Oct. 23, 1956 L. W. CAMP 2,768,364

UNDERWATER TRANSDUCER HAVING ANNULAR ELEMENTS

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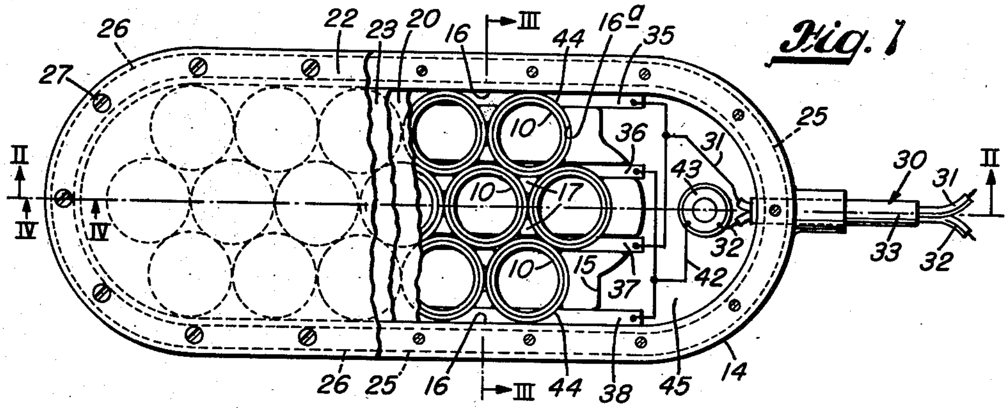

Fig. 1

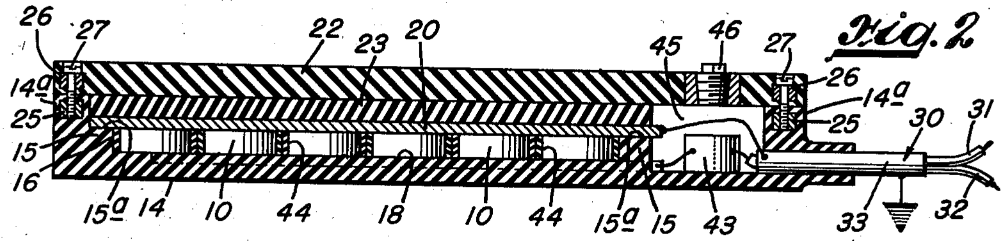

Fig. 2

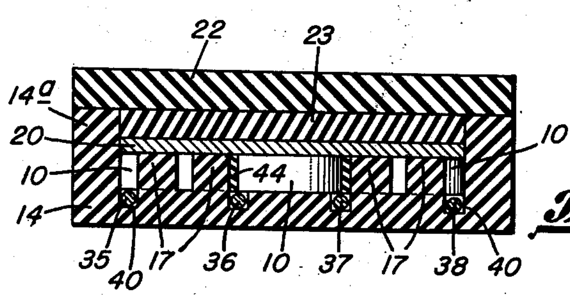

Fig. 3

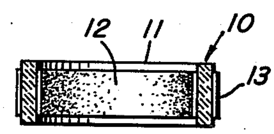

Fig. 5

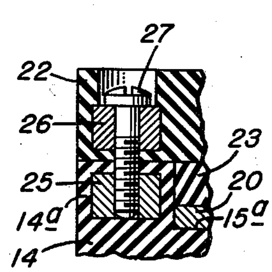

Fig. 4

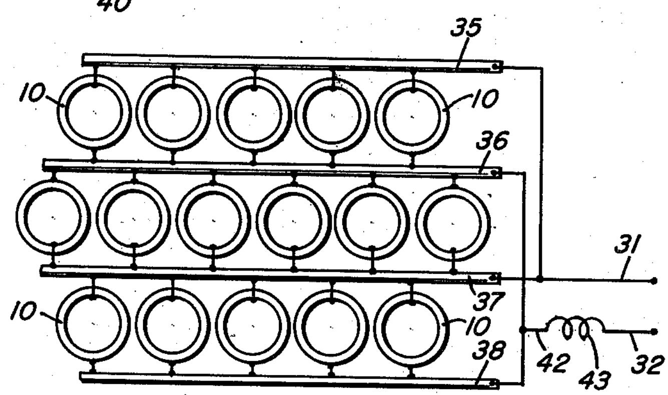

Fig. 6

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UNDERWATER TRANSDUCER HAVING ANNULAR ELEMENTS

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7 Claims. (Cl. 340—9)

This invention relates to transducers for converting electrical oscillations into traveling pressure waves in fluids, and vice versa, and is particularly adapted to utilize annular vibrating ring elements. Although not specifically limited thereto, the invention is particularly useful with electromechanically responsive ceramic rings employing barium titanate.

