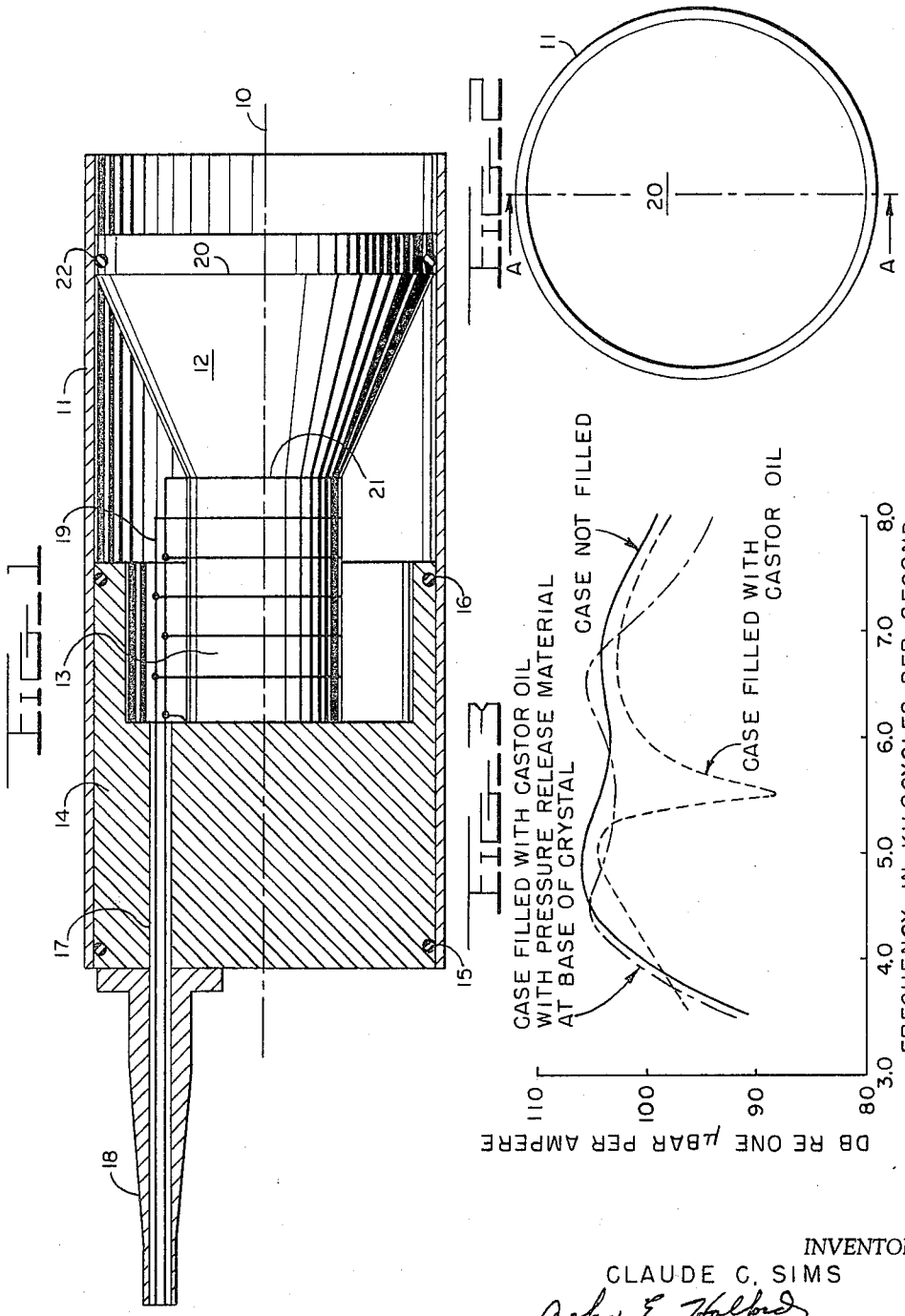
Oct. 25, 1966 C. C. SIMS 3,281,770

CAVITY LOADED PISTON RESONATOR

Filed June 18, 1963 3 Sheets-Sheet 1



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CAVITY LOADED PISTON RESONATOR

