Aug. 3, 1965 F. MASSA 3,199,071

ELECTROACOUSTIC TRANSDUCER CONSTRUCTION SUITABLE FOR OPERATION IN DEEP WATER

Filed April 20, 1961

Fig. 1

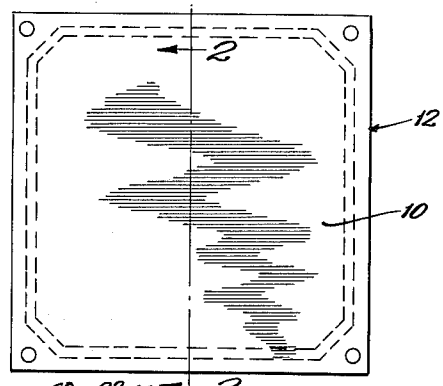


Fig. 2

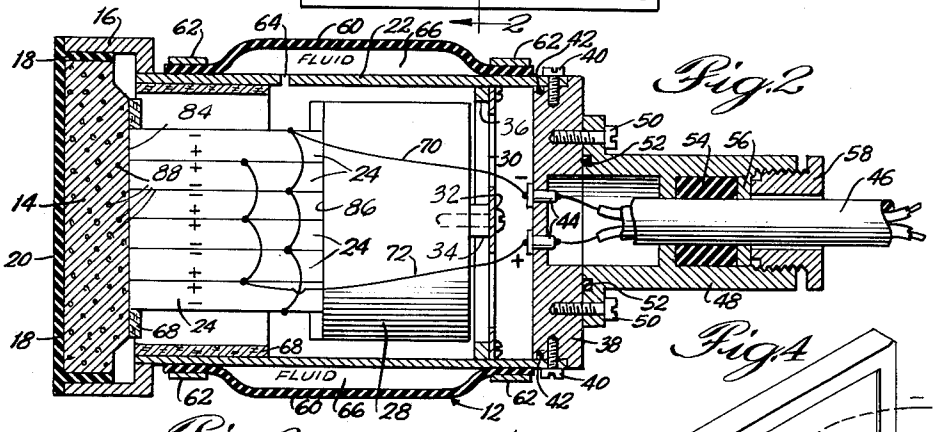


Fig. 3

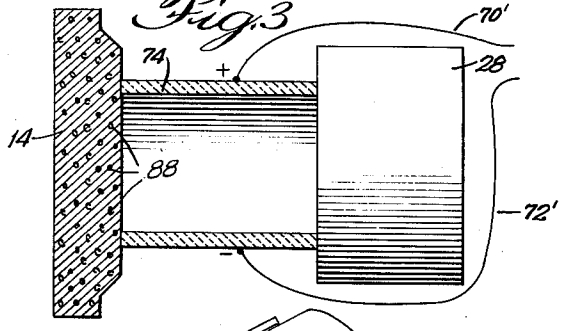


Fig. 4

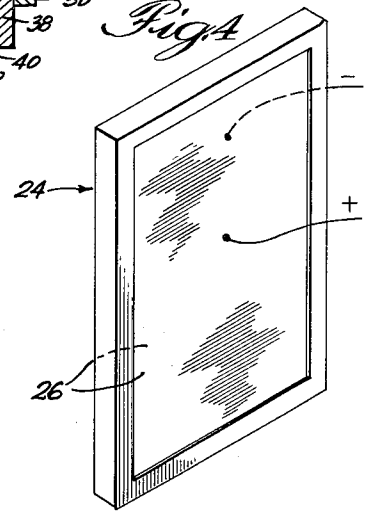
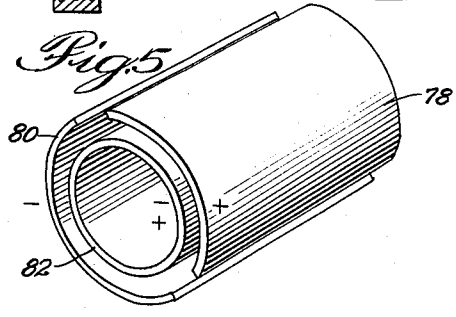


Fig. 5



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ELECTROACOUSTIC TRANSDUCER CONSTRUCTION SUITABLE FOR OPERATION IN DEEP WATER

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16 Claims. (Cl. 340—10)

This invention relates generally to underwater sound transducers and more particularly to new and improved electro-acoustic transducers adapted for the conversion of electrical energy to acoustic energy and also for the converison of acoustic energy to electrical energy.

