Oct. 22, 1963 W. T. HARRIS 3,108,247

DEPTH-COMPENSATED TRANSDUCER

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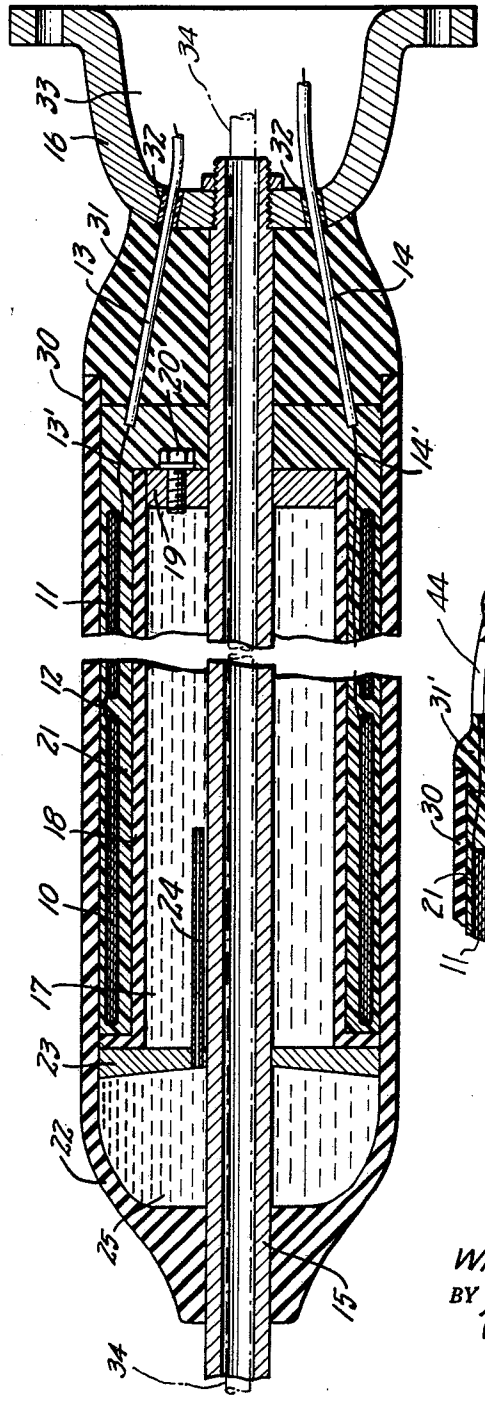


FIG. 1.

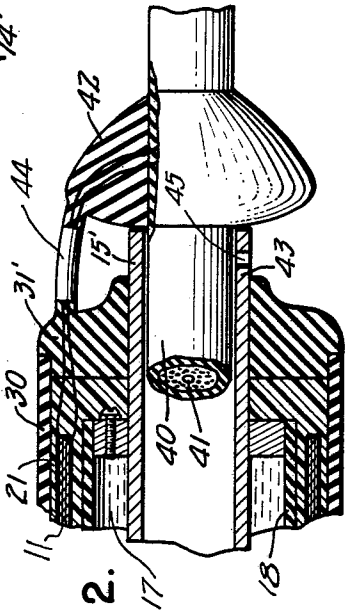


FIG. 2.

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DEPTH-COMPENSATED TRANSDUCER

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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 applications Serial No. 291,706, filed June 4, 1962, now Patent No. 2,749,532 of June 5, 1956, and Serial No. 541,981, filed October 21, 1955, now Patent No. 3,018,466 of January 23, 1962. The latter patent was copending with this application. 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.

It is another specific object to provide a transducer meeting the above objects and centrally accommodating a through cable such as a tension cable of the kind used in underwater towed-hydrophone applications.

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

FIG. 2 is a fragmentary view illustrating a modification.

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 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 the 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 the 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.

The invention will be described in particular application to structures in which a hard tubular central core permits rugged mounting of the device to other structures and also facilitates adaptation to an elongated multiconductor cable which may be run longitudinally through the device.

Referring to FIG. 1 of the drawings, my invention is shown in application to a radially strictive transducer construction employing an array of longitudinally spaced elongated cylindrical transducer elements 10—11. In the form shown, these elements 10—11 are magnetostrictive, embodying a multilayer core of magnetostrictive material and a toroidal winding enveloping the same; the core may be permanently magnetized. The transducer elements may be electrically interconnected, as suggested at 12, and leads 13—14 are brought out one longitudinal end of the structure.

The basic supporting and pressure-release structures are formed on an elongated hard core 15 comprising a length of rigid tubular material, such as steel or aluminum pipe, and in the form shown, a rigid cup-shaped mounting flange 16 is secured at one longitudinal end of the core 15. In accordance with the invention, I provide a reservoir 17 in the annular space between the core 15 and the transducer elements 10—11, said reservoir being substantially co-extensive with the length of the array 10—11 and containing a pressure-release liquid having 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 17 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 17 may be defined by a bag or tube 18 of yieldable sound-transmitting material, such as neoprene. The bag 18 may be open at one end (left, in the sense of FIG. 1) and closed at the other. In the form shown, closure is effected by a bushing 19 bonded to the bag 18 and to the core 15 and having formed therein a filler aperture, which is shown closed by a bolt 20. The filler aperture will be understood to provide means for introducing the pressure-release liquid into the reservoir 17.