These titanate ceramics resemble piezoelectric crystals, in that they deform physically in response to electrical potential, and vice versa, but have the great advantage over piezoelectric crystals in that they are not limited as to shape or size, are very rugged, and are relatively efficient converters of energy from electrical to mechanical form, and vice versa.

An object of the invention is to provide a transducer design utilizing annular radially vibratile transducer elements to high advantage in converting pressure waves in fluids to electrical oscillations, and vice versa.

Another object is to provide a simple transducer design that is well adapted for manufacture at reasonable cost.

Another object is to provide a transducer of high power and sensitivity in relatively compact form.

Other more specific objects and features of the invention will appear from the description to follow of certain specific embodiments of the invention.

In the drawing:

Fig. 1 is a bottom view, with portions broken away, of one form of the invention.

Fig. 2 is a longitudinal vertical sectional view taken in the plane II—II of Fig. 1.

Fig. 3 is a cross section taken in the plane III—III of Fig. 1.

Fig. 4 is an enlarged sectional view in the plane IV—IV of Fig. 1.

Fig. 5 is a detailed cross section through one of the annular transducer elements.

Fig. 6 is a schematic diagram of the electrical connections in the transducer of Fig. 1.

The present invention is directed, not to any particular construction of annular vibrator, but to means and methods of employing annular vibrators to obtain efficient transducers. However, the most suitable present known annular vibrator for use in my transducers is one made of electromechanically responsive dielectric material. Barium titanate is a common basic ingredient of presently known ceramic electromechanically responsive dielectric materials, and for disclosures of compositions of some such materials that may be used, reference is made to Wainer Patents 2,402,515, 2,402,516 and 2,402,518; but the present invention is in no sense limited to those particular compositions. Various other compositions have been developed and are being developed, but for the purpose of the present invention it is merely necessary that the material be electromechanically responsive and be capable of being formed into ring shape. Such shaping may be done by molding or extruding the material in plastic form prior to firing, or by cutting or machining after firing. The material is polarized after firing by applying thereto a high unidirectional electric field in the direction of desired polarity, which is between the working electrodes on the inner and outer faces of the ring, so that the working electrodes can be used to apply the polarizing potential. For convenience, electromechanically responsive materials capable of being formed into the shapes disclosed herein will be referred to simply as "ceramics."

It is characteristic of presently known ceramics that the direction of the primary mechanical forces produced by an electrical field therein is parallel to the field, in contrast to piezoelectric crystals in which the primary mechanical force is perpendicular to the field in most sonic and ultrasonic applications. The present invention utilizes this characteristic of a ceramic to full advantage.

Thus, referring to Fig. 5, there is shown a radially vibratile annular vibrator element **10** consisting of a cylindrical ring **11** of electromechanically responsive ceramic material having electrodes **12** and **13**, respectively, on its inner and outer surfaces. These electrodes may consist of thin films of silver fused to the ceramic. The electrodes **12** and **13** constitute electrical means for associating the ring **11** with an electrical circuit. When an electric potential is impressed between the electrodes **12** and **13**, the direction of the electric field in the element **11** is radial, and this field causes the element to compress or expand radially. In practice, the rings are so utilized that the inner surface to which the electrode **12** is attached is exposed to a fluid medium through which sound is to be transmitted or received, and the outer surface to which the electrode **13** is attached is acoustically shielded from the fluid and from the inner surface. As used herein, the term sound includes vibrations in both the sonic and ultrasonic range of frequencies.

Figs. 1, 2 and 3 disclose a transducer particularly adapted for underwater use, and employing sixteen of the elements **10** positioned in an array that is relatively long compared to its width. Thus, the elements **10** are positioned in three rows, the inner row containing six units, and each of the outer rows containing five units. The use of a large number of elements in this manner not only increases the power capacity over that obtainable from a single element, but produces highly desirable directional properties.

The elements **10** are positioned in a recess formed in the rear face of a front wall member **14**, which is of a sound-transparent rubber composition. In other words, the material of which the front wall **14** is constructed is capable of propagating sound therethrough and has approximately the same impedance characteristics as water, so that when the device is immersed in water there is little reflective loss of energy at the boundary between the wall member **14** and the water.

