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COMPENSATED HYDROPHONE

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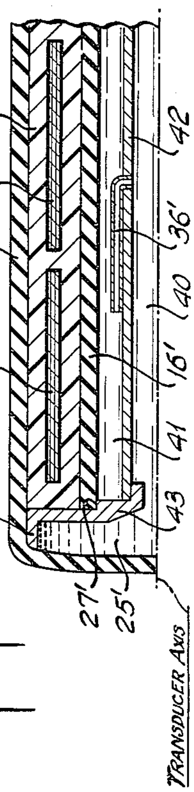

FIG. 3.

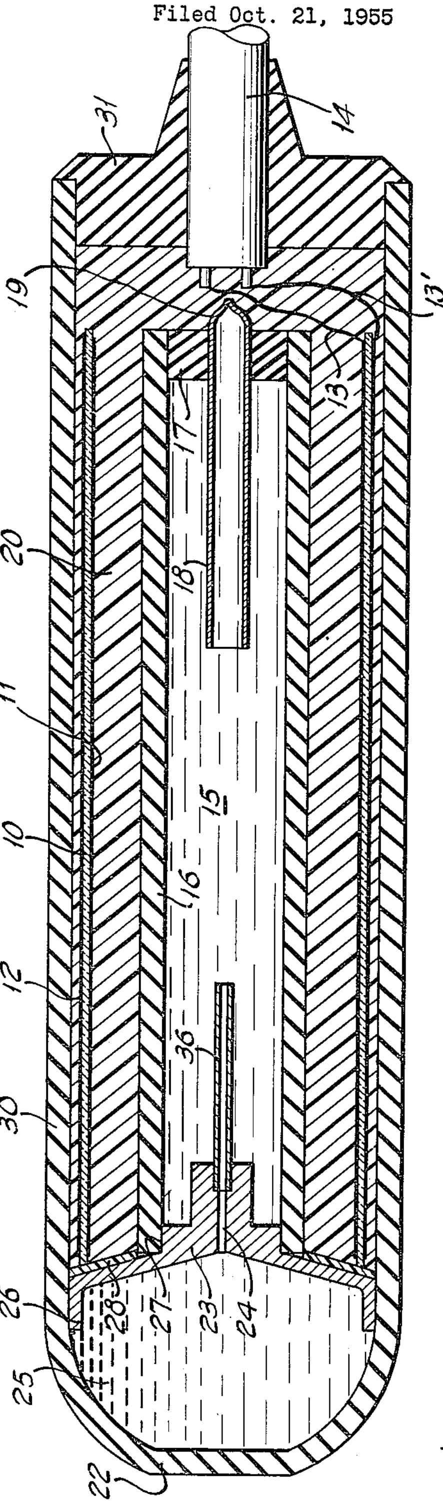

FIG. 1.

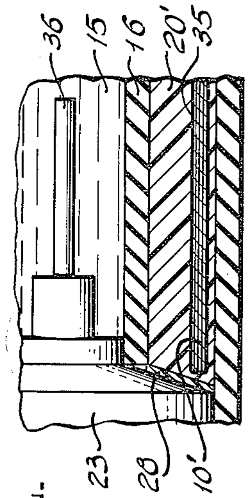

FIG. 2.

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My invention relates to improved electroacoustic devices, and in particular to those suitable for underwater use under conditions in which ambient pressures may vary between wide limits as, for example, when such transducers are to be subjected to use at extreme depths or to a wide range of depths.

More conventional transducers of the general construction contemplated herein are illustrated and described in my Patent No. 2,749,532. Such transducers employ an elongated cylindrical transducer element of the radially strictive variety, and pressure-release materials are provided radially within the cylindrical element in order to permit pressure-response of the transducer. The materials ordinarily used for this purpose are relatively soft air-cell materials, such as cork, air-filled rubber, and wood dowel. However, for deep submergence, where the hydrostatic pressure may exceed a few hundred pounds per square inch, such pressures may damage or crush the structure, or otherwise impair performance.

It is, accordingly, an object of the invention to provide improved transducers of the character indicated.

It is another object to provide an improved depth-compensated underwater transducer construction, in which depth-compensation is automatically effected.