It is well known in the art that an efficient electro-acoustic transducer may be designed by employing piezoelectric materials for the conversion of electrical signals to mechanical vibrations. A conventional design of such a transducer makes use of an assembly of piezoelectric expander plates, cut from ammonium dihydrogen phosphate or some other suitable piezoelectric material, which are operated at their natural resonant frequency as illustrated, for example, in U.S. Patent 2,521,642 Such a design is limited to relatively high frequency efficient operation because the natural frequency of typical prior art crystal plate assemblies usually falls in the frequency range above 15,000 cycles per second. For lower frequencies, the plates of these prior art arrangements become impractically long in their dimensions and are subject to easy fracture when their assembly is attempted.

Accordingly, it is a general object of this invention to improve the construction of underwater transducers, and especially transducers operating at frequencies generally in the region below approximately 15,000 cycles per second.

Another object of this invention is to provide a new and highly efficient transducer construction which is pressure equalized so that satisfactory operation can be achieved at great submerged depths under water.

It is still another object of this invention to provide a transducer of an efficient size wherein the radiating surface occupies a large portion of the housing dimensions.

It is another object of the invention to provide a transducer unit that may be conveniently assembled in multiple arrays whereby a very large radiating surface may be achieved with low manufacturing cost.

Other objects of the invention will become obvious to those skilled in the art from the following description in which the novel features which characterize the invention are set forth with particularity in the appended claims. The invention, itself, however, both as to its organization and method of operation, as well as advantages thereof, will best be understood from the following description of several embodiments thereof taken in conjunction with the accompanying drawings wherein:

FIGURE 1 is an end view showing the radiating surface of a new transducer embodying the invention;

FIGURE 2 is an elevational view, partially in cross section, of a new transducer taken along the line 2—2 of FIGURE 1;

FIGURE 3 is a partial sectional view, similar to FIGURE 2, showing another illustrative embodiment of active transducer element adapted for use in the transducer assembly of the present invention;

FIGURE 4 is a perspective view of one of the crystal plates used in the embodiment of FIGURE 2, and

FIGURE 5 is a perspective view of a split polarized ceramic cylinder which may be used as an alternative construction to the illustrative embodiment of FIGURE 3.

Referring now to the drawings, and more particularly to FIGURE 1 thereof, the reference numeral 10 identifies the radiating plane surface of a transducer assembly 12. Although the radiating surface 10 is shown as a square, it will be appreciated that any other configuration, such as a circle or a polygon could be used.

Referring now to FIGURE 2, the transducer assembly 12 is shown as comprising a vibratile plate member 14 mounted within the frame-like portion 16 of the housing structure and flexibly attached to the housing structure by the molded rubber member 18. The rubber member 18 also is molded over the front radiating surface of the vibratile plate member 14 to provide a protective surface 20 for permitting improved long-life performance under water.

Advantageously, a cylindrical housing member 22 is secured as by brazing or any other suitable means, to the frame-like portion 16 to provide a completely sealed housing to enclose the active transducer assembly. In accordance with a feature of this invention, the unique transducer structure comprises the vibratile plate member 14 and an assembly of piezoelectric crystal plates 24, such as 45° Z-cut ammonium dihydrogen phosphate, or 45° X-cut rochelle salt, or any other piezoelectric crystals which may be set into vibration by the application of an alternating voltage to a set of electrodes 26. The crytsal plate assembly is firmly bonded to a prepared flat face 84 of the vibratile plate member 14, and to a similarly prepared flat surface 86 of a weight 28 as shown in FIGURE 2. A thin insulating Bakelite sheet (not shown) may be interposed and securely bonded between the ends of the crystal plates 24 and the surfaces of the adjoining plate 14 and weight 28, if desired.

