Conservation of Compensating Gas

Several tests were carried out to determine the amount of depth change that can be compensated by the rubber bladder alone. At the maximum depth of 183 m, the rubber bladder will provide compensation for a decrease in depth of 115 m. The amount of compensation by the bladder is reduced with decrease in operating depth as shown in Fig. AA4.

Calculations show that if the gas supply is fully charged to start with, seven excursions can be made from the surface to 183 m and back before it becomes necessary to replenish the gas supply. The amount of gas used from the bottle for each full-depth excursion is based on the drop in bottle pressure recorded during tests in the pressure tank.

The maximum pressure differential that occurred within the transducer was not measured. The maximum value would occur during rapid descent to or ascent from operating depth, when the highest demands are made on the supply regulators and the relief valve. Maximum rates of descent and ascent during the tests were recorded, however. The highest rate of descent was 2.53 m/sec; the highest ascent rate was 2.8 m/sec. These rates were experienced without structural failure of the transducer.

Reference

G. D. Hugus, III, "Pressure-Compensating System for Gas-Filled Transducers," NRL Report 6981, 25 Sep 1969 [AD-693 451].

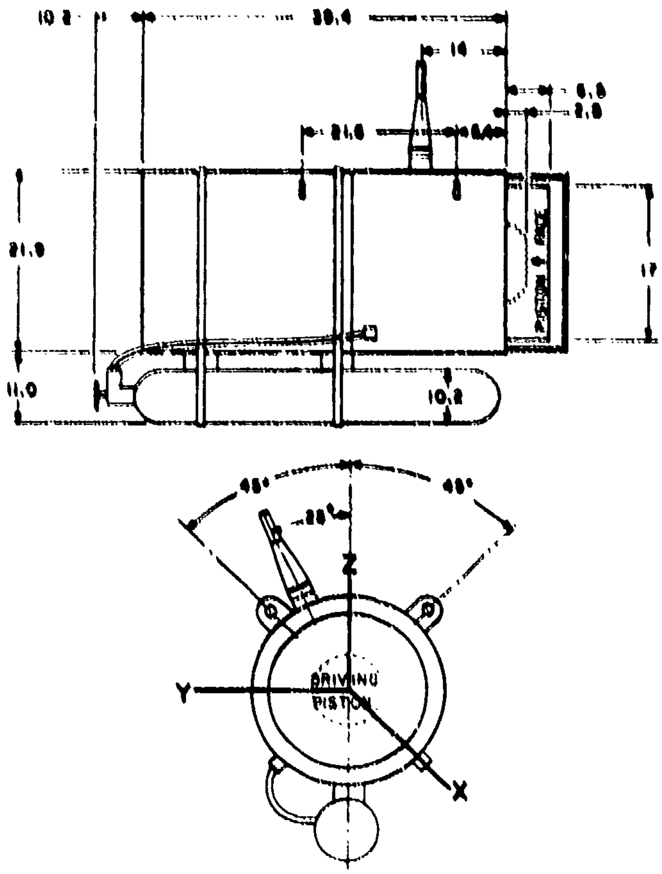


Fig. AA2. (Right) Dimensions (in centimeters) and orientation, type J13S transducer.

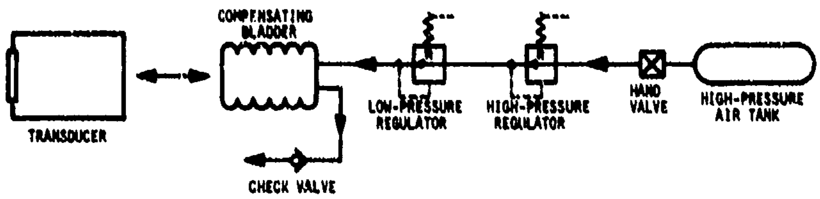
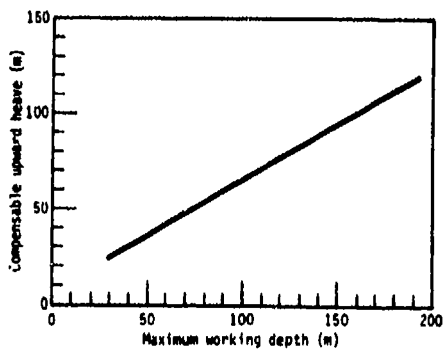


Fig. AA3. Gas flow in the system.

Fig. AA4. (Right) Relation of compensable upward heave to maximum working depth, type J13S transducer.