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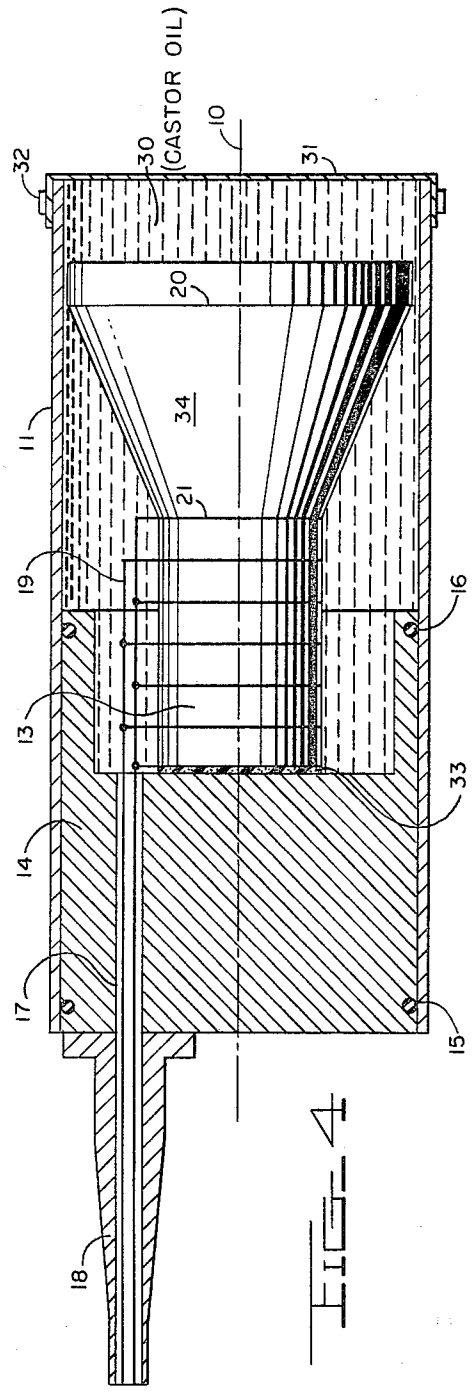