The purpose of providing the weight member 28 to load the crystal structure is to resonate the vibrating crystals at a lower frequency than would be possible were the loading weight omitted. In order that the crystal vibration amplitude may be held at a minimum with the corresponding advantageous reduction in stress, it is advantageous to make the vibratile plate 14 as light as possible, while making most of the load for frequency reduction reside in the non-radiating weight member 28. The vibratile plate 14 therefor, in one illustrative embodiment, is made of aluminum and, in cases where still further weight reduction is desired, the aluminum may be cast as a porous sponge-like mass which will preserve the rigidity of the plate, which is essential for satisfactory radiation of sound under water. The vibratile plate 14 illustrated in FIGURE 2 is shown as a porous sponge-like aluminum mass having inclusions of gas pockets 88 dispersed through its volume whereby its density is reduced.

The magnitude of the weight 28 is adjusted to result in a combined resonant frequency of the crystal plates 24, and the masses of the plate 14 and weight 28 as desired for the operating frequency of the transducer. Advantageously a flexible spider member 30 is securely fastened to the center of the weight 28 as by the threaded fastener 32 and spacer 34, and is also secured at its periphery to a ring member 36, which, in turn, is secured by any suitable means, such as brazing or welding, to the inner periphery of the housing structure 22. In accordance with the invention, the spider member 30 has transverse rigidity and keeps the weight 28 from being sheared off

at the bonded crystal surface during shock and vibration of the transducer.

An end cap 38 is fastened to the housing 22, as by means of the radially disposed screws 40. Advantageously an O-ring 42 provides a seal between end cap 38 and housing 22, as shown. Insulated terminals 44 are provided to permit transfer of the electrical connections from the electrodes 26 of the crystal plates 24 to the external cable 46. A cable gland housing 48 is fastened to the end cap 38 as by means of the screws 50 and and O-ring 52 provides the necesary underwater seal. The cable 46 is sealed by the assembly of the compression rubber gland 54, the washer 56 and the nut 58. Those skilled in the art will appreciate that nut 58 is tightened sufficiently to provide compression of the gland 54 to the surface of the cable 46.

In order to pressure equalize the assembly so that the structure will not be damaged due to the higher static pressure developed in deep water, it is a feature of this invention to provide a flexible rubber sleeve 60 which is sealed to opposite ends of the cylindrical housing 22, as by means of the metallic bands 62 or other suitable means. An orifice 64 is formed through the wall of the housing 22, as shown, to provide communication between the inner enclosure of the housing 22 and the reservoir enclosure 66 defined by the sealed rubber sleeve 60 and the outer surface of housing 22. A suitable fluid, such as castor oil, fills the inner enclosure of the transducer assembly and the reservoir enclosure 66 of the assembly. The oil may be poured into the transducer before the attachment of the end cap 38, and the rubber sleeve 60 may be pulled out from the housing as by means of a vacuum, to allow the oil to run into the formed reservoir enclosure 66.

In accordance with a further feature of this invention, a low acoustic impedance member 68, such as cork, is placed inside the transducer structure. The members 68 serve as a pressure release during the vibration of the plate 14 during operation of the transducer and prevents sound pressure from radiating through the rear or through the housing of the assembly. The pressure release function is achieved because the air cells that are trapped within the cork act as springs which are compressed when vibration is set up within the fluid. In other words, the compression of the air cells prevents the pressure from being built up in the fluid, and therefore, serves as a pressure release.

The above description of the new low frequency transducer contemplates the use of piezoelectric crystals forming the vibrating transducer material. An illustrative detailed showing of a 45° Z-cut ammonium di-hydrogen phosphate crystal which is suitable for use in the invention is shown in FIGURE 4 of the drawing. A pair of metaltic electrode surfaces 26 are cemented to the opposite faces of the crystal plate 24 as shown. When alternating potentials are applied to the electrodes 26, the crystal plate will vibrate correspondingly in a manner well known in the art. Advantageously, a plurality of crystal plates 24, as shown in FIGURE 2, may be provided with all the positive polarities connected together as shown. Suitable electrical conducting leads 70 and 72 conect the crystal plate electrodes 26 to the terminals 44 so that electrical operating power may be supplied to the transducer, through the cable 46.