Type J15-1 TRANSDUCER

General Description

The USRD type J15-1 transducer is a standard underwater sound transducer for use as a c-w source in the infrasonic and low audio-frequency range 10 to 900 Hz. Figure BB1 is a photograph of the transducer.

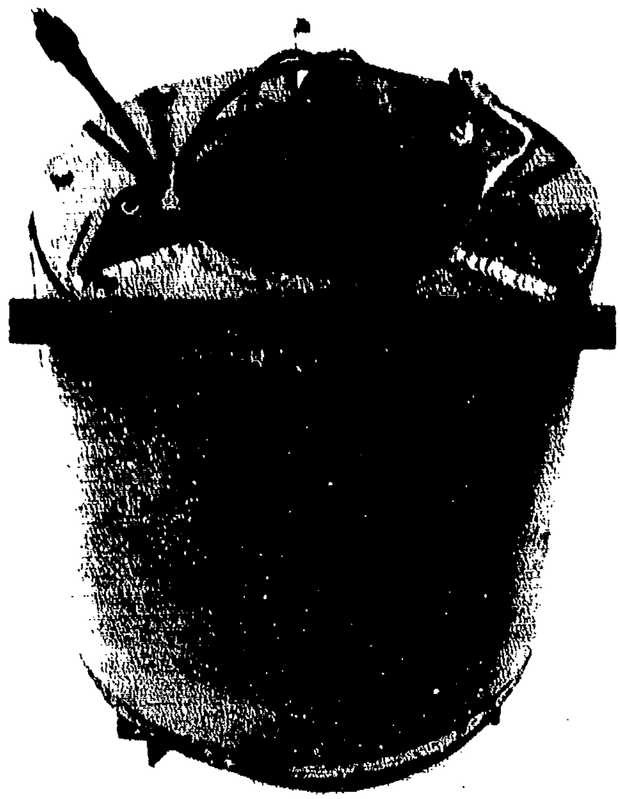


Fig. BB1. USRD type J15-1 transducer.

The 10-cm-diam, truncated-cone diaphragm is supported by a novel rubber suspension system that permits 1.2-cm peak-to-peak linear movement of the diaphragm, but offers high acoustic impedance to the region around it. The diaphragm is driven by a large moving coil positioned in the field of a permanent magnet.

When the transducer is submerged, water enters the rear compensation chamber and compresses the butyl rubber bags until the internal air pressure is equal to the external water pressure on the face of the diaphragm, which does not then undergo any static displacement for water depth to 165 m.

Each type J15-1 transducer is supplied with up to 183 m of shielded, 2-conductor cable. The electrical connections are shown in Fig. BB2.

Specifications

Operating range:	10 to 900 Hz
Maximum input power:	250 W, continuous duty (50-600 Hz)
Loaded impedance:	35 Ω at 100 Hz
Maximum depth:	165 m
Weight:	46 kg
Shipping weight:	80 kg

Electroacoustic Characteristics

Typical *transmitting current response* is shown in Fig. BB3, typical *impedance* data are given in Fig. BB4. Measurements are made unbalanced with the shield and black lead connected together.

Power Limitation

Above 50 Hz, the maximum input power is limited by the rate at which the heat generated in the driving coil can be dissipated, and should not exceed 250 W for continuous use. Sufficient data have not been obtained to enable the maximum allowable continuous-duty driving power to be determined. Accordingly, it is recommended that the input power be reduced or turned off whenever possible; *do not exceed 3 A.*

At low frequencies (below 50 Hz), the power limitation is imposed by the allowable displacement of the diaphragm. To prevent overdriving below 50 Hz, observe the output of a monitoring hydrophone and adjust the power into the transducer to maintain a waveform similar to that observed at low levels. Take care to avoid transients such as those caused by switching at the input to the power amplifier when driving at or near the maximum input power.

Compensation for Hydrostatic Pressure

The transducer will operate at depth to 165 m with some changes in response. To determine the source level accurately, therefore, a calibrated hydrophone should be used.

Inflate the compensation bag with air as dry as possible; *do not inflate by mouth.* Open the small valve located on the compensation housing and gently fill the bag with air; do not overinflate. The bag is accessible through the holes in the back plate and should feel slightly firm (just slightly above atmospheric pressure). After inflating the bag, insert the plug and tighten.