FIG. 4

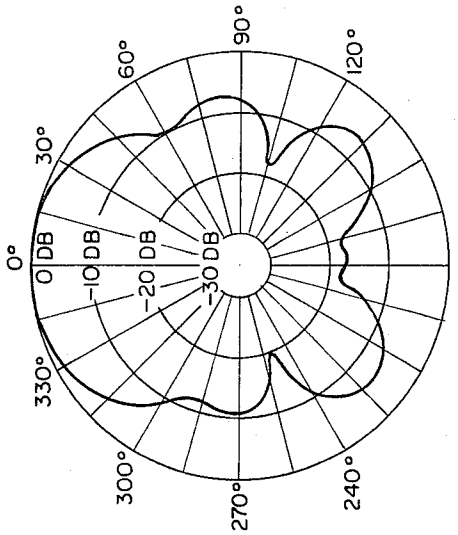


FIG. 5

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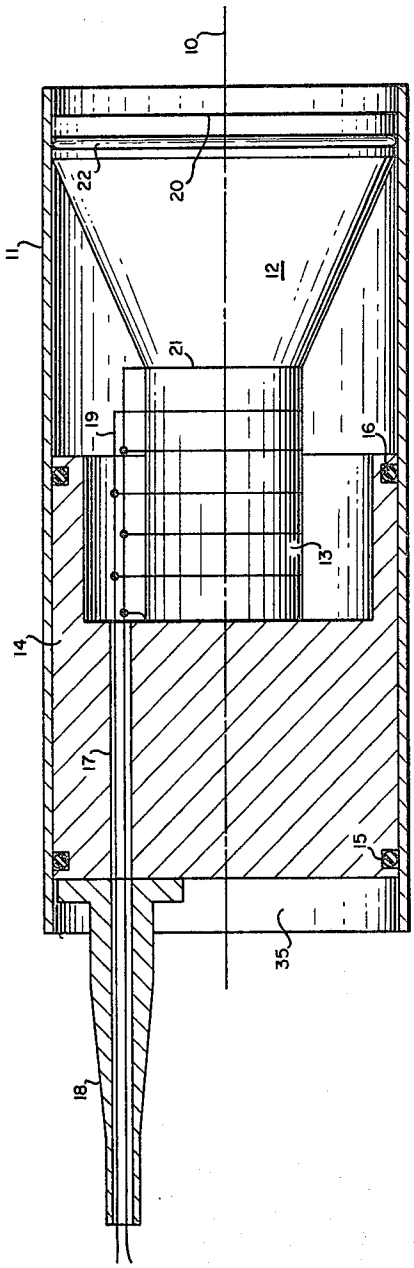


FIG. 6

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CAVITY LOADED PISTON RESONATOR

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Filed June 18, 1963, Ser. No. 288,841
2 Claims. (Cl. 340—8)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an improved transducer for converting electrical signals to sound or mechanical vibrations in a fluid medium. More particularly, it relates to a transducer design wherein a portion of the fluid medium is partially confined in an open chamber or cavity adjacent the radiating face of the transducer.

The first successful high power transducers for underwater use operated in the supersonic range. The small high speed excursions of the transducer diaphragm at these frequencies was well suited to the low compressibility of the propagating medium. Most of the energy was radiated normally from the diaphragm, so that the units could be used individually or combined in arrays for greater directivity.

As the need for longer range sonars developed, it became apparent that low frequency audible sound waves propagated over the longer distances with less loss and less confusion. However, the transducers which produce these frequencies tend to become inefficient and lose their directivity. Instead of being compressed, the water ahead of the low frequency diaphragm tends to slip around the sides of the transducer. Since the sides and/or back of the transducer are generally coated with sound absorbent material to increase directivity, much of the energy supplied by the diaphragm is lost.

It was hoped that by properly utilizing these transducers in an array this effect might be minimized. In an array, the spaces between transducers, if any, are filled with rigid material so that the pressure cannot be released along the sides of the transducer. For reasons that are not fully understood, these arrays have not performed according to expectations. Theoretically, a transducer with a very large diaphragm would serve the purpose, but such a structure is impractical to fabricate and maintain.

An object of the present invention is, therefore, to provide a low frequency underwater sound transducer having a small diaphragm compared to the operating wavelength and a high coupling efficiency.

A further object is to provide a transducer of the type described above which employs a cavity of partially confined fluid in contact with the radiating face of the diaphragm.

These and other objects or attendant advantages of the present invention will be best understood with reference to the following specification taken with the accompanying drawings wherein:

FIG. 1 shows a cutaway side view of an air-filled embodiment of a transducer in accordance with the present invention;

FIG. 2 shows an end view of the invention and the section line A—A along which the cutaway view of FIG. 1, was taken;

FIG. 3 shows a graph of the transmitting current response at one meter as a function of frequency;

FIG. 4 shows a cutaway side view of a second embodiment of the invention;

FIG. 5 shows a plot of the directivity of an embodiment of the invention similar to that shown in FIG. 4, but having a rear cavity; and

FIG. 6 shows a modification of the embodiment illustrated in FIG. 1.

Referring to FIGS. 1 and 2 the internal structure of the transducer may be seen. Generally the transducer consists of a series of elements arranged along a longitudinal axis **10**, which is the axis of directivity, and surrounded by a housing tube **11**. Nearest the right or radiating end of the tube is a solid metal horn element presenting a radiating face to the medium surrounding the transducer and an internal coupling face within the tube. One or more crystal driving elements **13** within the tube **11** are attached to the horn **12** at its coupling face. Nearest the opposite end of the tube and also attached to the crystal element **13** is a backing plate **14**.