The recess in the rear surface of the front wall member **14** is bounded by a shoulder **15**, which also defines the edge **16** of the recess. As shown at **16***a* in Fig. 1, at the ends of the recess this edge **16** is shaped to conform to the adjacent surfaces of the end rings of the array. The front wall member **14** also contains bosses **17** rising from the floor **18** of the recess, which bosses, together with the edge surface **16** of the recess, define individual pockets for receiving and retaining the annular elements **10**. The rear face **15***a* of shoulder **15** on the front wall member **14** and the rear faces of the bosses **17** lie in a common plane which is spaced from the recess floor **18** the axial length of the annular elements **10**. The recess is closed on the rear by a sound-reflective wall member **20** which is formed of some relatively dense material, such as metal, and which acts as a sound reflector. The thickness of this sound-reflective rear wall member **20** should be one-quarter wave length of sound in the material, and the wave length is less with denser materials. In the present construction it is desirable, in order to keep the overall thickness of the transducer relatively low, to form the sound-reflective wall 20 of some relatively heavy material, such as lead.

The individual pockets defined by the edge 16 of the recess and the bosses 17 are larger than the annular elements 10, to provide room for a ring 44 of sound-absorptive material, such as soft air cell rubber, around each element 10. These rings 44 acoustically insulate the outer surfaces of the elements 10 from each other and from the inner "working" surfaces of the elements 10 and the front wall member 14.

The sound-reflective wall member 20 is held against the face 15*a* and the bosses 17 to form an enclosure for the elements 10 by a rear wall member, which in this instance consists of an outer wall 22 of relatively hard rubber material and an inner layer 23 of sound-absorptive solid material such as Corprene or air cell rubber. The inner layer 23 is coextensive only with the shoulder 15 of the front wall member. The outer layer 22 of the rear wall member is coextensive with the outer edge of the front wall memeber and is solidly secured thereto. Thus the front wall member 14 may have a flange portion 14*a* projecting rearwardly from its edges, in which flange portion there is imbedded a continuous metallic reinforcing member 25, and the rear wall member 22 may have a similar continuous reinforcing member 26 molded therein. The member 26 may have apertures extending therethrough to pass screws 27, and the reinforcing element 25 may have threaded apertures therein for threadedly engaging the screws for drawing the rear wall member in tight sealing engagement with the front wall member. Some suitable cement or sealing compound may be interposed between the contacting surface of the front and rear wall members to insure a watertight connection.

Electrical connection is made to the unit by means of a cable 30 which extends through one end of the front wall member 14 in a sealing relation thereto. This cable 30 may contain two conductors 31 and 32 and may have a metallic external shield 33 which is at ground potential. If the transducer is employed under water, the sheath 33 would be grounded directly to the water by contact therewith. In some instances it may be desirable to ground the plate 20 by connecting it to the sheath 33 as shown in Fig. 2.

As previously indicated, each of the annular transducing elements 10 has inner and outer electrodes 12 and 13, respectively. These electrodes are connected to the conductors 31 and 32, as shown in Fig. 6. Thus, there are four bus bars 35, 36, 37 and 38 which extend longitudinally through grooves 40 provided therefor in the bottom wall of the recess containing the transducer elements 10. As clearly shown in Fig. 6, the bus 35 is connected to the inner electrodes of all of the transducer elements in one outer row, and the outer elements of the transducer in this row and in the middle row are connected to the bus 36. The bus 37 is connected to the inner electrodes of all of the elements in the middle row and in the other outer row, and the bus 38 is connected to the outer electrodes of all the elements in the said other row. With this arrangement, it will be observed that all of the inner electrodes are connected directly to the conductor 31, and all of the outer electrodes are connected directly to a conductor 42, which may be connected through an inductance element 43 to the conductor 32. The purpose of this inductance element 43 is to match the capacitive reactance of the transducer elements and thereby reduce the over-all input impedance presented to the cable conductors 31 and 32. It is also desirable to connect all of the electrodes of the various transducing elements in parallel with respect to each other, as shown, to reduce the electrical impedance, since the impedance of each of the individual elements 10 is relatively high.

The inductance element 43, as best shown in Figs. 1 and 2, is positioned in a cavity 45 provided between the front and rear walls 14 and 22, respectively.