It is specifically an object to provide a transducer meeting the above objects and capable of delivering useful output, without destruction of the instrument, at ambient pressures ranging from 15,000 to 25,000 lbs./sq. in.

Other objects and various further features of novelty and invention will be pointed out or will occur to those skilled in the art from a reading of the following specification in conjunction with the accompanying drawings. In said drawings, which show, for illustrative purposes only, preferred forms of the invention:

FIG. 1 is a longitudinal sectional view of an underwater transducer incorporating features of the invention; and

FIGS. 2 and 3 are fragmentary views in longitudinal section to illustrate modifications.

Briefly stated, my invention contemplates rendering transducers of the character indicated adaptable to withstand the crushing force of extreme ambient hydrostatic pressures by employing, instead of the conventional pressure-release materials, a liquid filling within the transducer core, said liquid filling being substantially more compressible than the liquid medium in which pressure response is to be observed. To render the device substantially uniformly responsive regardless of depth of submergence, I provide collapsible pressure-compensating means at one end of the structure and defining all or part of a depth-compensating volume or reservoir communicating with a pressure-release volume or reservoir within the transducer, both volumes being flooded with the pressure-release liquid. A restrictive orifice between the depth-compensating volume and the pressure-release volume enables ambient-pressure equalization without dynamic-pressure equalization, so that acoustic sensitivity may be assured while maintaining static equilibrium, all except for very low frequencies.

Referring to FIG. 1 of the drawings, my invention is shown in application to a radially strictive transducer construction employing an elongated cylindrical transducer element **10**, which, in the form shown, is a piezoelectric

ceramic, such as barium titanate or a zirconate ceramic; the element **10** may be an axial array of like members **10** but for present purposes will be referred to merely as the element **10**. The core **10** is covered with inner and outer foil electrodes **11—12** having lead connections **13—13'** to a lead cable **14** at one longitudinal end of the device.

In accordance with the invention, I provide a central reservoir **15** within the transducer element **10**, said reservoir containing a pressure-release liquid having a compressibility substantially exceeding that of the fluid medium in which the transducer is to be immersed. For example, for pressure response in water, the filling in the reservoir **15** may have a compressibility twice that of water and the filling may be several times more compressible than the rest of the transducer structure; I have found satisfactory performance when employing a silicone liquid filling of appropriate compressibility.

The reservoir **15** may be defined by a tube **16** of yieldable sound-transmitting material, such as neoprene. The tube **16** may be open at one end (left in the sense of FIG. 1), and closed at the other end. In the form shown, closure is effected by a bushing **17** bonded to tube **16** and carrying a central filler tube **18** to introduce the pressure-release liquid into the reservoir **15**. The projecting end **19** of the filler tube may be pinched off when filling has been accomplished.

The reservoir tube **16** is preferably in direct pressure-transmitting relation with the inner surface of the piezoelectric member **10**, as by direct intimate contact with the inner foil electrode **11**; however, in the form shown, I increase the basic strength of the structure by employing a potting **20** of hard, sound-transmitting plastic to establish the pressure-transmitting relation between the core **10** and the fluid in reservoir **15**. The single potting **20** may fully encase the transducer element, even along the outer surface thereof, and at the same time cover and permanently insulate the leads **13—13'** and the end of the lead-in cable **14**. Thus, potting **20** may be viewed as a hard basic structure having a central opening to define the reservoir **15**, said basic structure being closed at the lead-in end and open at the other end.

In accordance with a feature of the invention, I provide depth-compensation for my transducer by employing a yieldable diaphragm or envelope **22** over the open end of the transducer, and by using a metallic closure wall **23** to define a depth-compensating reservoir **25**, apart from the pressure-release reservoir **15**; a restrictive orifice **24** in wall **23** assures only limited (depth-compensating) flow between reservoirs **15—25**, and, if desired, a capillary tube **36** may extend orifice **24** to improve the low-frequency response of the transducer. In the form shown, the closure **23** is formed as part of a rigid base extending in radially overlapping relation with the end of the transducer element and having an axial flange **26** in order to protect the transducer against abuse. The base **23** includes a step or boss **27** to which the open end of the yieldable tube **16** may be affixed, for central support, while applying the potting **20**. A suitable plastic washer **28** separates the end of the transducer element from the base **23** while this operation is performed, but it will be understood that the potting **20** nevertheless substantially fully encases, seals and protects the transducer element **10**. The flexible closure or diaphragm **22** may form part of a boot structure **30** of yieldable sound-transmitting material, such as neoprene. Said boot is shown at least as longitudinally co-extensive as the transducer element and is intimately sealed to and united with the potting and, therefore, with the rest of the transducer structure. Preferably, the boot **30** extends longitudinally beyond the closed end of the potting **20** so as to define a cup space into which a closure plug **31** of neoprene or the like may be fitted, sealed, and bonded to complete the structure.