As an alternate transducer material which may be utilized in the invention, the crystals of FIGURE 2 may be replaced by other materials, as for example, a stack of magnetostrictive elements or by a polarized polycrystaline ceramic such as barium titanate or lead zirconate as illustrated in FIGURE 3. As shown in FIGURE 3, the crystal plates 24 of FIGURE 2 have been replaced by the polarized ceramic cylinder 74. The loaded ceramic cylinder 74 will operate at reduced resonant frequency for the same reason described above with the

crystal structure. The electrical conducting leads 70' and 72' connect the polarized ceramic cylinder 74 to the terminals of a suitable power cable so that electrical operating power may be supplied to the transducer.

In accordance with another feature of this invention, it has been found advantageous to split the outer cylindrical electrode into two separate semi-cylindrical half-electrodes 78 and 80 as illustratively shown in FIGURE 5. In polarizing the ceramic cylinder, the D.-C. polarizing potential is applied between the half electrodes 78 and 80, and a center tap from the polarizing potential is connected to the inner continuous cylinder electrode 82. By this polarizing arrangement, the two A.-C. connections will remain on the external surfaces 78 and 80 of the ceramic cylinder and thereby increase the convenience of the assembly. It will be appreciated by those skilled in the art that it is, of course, equally possible to polarize the ceramic cylinder in a conventional manner using a continuous outer cylindrical electrode for one potential surface and the inner cylindrical electrode for the second potential surface. The inner electrode connecting wire would then be passed through a hole that would be provided through the loading weight 28 in order to permit electrical connection to be established between the inner surface of the cylinder and the terminals 44.

While there has been shown and described several specific embodiments of the present invention, it will of course, be understood that various modifications and alternative constructions may be made without departing from the true spirit and scope of the invention. Therefore, it is intended by the appended claims to cover all such modifications and alternative constructions as fall within their true spirit and scope.

What is claimed as the invention is:

1. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means having first and second plane surfaces spaced from each other and capable of being set into vibration by the application of an alternating current to said transducer means, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted to said housing structure, and secured to said first plane surface of said transducer means, a solid weight member having a plane surface secured to said second plane surface of said transducer means, flexible suspension means for supporting said solid weight member in said housing structure, a flexible chamber member defining an exteriorly sealed compartment, said exteriorly sealed compartment being in internal fluid communication with the enclosure of said housing structure through a passageway formed in said housing structure, a fluid disposed within the enclosure of said housing structure and within said exteriorly sealed compartment, said fluid being capable of easily flowing between the enclosure of said housing structure and the exteriorly sealed compartment, and electrical terminal means on said housing structure for connecting external electrical power to said transducer means.

2. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means capable of being set into vibration by the application of an alternating current, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted to said housing structure and secured to said transducer means, a solid weight member attached to said electromechanical transducer means, flexible suspension means for supporting said solid weight member from said housing structure, a flexible chamber member defining an exteriorly sealed compartment, said exteriorly sealed compartment being in fluid communication with the enclosure of said housing structure through a passageway formed in said housing structure, a fluid disposed within the enclosure of said housing structure and within

said exteriorly sealed compartment, said fluid being capable of easily flowing between the enclosure of said housing structure and the sealed compartment through said passageway, and electrical terminal means on said housing structure for connecting external electrical power to said transducer means.

3. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means capable of being set into vibration by the application of an alternating current, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted to said housing structure and secured to said transducer means, said vibratile plate being formed with cellular inclusions of gas to reduce the density of said plate, a solid weight member attached to said electromechanical transducer means, flexible suspension means supporting said solid member from said housing structure, a flexible chamber member defining an exteriorly sealed compartment, said sealed compartment being in fluid communication with the enclosure of said housing structure through a passageway formed in said housing structure, a fluid disposed within the enclosure of said housing structure and within said sealed compartment, said fluid being capable of easily flowing between the enclosure of said housing structure and the sealed compartment through said passageway, and electrical terminal means on said housing structure for connecting external electrical power to said transducer means.

4. The improvement of an electroacoustic transducer assembly in accordance with claim 3 wherein said housing structure and sealed enclosure are filled with a liquid.

5. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means having first and second spaced apart plane surfaces capable of being set into vibration by the application of an alternating current, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted to said housing structure and attached to said first plane surface of said transducer means, a solid weight member having a plane surface attached to said second plane surface of said electromechanical transducer means, flexible suspension means for supporting said solid weight member in said housing structure, and electrical terminal means on said housing structure for connecting external electrical power to said transducer means.

6. The improvement of an electroacoustic transducer assembly in accordance with claim 5 wherein said vibratile plate is formed with cellular inclusions of gas to reduce the density of said plate.

7. The improvement of an electroacoustic transducer assembly in accordance with claim 5 wherein one face of said vibratile plate is exposed to the exterior of said housing structure and further comprising a flexible water impervious material covering the exposed face of said vibratile plate.

8. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means formed of a plurality of stacked piezoelectric plates capable of being set into vibration by the application of an alternating current, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted in said housing structure and attached to said transducer means, a weight member attached to said electromechanical transducer means, flexible suspension means for supporting said weight member from said housing structure, a flexible chamber member defining an exteriorly sealed compartment, said sealed compartment being in fluid communication with the enclosure of said housing structure through a passageway formed in said housing structure, a fluid disposed within the enclosure of said housing structure and within said sealed compartment, said fluid being capable of easily flowing between the enclosure of said housing structure and the sealed compartment through the passageway and electrical terminal means on said housing structure for connecting external electrical power to said transducer means.

9. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means formed of polarized ceramic material capable of being set into vibration by the application of an alternating current, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted to said housing structure and attached to said transducer means, a weight member secured to said electromechanical transducer means, flexible suspension means for supporting said weight member from said housing structure, a flexible chamber member defining a sealed compartment, said sealed compartment being in fluid communication with the enclosure of said housing structure through a passageway formed in said housing structure, a fluid disposed within the enclosure of said housing structure and within said sealed compartment, said fluid being capable of easily flowing between the enclosure of said housing structure and the sealed compartment through said passageway and electrical terminal means on said housing structure for connecting external electrical power to said transducer means.

10. The improvement of an electroacoustic transducer assembly in accordance with claim 9 wherein said polarized ceramic material is in the form of a polarized ceramic cylinder having first and second plane surfaces respectively at opposite ends of the cylinder, said first plane surface being attached to said vibratile plate and said second plane surface being attached to said solid weight member.

11. The improvement of an electroacoustic transducer assembly in accordance with claim 10 wherein said polarized ceramic cylinder is provided with at least two electrically separated metallic electrodes.

12. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means having a pair of parallel plane surfaces capable of being set into vibration by the application of an alternating current, a fixed housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted in said housing structure and attached to one of said parallel plane surfaces of said transducer means, a weight member secured to the other parallel plane surface of said electromechanical transducer means, flexible suspension means for supporting said weight member from said housing means, a flexible chamber member defining a compartment, said compartment being in fluid communication with the enclosure of said housing structure, a fluid disposed within the enclosure of said housing means and within said compartment, said fluid being capable of easily flowing between the enclosure of said housing structure and the compartment.

13. The improvement of an electroacoustic transducer assembly in accordance with claim 12 characterized in that said weight member is of greater mass than said vibratile plate.

14. The improvement of an electroacoustic transducer assembly for generating underwater sound comprising the combination of electromechanical transducer means having first and second, spaced-apart, parallel plane surfaces, electrical conductor means connected to said transducer means for applying an alternating current to set the transducer means into vibration, a housing structure defining an enclosure for said transducer means, a vibratile plate flexibly mounted in said housing structure and attached to said first parallel plane surface of said electromechanical transducer means and a weight member secured to said second parallel plane surface of said electromechanical transducer means.

15. The improvement of an electroacoustic transducer assembly in accordance with claim 14 wherein the mass of said weight member is greater than the mass of said vibratile plate.

16. The improvement of an electroacoustic transducer assembly in accordance with claim 14 wherein said electromechanical transducer means is maintained under a static pressure bias between said vibratile plate and said weight member.

No references cited.

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