Preparation for Use

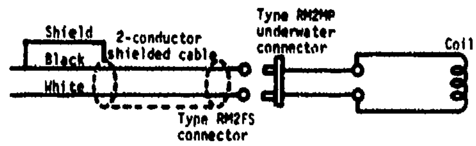
Figure BB5 is a dimensioned outline drawing of the transducer.

For proper operation, the J15-1 must be mounted with the driving face looking toward the water surface. Mounting in any other position will prevent proper compensation and free movement of the driven diaphragm.

Before submerging the transducer, wash it thoroughly with a wetting agent to aid in removing air on or around the diaphragm and the housing. While the transducer is in the water, move it briskly from side to side a few times to help dislodge air bubbles.

Examine the compensation bag after a few hours of operation and occasionally thereafter, to insure that no air leaks exist.

Fig. BB2. (Right) Cable connections for type J15-1 transducer; d-c resistance between white and black leads: 25 Ω (approx).



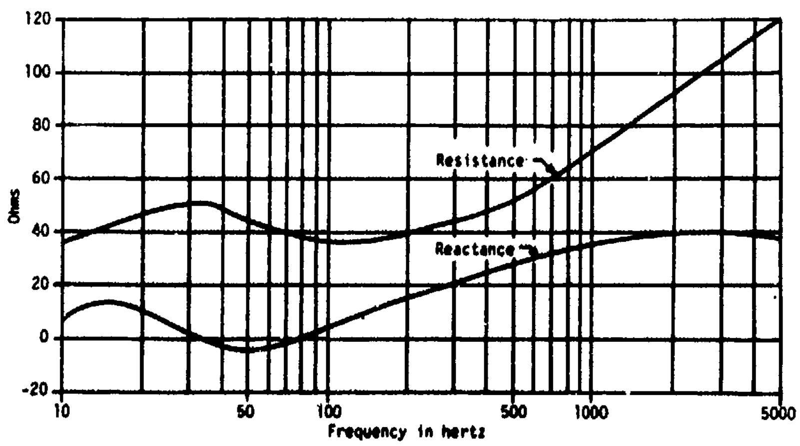


Fig. BB3. Typical transmitting current response, type J15-1 transducer.

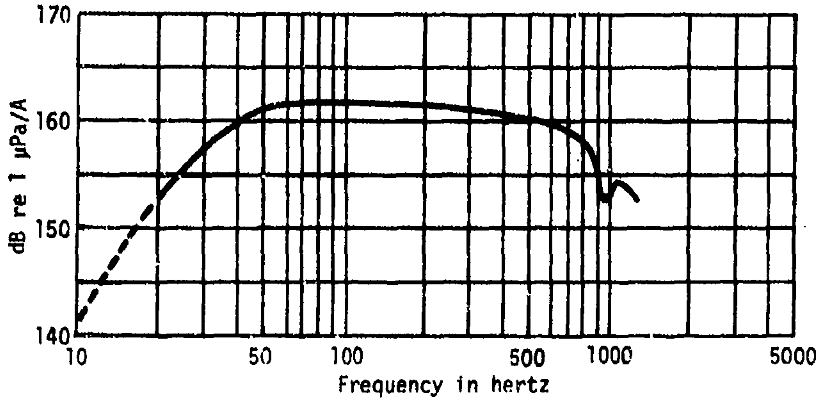


Fig. BB4. Typical impedance, type J15-1 transducer.