In FIG. 2, I illustrate a substantially identical structure to that described in FIG. 1, except that the radially strictive element **10'** comprises a core of magneto-strictive material as, for example, a cylinder of helically developed laminations of sheet material. In such event, a toroidal winding **35** envelopes the core **10'** to provide the desired electrical response. The potting **20'** again intimately connects the reservoir envelope **16** to the core **10'** and fully protects the toroidal winding **35**.

In FIG. 3, I show a further modification in which the depth-compensating reservoir **40** is substantially contained within the cylindrical transducer assembly and radially within the primary pressure-release reservoir **41**. A rigid tubular barrier **42** separates the two reservoirs and may be formed as a part of the base **43**; however, in the form shown the base **43** is a separate member to which the tube **42** is secured. As in the case of the constructions previously described, the yieldable tube **16'** may be located on a circular step **27'** on the base **43**. Separate cylindrical magnetostriction transducer elements **44—45** are shown potted by means **46**, within the volume defined externally of the yieldable member **16'**, said volume extending as far as the outer radial limit or flange **26'** of the base **43**. A boot **30'** of rubberlike material fully jackets the described assembly and defines (within the end space **25'** adjacent the base **43**) a part of the depth-compensating reservoir **40**. Restrictive-orifice communication between the two reservoirs **40—41** may be achieved merely by provision of one or more small radially drilled openings in the rigid tube **42**; however, in the form shown, a bent capillary tube **36'** carried on the outer side of the tube **42** is employed for restrictive-orifice purposes. The other axial end of the assembly may be generally as described in connection with FIG. 1, and therefore no illustration of lead-in parts is included in FIG. 3.

It will be seen that I have described substantially improved transducer constructions lending themselves to useful output at extreme depths of submergence and for a wide range of depths of submergence. The low-frequency response of the transducer may be substantially unaffected (as compared with transducers of said copending application) if care is taken in matching the viscosity of the pressure-release fluid to the characteristics of the orifice **24**. In particular, by extending the orifice, as by insertion of an elongated capillary tube **36** or **36'**, improved low-frequency response may be obtained without impairing the depth-compensation feature. The reservoir **25** provided for depth-compensation purposes will of course have to be of sufficient volume compared with that of the pressure-release reservoir **15** to enable fluid supply to reservoir **15** for the full range of hydrostatic pressures expected for any particular application.

While I have described the invention in detail for the preferred forms illustrated, it will be understood that modifications may be made within the scope of the invention as defined in the claims which follow.

I claim:

1. An electroacoustic transducer, comprising an elongated cylindrical radially strictive element electrically responsive to incident pressure, a fluid reservoir within said cylinder and in pressure-transmitting relation with the inner wall of said cylinder, a relatively compressible fluid in said reservoir, envelope means carried at one longitudinal end of said cylinder and including a yieldable wall portion, and means including a restrictive orifice substantially closing said reservoir from the space defined by said envelope, the space defined by said envelope being also filled with said relatively compressible fluid.

2. An electroacoustic transducer, comprising an elongated cylindrical pressure-responsive hydrophone element electrically responsive to incident pressure, a body of sound-transmitting material substantially fully encasing said transducer element on both the inner and outer surfaces thereof, said body having an elongated hollow interior defining a reservoir, a relatively compressible liquid filling in said reservoir, said body being closed at one longitudinal end and open at the other longitudinal end, means including a yieldable closure member covering said open end, barrier means between said closure member and said reservoir and defining a volume between said closure member and said barrier means, said barrier means including a restrictive orifice communicating between said volume and said reservoir, whereby said fluid may be free-flooding on both sides of said orifice, said orifice being sufficiently restrictive to substantially not reduce the A.-C. response of said transducer element, but being sufficiently open to allow the part of said reservoir within said transducer element to achieve ambient pressure.