The backing plate is resiliently mounted within the tube by means of gaskets **15** and **16** and supports the horn **12**, crystals **13**, and associated electrical wiring. An aperture or tunnel **17** is drilled through the backing plate to admit a cable **18**. Each of the leads from the cable are connected to one terminal of every crystal, the terminals being preplated on the crystals in the usual fashion.

The tube is designed to provide a rigid enclosure for the horn and extends beyond the horn providing a cup-shaped open cavity at the radiating end of the transducer. Preferably, the tube has a regular cross-section radially symmetrical about the axis of directivity describing, for example, concentric circles, squares, hexagons or the like as shown in FIG. 2. The walls of the tube are of fairly large uniform thickness, i.e. about 3% of the maximum cross-sectional dimensions or greater. For reasons which will be explained the tube may also extend beyond the backing plate to form a secondary cavity.

The backing plate has outer cross-sectional dimensions to substantially match the inner cross-sections of the tube. The end of the plate to which the crystals are attached is recessed, so that parts of the crystals and/or horn are within the plate. This allows the center of gravity of entire structure within the tube to be located midway between the gaskets **15** and **16**. Grooves are provided in either or both the backing plate and tube to position the gaskets.

The crystals are available in a variety of forms. Most common are those of generally cylindrical form. For ruggedness and a higher coupling coefficient it is preferred that these elements be solid with electrodes plated on their opposite faces. Hollow cylinders, however, are also available with electrodes plated on their inner and outer surfaces. Six elements proved satisfactory for the present embodiment. More or less elements may be used depending on the materials and size of the transducer.

The horn may be considered to be composed of two parts, although a single member is preferred. The first part which includes the radiating face **20** is of uniform cross section, having substantially the same dimensions as the inner cross-section of the tube, but slightly spaced from the latter so that there is no friction therebetween. In some embodiments a groove may be provided to hold

a sealing gasket 22. This element differs from gaskets 15 and 16 in that its normal size is only slightly greater than the spacing between the elements. The difference between the gasket and the spacing is many times greater for gaskets 15 and 16. In addition, the surface of gasket 22 may be coated to reduce friction.

The second part of the horn is a tapered section having the shape and size of the cross-section of the first part of the horn at one end and of the crystals at its opposite end to form a coupling face 21. Where the crystals and the tube have the different geometrical forms suitable transitions well known in the prior art may be employed. For ease of manufacture it is preferred that both these elements have the same shape.

The various parts are formed from readily available materials. The tube and the backing plate, for example, may be made of steel alloyed or surface treated for protection against corrosion. The backing plate is desirably as dense a material as practicable, hence tungsten or other high density materials may also be used. The horn is made from low density materials such as aluminum or magnesium in conventional alloys to provide structural strength. The crystals are preferably formed from mixtures of piezoceramic lead compounds such as ziconate, titanate, niobate and tantalate, numerous examples of which are available commercially. Several are described in Patent No. 2,708,244 issued May 10, 1955 to Bernard Jaffe. Any type of waterproof cable may be used. The gaskets may be made from neoprene rubber and are commonly referred to as O-ring seals.

Those parts which are not commercially available are easily fabricated. The crystals, round tubing, cable and O-ring seals are available commercially. The backing plate and horn may be easily formed on a lathe. The parts may be joined by means of epoxy resin cement or by an amalgam method described by Trott and Radford in patent application 138,204 filed Sept. 14, 1961. Electrical connectors may be soldered and coated, if desired, with a layer of a suitable insulating material such as rubber, polyvinyl chloride, epoxy resin, or the like.

The dimensions of one embodiment, circular in cross-section, are given in the following table:

TABLE A

Tubing:	
Inside diameter	4.25
Wall thickness	0.125
Length	[1] 10.25
Backing Plate:	
Outside diameter	[2] 4.25
Lenth	5.00
Recess diameter	3.75
Recess depth	2.00
Horn:	
Max. diameter	[3] 4.25
Min. diameter	2.00
Uniform diameter length	0.50
Tapered diameter length	2.50
Crystals:	
Diameter	2.00
Thickness	0.50

Note.—All dimensions in inches.
[1] May vary with frequency.
[2] Snug fit.
[3] Sliding fit.