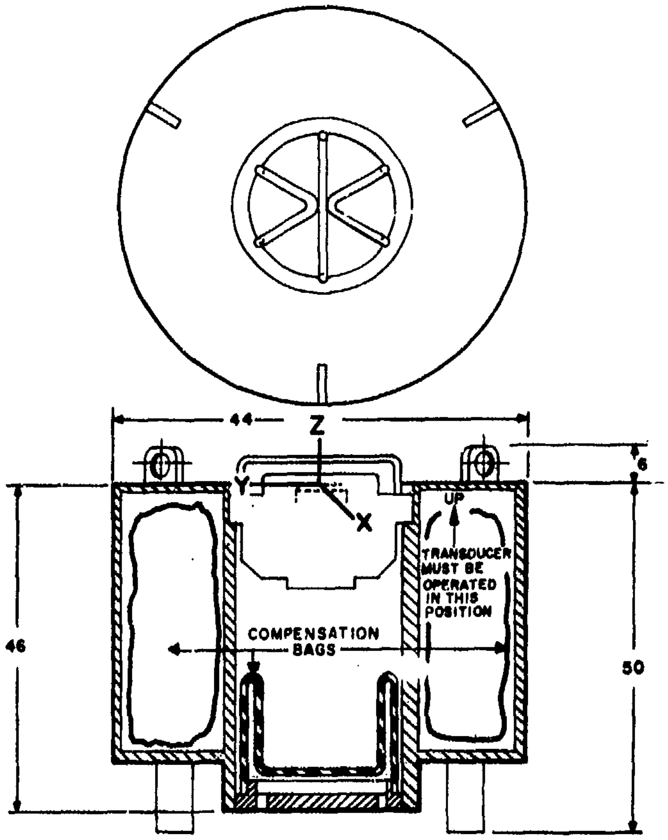


Fig. BB5. Dimensions (in centimeters) and orientation of type J15-1 transducer.

Type J15-3
TRANSDUCER

General Description

The USRD type J15-3 transducer is a standard underwater sound transducer for use as a c-w source in the infrasonic and low audio-frequency range 10 to 600 Hz. The transducer consists of three driven diaphragm assemblies. Each of the 10-cm-diam, truncated-cone diaphragms is supported by a novel rubber suspension system that permits 1.2-cm peak-to-peak linear movement of the diaphragm but offers high acoustic impedance to the region around it. The diaphragm is driven by a large moving coil positioned in the field of a permanent magnet. Figure CC1 is a photograph of the transducer.

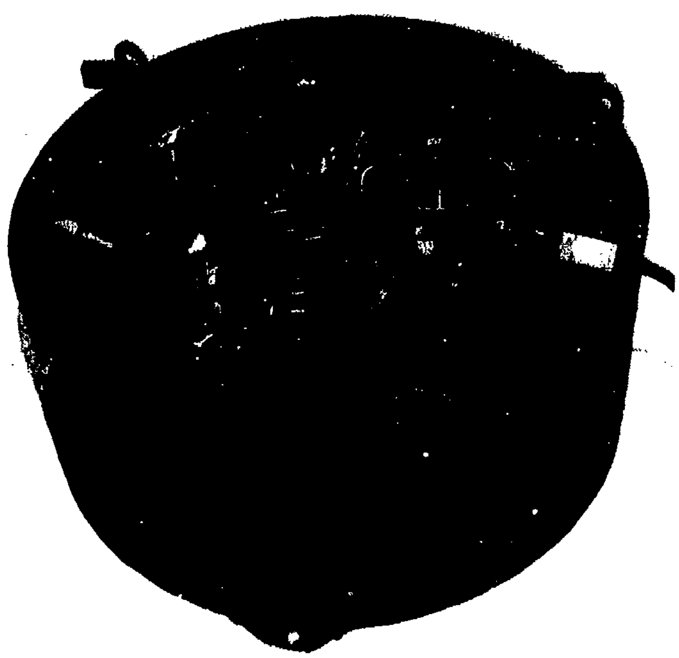


Fig. CC1. USRD type J15-3 transducer.

When the transducer is submerged, water enters the rear compensation chamber and compresses the butyl rubber bags until the internal air pressure is equal to the external water pressure on the face of the diaphragm, which does not then undergo any static displacement for water depth to 180 m.

Each type J15-3 transducer is supplied with up to 200 m of 2- or 6-conductor cable. The electrical connections are shown in Fig. CC2. A separate signal source can drive each of the three diaphragms, or they may be connected electrically in series and driven from a single source.

Specifications

Operating range:	10 to 600 Hz
Maximum input power	
Total power:	750 W, continuous duty (50-600 Hz)
Each diaphragm assembly:	250 W
Loaded impedance (100 Hz):	≈ 110 Ω, all in series; 35 Ω, each assembly
Weight:	170 kg
Shipping weight:	223 kg

Electroacoustic Characteristics

Typical *transmitting current response* is shown in Fig. CC3; typical *impedance* data are given in Figs. CC4 and CC5. Measurements are made unbalanced with the shield and black lead connected together.

Power Limitation

Above 50 Hz, the maximum input power is limited by the rate at which the heat generated in the driving coil can be dissipated and should not exceed 250 W total for continuous use. Sufficient data have not been obtained to enable the maximum allowable continuous-duty driving power to be determined. Accordingly, it is recommended that the input power be reduced or turned off whenever possible; *do not exceed 3 A*.

At low frequencies (below 50 Hz), the power limitation is imposed by the allowable displacement of the diaphragm. To prevent overdriving below 50 Hz, observe the output of a monitoring hydrophone and adjust the power into the transducer to maintain a waveform similar to that observed at low levels. Take care to avoid transients such as those caused by switching at the input to the power amplifier when driving at or near the maximum input power.