3. In an electroacoustic transducer of the character indicated, an elongated cylindrical radially strictive transducer element, a hollow member of yieldable material within said transducer element and substantially coextensive therewith, said member being in pressure transmitting relation with the inner wall of said cylindrical transducer element, said member being closed at one longitudinal end and open at the other, means including a restrictive orifice substantially closing said other end, and an envelope of yieldable material mounted on said transducer element and defining an outer-end pressure-compensating reservoir longitudinally beyond said orifice.

4. A transducer according to claim 3, in which said member and envelope are filled with the same relatively compressible liquid.

5. A transducer according to claim 4, in which said liquid has a compressibility on the order of twice that of water.

6. A transducer according to claim 4, in which a potting of sound-transmitting material intimately establishes said member in sound-transmitting relation with the inner surface of said transducer element.

7. In a transducer of the character indicated, an elongated cylindrical annular hydrophone element defining therewithin a pressure-release chamber, a liquid filling in said chamber and having substantially greater compressibility than the medium in which said transducer is to be immersed, a depth-compensating chamber including a yieldable externally exposed wall portion, and means including a flow restriction interconnecting said chambers.

8. A transducer according to claim 7, in which the viscosity of said liquid filling is sufficiently high to avoid such free flow through said restriction as to materially impair low-frequency response of said hydrophone element.

9. A transducer according to claim 7, in which said flow restriction includes and comprises essentially an elongated capillary tube.

10. In a transducer of the character indicated, an elongated annular hydrophone element including transducing structure and defining therewithin a pressure-release chamber, a tubular partition within said chamber and substantially axially coextensive with said transducer and defining a depth-compensating chamber radially inwardly of a pressure-release chamber, said tubular partition having a restrictive orifice communicating between the inner and outer surfaces thereof, one axial end of said depth-compensating chamber including a yieldable externally exposed wall portion, and a liquid filling in both said chambers and having substantially greater compressibility than the medium in which said transducer is to be immersed.

11. An electroacoustic transducer, comprising an elongated cylindrical radially strictive element electrically responsive to incident pressure, a fluid reservoir within said cylindrical element and in pressure-transmitting relation with the inner wall of said cylindrical element, a relatively compressible fluid in said reservoir, envelope means carried by said cylindrical element, said envelope means including a yieldable wall portion defining at least in part an interior space, said yieldable wall portion being in

fluid-pressure communication with the exterior of said cylindrical element, and means including a restrictive orifice substantially closing said reservoir from said interior space, said interior space being also filled with said relatively compressible fluid.

12. A transducer comprising an elongated radially strictive cylindrical transducer element, means operatively connected thereto for transducing purposes, an elongated member of yieldable material substantially coextensive with said transducer element and centrally contained therein, a base member substantially closing off one end of said elongated member, a body of sound-transmitting material substantially encasing said transducing element and in contact with the outer surface of said elongated member and closing off the space within said elongated member except for the end closed off by said base member, and a layer of yieldable sound-transmitting material encasing said body and sealed thereto substantially for the longitudinal length of said transducer element and having a closed end extending beyond said base member and defining with said base member a presure-compensating reservoir, said base member having a restrictive orifice within the radial limits of said elongated member and communicating between the space defined by said elongated member and said presure-compensating reservoir, and a liquid filling in said reservoir and in the space within said elongated member, said liquid filling having a compressibility substantially exceeding that of water.

13. A transducer according to claim 12, in which said transducer includes, at the end of said elongated member opposite said base member, a filler tube extending beyond said end, whereby after filling the interior of said elongated member with liquid, said projecting part of the filler tube may be sealed, the portion of said body closing off the space within said elongated member surrounding said closed end of said filler tube.

14. A transducer according to claim 12, in which electric lead-in connections to said transducer element are provided at the end thereof closed by said body, said lead-in connections being in sealing engagement with said body at said end.

15. A transducer according to claim 12, in which said transducer element comprises an elongated piezoelectric ceramic with inner and outer foil electrodes.

16. In a transducer according to claim 12, in which said transducer element comprises a cylindrical magnetostrictive core and a toroidal winding enveloping said core.

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