FIG. 3 shows the transmitting current response of the transducer at one meter. The curve labeled "Case Not Filled" refers to the interior of the tube between the junction of the first and second parts of the horn and the backing plate as the "Case," and the term "Not Filled" implies a filling of air. Pressure release material refers to such materials as corprene, a mixture of neoprene rubber and comminuted cork, or foam rubber.

Although the air filled embodiment appears to be the most promising for shallow water operation, it is obvious

that it is not well suited for deeply submerged equipment. As the water pressure increases at great depths, water leaks past the gasket 22. Being both corrosive and conductive, as well as under pressure, the seawater damages the electrical parts even when protected with conventional solid insulators.

FIG. 3 shows an alternate embodiment of the transducer for use at these greater depths. The tube, backing plate and crystal assembly are the same as those of the FIG. 1 embodiment except for a layer of pressure release material 33 at the base of the crystal stack. The horn 34 differs in that no provision is made for an O-ring seal or gasket. The remaining volume within the tube is filled with an electrically insulating noncorrosive liquid 30 which approaches as nearly as possible the sound conducting properties of the surrounding medium. Castor oil, while not ideal, operates satisfactorily when seawater is the external medium.

To retain the insulating liquid a thin diaphragm 31 of rubber or metal foil may be drawn over the end and held in place with conventional clamping means 32. If the transducer is to be placed in a conventional oil filled sonar dome or similar array housing, the diaphragm and clamp may be omitted. The spacing between the housing and the horn may be increased to reduce losses, but as this reduces the coupling efficiency of horn, it is not feasible to eliminate these losses entirely.

The optimum depth of the cavity defined by the tube and the radiating face of the horn is a function of frequency. This depth can be varied by sliding the entire assembly within the tube 11 as shown in FIG. 6 which is in all other respects identical to FIG. 1. As shown in FIG. 6, sliding the assembly forward in the housing tube 11 creates a cavity 35 at the back of the transducer which affects the frequency response and directivity.

FIG. 5 shows a plot of the directivity obtained with a three quarter inch deep front cavity and back cavity of twice this depth. Readings were taken at a frequency of 6 kc. The back radiation is reduced about 9 db below that obtained when no back cavity is present.

The length of the fluid filled chamber between the junction of the first and second parts of the horn and the backing plate can also be used to control the characteristics of the transducer. For example, when this chamber is between a quarter and a half wave-length long it presents a positive reactance which may be used to lower the mechanical resonance of the transducer.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A directional underwater sound transducer comprising;

a rigid, hollow, housing with first and second opposed open ends spaced from one another along a longitudinal axis extending between said ends,

a tapered low density horn having a larger end and a smaller end spaced from one another along said axis, said horn being mounted in said housing with said larger end adjacent to but spaced axially from said first open end of said housing and having a slidable connection with said housing,

a high density backing plate mounted within said housing adjacent to the second open end of said housing,

each end of said backing plate being secured to said housing by means of first and second O-ring seals substantially greater in thickness than the spacing between said housing and said plate and wherein said connection between said housing and said larger end of said horn is made by a third O-ring seal only slightly greater in thickness than the spacing between said housing and said larger end of said horn,

a longitudinally responsive piezoelectric crystal assembly interconnecting said smaller end of said horn and said backing plate,

said backing plate having a re-entrant surface portion surrounding said crystal assembly,

whereby the center of gravity of said assembly, said horn and said backing plate lies within said backing plate.

2. A transducer according to claim 1; wherein,

said backing plate is spaced along said axis from said second open end of said housing in which the spacing of said backing plate from said second end is substantially twice the distance from the outer end of said horn to said first end of said housing.

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