Compensation for Hydrostatic Pressure

The transducer will operate at depth to 180 m with some changes in response. To determine the source level accurately, therefore, a calibrated hydrophone should be used.

Inflate the compensation bag with air as dry as possible; *do not inflate by mouth.* Remove the cap at the T fitting located on top of the compensation housing and gently fill the bags with air; do not over-inflate. The bags are accessible through the holes in the back plate of each tubular housing and should feel slightly firm (just slightly above atmospheric pressure). After inflating the bag, replace the cap and tighten. Excess pressure can damage the diaphragm assemblies.

Preparation for Use

Figure CC6 is a dimensioned outline drawing of the transducer.

For proper operation, the J15-3 must be mounted with the driving face looking toward the water surface. Mounting in any other position will prevent proper compensation and free movement of the driven diaphragms.

Before submerging the transducer, wash it thoroughly with a wetting agent to aid in removing air on or around the diaphragm and the housing. While the transducer is in the water, move it briskly from side to side a few times to help dislodge air bubbles.

Examine the compensation bag after a few hours of operation and occasionally thereafter to insure that no air leaks exist.

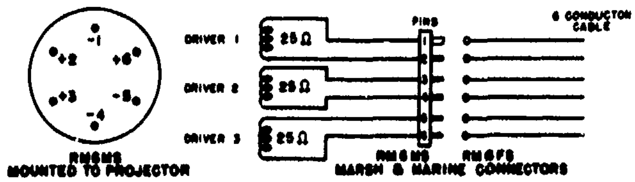


Fig. CC2. (Right) Cable connections, type J15-3 transducer.

For series connection of driver assembly coils, connect pin 2 to pin 4 and pin 3 to pin 5. The input then will be pins 1 and 6.

The d-c resistance for series connection is 75 Ω.

The drivers must be in phase. Check this by gently pressing on each head and reading the deflection on a meter. The three heads must deflect in the same direction.

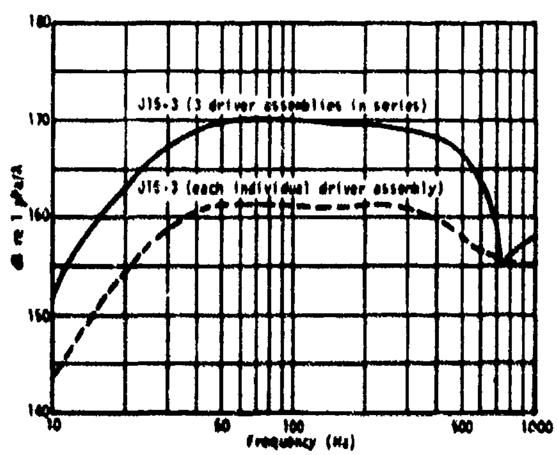


Fig. CC3. (Right) Typical transmitting current response, type J15-3 transducer.

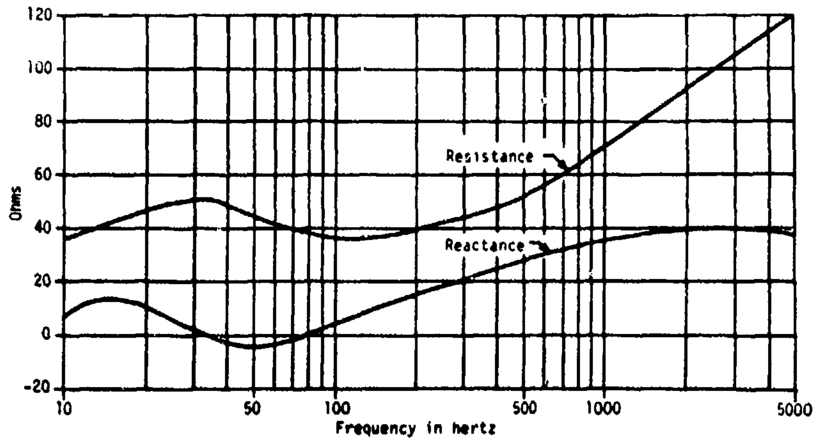


Fig. CC4. Typical impedance, each driver assembly, type J15-3 transducer.