It is necessary to the operation of the structure as so far described that the space within the transducing elements 10 and between the front wall member 14 and the sound-reflective wall 20 be filled with a suitable sound-propagating, pressure wave medium, such as castor oil, which has an acoustic impedance matching that of the front wall member 14 and of the water with which it is in contact when in use. In the construction shown, this liquid medium completely fills the interior of the device, a filling aperture 46 being provided in the rear wall 22 for this purpose. This filling aperture is closable by a screw plug.

Although it is most convenient to fill the entire interior space within the transducer with a suitable oil, it is not essential to the operation that the oil be provided anywhere except within the elements 10 between the sound-reflective wall 20 and the front wall 14. Hence, if desired, the recess containing the annular elements 10 may be filled with oil prior to placing the sound-reflective wall 20 in place, and the wall 20 then sealed to the shoulder 15 with a suitable cement. Limiting the location of the oil to the place where it is needed has the advantage that a more effective acoustic insulation of the reflective wall member 20 from the rear wall member 22 can be obtained. This is for the reason that acoustic insulation, such as air cell rubber or Corprene, remains efficient for a longer period when in air than when immersed in oil or other liquid. When the oil is to be limited to the enclosure containing the elements 10, the grooves 40 are filled with a sealing compound where they extend through the shoulder 15 to the space 45.

The construction described has substantial advantages from a manufacturing standpoint by virtue of the fact that all of the transducing elements 10 and all of the electrical elements are contained within the front wall member 14. In this connection, it has been found that the location of the bus bars 35, 36, 37 and 38 in the front wall member 14 and the provision of the rearwardly extending bosses 17 does not impair the operation of the front wall as a sound window.

Although for the purpose of explaining the invention a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art, and I do not desire to be limited to the exact details shown and described.

I claim:

1. In a transducer for translating sound waves in a fluid medium into electrical waves in an electric circuit, and vice versa: a front wall member of sound-transparent material; a sound-reflective solid wall member back of said front wall member in generally parallel relation thereto and substantially coextensive therewith; a marginal integral flange on said front wall member extending rearwardly past the solid wall member; a rear wall member coextensive with and parallel to said front wall member and joined to said flange to form an enclosure, said rear wall member lying against said solid wall member; an array of radially vibratile annular vibrator elements positioned in said enclosure, said elements resting at one end against said solid wall member; means including sound-absorptive material interposed between said elements for supporting them in separated relation and preventing effective acoustic coupling between their outer surfaces and said front wall member; a sound-propagating pressure wave medium filling the free space within said enclosure for propagating sound between said front wall member and the annular inner surfaces of said elements; and electrical means associating said elements with said electric circuit.

2. A transducer according to claim 1 in which said front and rear walls are of rubber material relatively flexible as compared to said solid wall member.

3. A transducer according to claim 1 in which said rear wall member comprises an outer layer of relatively hard material and an inner layer of sound-absorptive rubber material.

4. In a transducer for translating sound waves in a fluid medium into electrical waves in an electric circuit, and vice versa: a front wall member of sound-transparent material; a sound-reflective solid wall member back of said front wall member in generally parallel relation thereto and substantially coextensive therewith, and means joining said wall members together at their edges to form an enclosure; an array of radially vibratile annular vibrator elements positioned in said enclosure, each element resting at one end against said solid wall member, said front wall member having in its inner side a recess in which said elements are positioned, said recess being of depth equal to the thickness of said elements whereby the latter are substantially completely contained within said front wall member; means including sound-absorptive material interposed between said elements for supporting them in separated relation and preventing effective acoustic coupling between their outer surfaces and said front wall member; a sound-propagating pressure wave medium filling the free space within said enclosure for propagating sound between said front wall member and the annular inner surfaces of said elements; and electrical means associating said elements with said electric circuit.

5. A transducer according to claim 4 in which said means interposed between said elements for supporting them in separated relation includes bosses integral with said front wall member and extending rearwardly from the floor of said recess to said solid wall member.

6. A transducer according to claim 5 in which said bosses and the edge surfaces of said recess define individual pockets of larger size than the elements, and individual rings of sound-absorptive material surrounding said elements and supporting them with respect to said bosses and edge surfaces.

7. A transducer according to claim 4 in which said electrical means associating said elements with said electric circuit comprises electrodes on said elements and a cable connection extending through said front wall member; said front wall member defining grooves in the floor of said recess extending past said elements; and connecting leads in said grooves extending from said element electrodes to said cable connection.

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