The reservoir bag 18 is preferably in direct pressure-transmitting relation with the inner surface of the hydrophone elements 10–11, as by direct intimate contact with the same. However, in the form shown, I increase the basic strength of the structure by employing a potting 21 of hard sound-transmitting plastic to establish the pres-

sure-transmitting relation between the hydrophone elements 10–11 and the fluid in reservoir 17. The single potting 21 may fully encase the transducer elements even along the outer surfaces thereof and at the same time cover and permanently insulate the lead wires 13'—14'. Thus, potting 21 may be viewed as a hard basic structure having a central opening to contain the reservoir 17, said basic structure being closed at the lead-in (right) end and open at the other (left) 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 rigid closure wall 23 to define a depth-compensating reservoir 25 apart from the pressure-release reservoir 17; in the form shown, the closure 23 is part of a rigid base carried by the core 15 and extending in radially overlapping relation with the end of the transducer element 10. A restrictive orifice or bleed means 24 in the wall 23 assures limited (depth-compensating) flow between reservoirs 17 and 25. If desired, the orifice 24 may be an extended capillary tube whereby transient flow of liquid between reservoirs 17 and 25 is more impeded, so that the low-frequency response of the transducer may be improved.

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 extensive as the transducer array 10—11 and is intimately sealed to and united with the potting 21 and therefore with the rest of the transducer structure. Preferably, the boot 30 extends longitudinally beyond the closed end of the potting 21, so as to define a cupped space into which a closure plug 31 of neoprene or the like may be fitted, sealed and bonded, said closure plug 31 constituting filler means for said space. It is convenient to bring the lead cables 13—14 through insulated bushings 32—32 centrally of the mounting flange 16, so that the plug 31 may fully encase and permanently support those portions of the cables 13—14 which pass through it. The mounting flange 16 is preferably bell or cup-shaped as shown so as to define a volume 33 within which impedance-matching transformers (not shown) and appropriate junction connections (not shown) may be accommodated; such a volume 33 is closed off or defined by securing flange 16 to a closure plate or end bell, or by securing to each other the flanges 16 of two hydrophone assemblies of FIG. 1, in end-for-end adjacency. A towing or suspension lead cable is suggested at 34.

In FIG. 2, I illustrate a slightly different arrangement whereby the same basic transducer structure is adapted to a continuous multi-conductor cable 40, as of the variety employed in towed-hydrophone arrays, discussed in greater detail in said application Serial No. 291,706, now Patent No. 2,749,532. In that event, the cable 40 is preferably of the tension-core variety, that is, it includes a core element 41 as of stranded-steel cable to take the entire longitudinal (tension) load on the cable. The cable 40 is shown with a jacket of neoprene or the like, and at the point of connection to my transducer construction, an abutment 42 is bonded preferably circumferentially continuously to the cable sheath. The abutment 42 serves to retain the end of the core member 43 for the transducer structure, as distinguished from the flange connection described in connection with FIG. 1. The take-off lead cable 44 to the end plug 31' represents a splice connection that is readily available for servicing. An externally exposed aperture 45 in the end of the core tube 43 facilitates free-flooding of the core. Other parts of the structure are as discussed for FIG. 1 and therefore the same reference numerals are employed.

It will be seen that I have described an improved transducer construction lending itself to useful output at extreme depths of submergence and for a wide range of depths of submergence. The low-frequency response may be substantially unaffected if care is taken in matching the viscosity of the pressure-release fluid to the characterstics of the orifice 24. The structure lends itself particularly to installation alone or as one of several structures on a suspension cable for hanging in a vertical orientation, as when suspended in a very deep drilled oil-prospecting hole.

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 acoustic transducer, comprising an elongated hard core, an elongated cylindrical transducer element encircling and radially spaced from said core, a hollow bag of yieldable material in the space between said transducer element and said core and substantially longitudinally coextensive therewith, said bag being in pressure-transmitting relation with the inner wall of said transducer element, said bag 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 sealed to said transducer element, spaced from said means and defining between itself and said means an outer-end pressure-compensating reservoir longitudinally beyond said orifice.

2. A transducer according to claim 1, in which said bag and envelope are filled with the same relatively compressible fluid.

3. A transducer according to claim 2, in which said fluid has a compressibility substantially twice that of water.

4. A transducer according to claim 1, in which a rigid mounting flange is secured to said core at the end of said core corresponding to said one end of said bag, lead connections to said transducer element passing through a generally central part of said flange, and filler means substantially fully encircling said lead connections between said transducer element and said flange, said flange being generally bell-shaped, whereby impedance matching transformer means or the like may be contained within the hollow thereof.

5. An acoustic transducer comprising an elongated core, an elongated cylindrical transducer element coaxially overlapping a part of said core and radially spaced therefrom, a body of sound-transmitting material substantially encasing said transducer element, said body being hollow and radially spaced from said core for the substantial length of said transducer element so as to define an annular reservoir space between said core and said body, means closing the respective longitudinal ends of said space and supporting said transducer element on said core, a yieldable envelope engaging said core and defining between itself and said core an annular reservoir at one longitudinal end of said transducer, flow-limiting means communicating between said reservoirs, and a compressible liquid in both said reservoirs.

6. An acoustic transducer comprising an elongated tubular core, an elongated cylindrical pressure-responsive transducer element coaxially overlapping said core in radially spaced relation therewith, a body of sound-transmitting material substantially encasing said transducer element on both the inner and outer surfaces thereof, said body having an elongated hollow interior radially spaced from said core and defining an annular reservoir between said core and said body, a relatively compressible liquid filling in said reservoir, said body being closed at one longitudinal end, thereby closing that end of said reservoir, said body being open at the other longitudinal end thereof, means including a yieldable closure member covering said open end, barrier means including a restrictive orifice contained within said reservoir at said open end and spaced from said yieldable closure member, whereby said fluid may be free-flooding on both sides of said orifice, said orifice being sufficiently restrictive so

as not to reduce substantially the A.-C. response of said transducer element but being sufficiently open to allow the parts of said reservoir within said transducer element to achieve ambient pressure equalization.

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