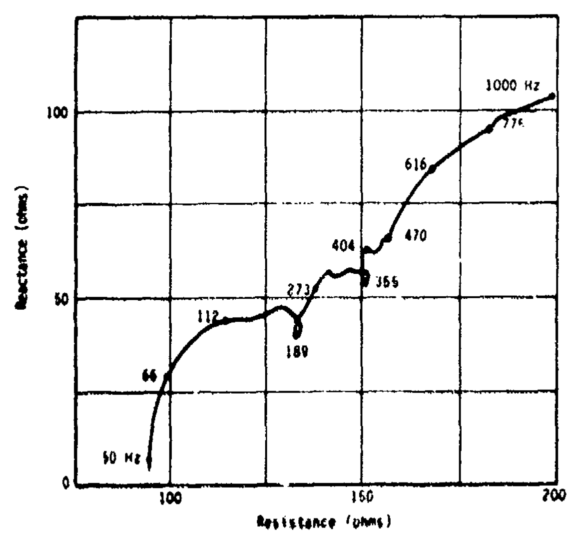


Fig. CC5. Typical impedance, three driver assembly coils in series, type J15-3 transducer.

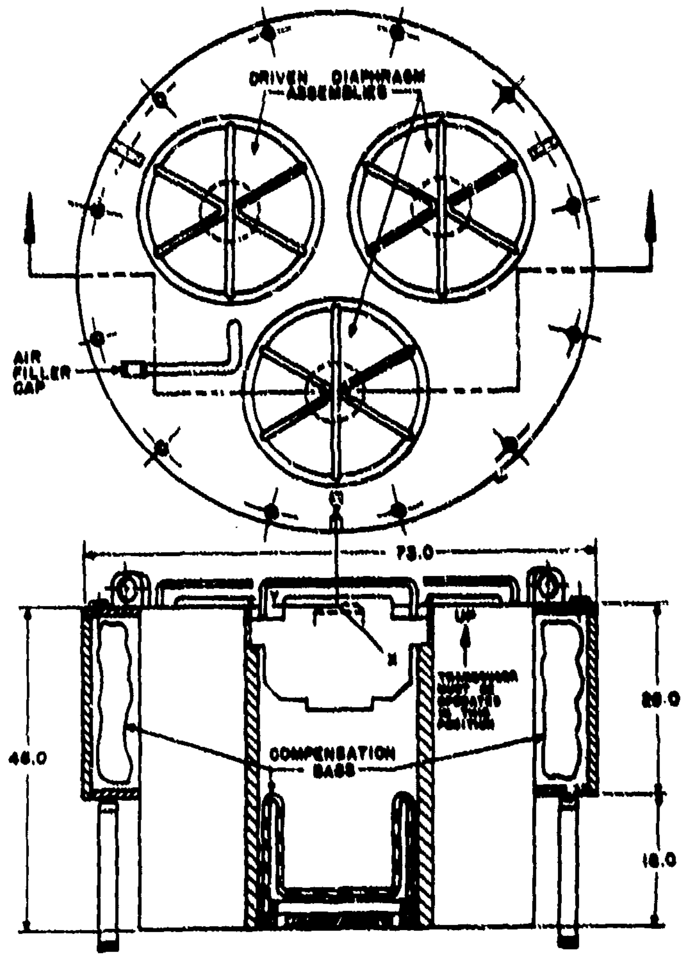


Fig. CC6. Dimensions (in centimeters) and orientation of type J15-3 transducer.

COORDINATE SYSTEM FOR TRANSDUCER ORIENTATION

The coordinate system shown in the sketch below is assigned to the transducer and moves with it, regardless of its physical position. The angle θ is a depression angle measured from the +Z axis; the angle φ is azimuth angle in sonar operation.

Response and *sensitivity* measurements are made with sound propagated parallel to the positive X axis unless otherwise specified. Transducers are oriented as follows:

Active Acoustic Surface	Orientation
Cylinder	The cylindrical axis is the Z axis. A reference mark for another axis is specified.
Plane	The plane (or piston) face is in the YZ plane, with the X axis normal to the face at the geometric center. The top of the transducer is in the +Z direction.
Sphere	Specify points on the surface for any two of the three axes.
Other	Provide a sketch of nonconforming configurations and offset acoustic centers.

Directivity Patterns: Unless otherwise specified, the following apply:

Specified Plane	Axis of Rotation	Position of axes on polar plots		
		+X axis	+Y axis	+Z axis
XY	Z	0°	90° cw	upward
XZ	Y	0°	downward	90° cw
YZ	X	upward	0°	90° cw