Jan. 31, 1956 L. W. CAMP 2,733,423

CERAMIC TRANSDUCERS HAVING ANNULAR ELEMENTS

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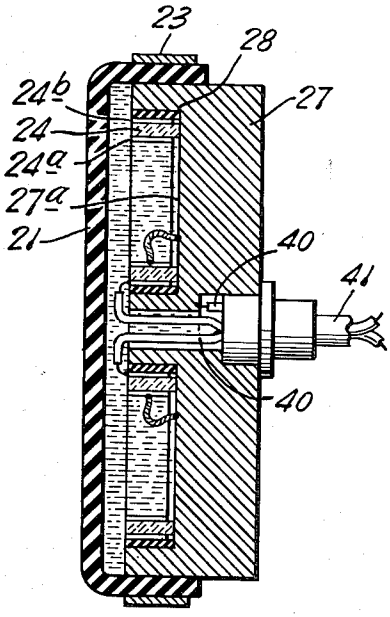


Fig. 2

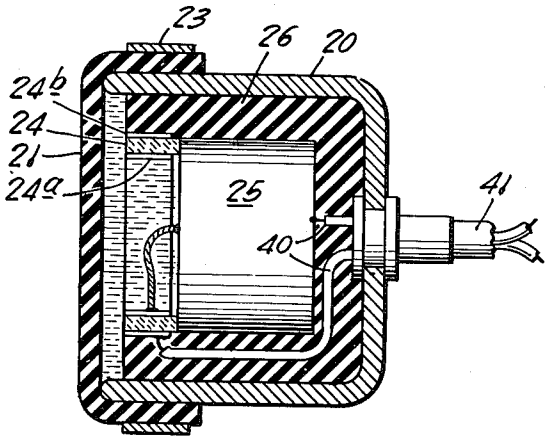


Fig. 1

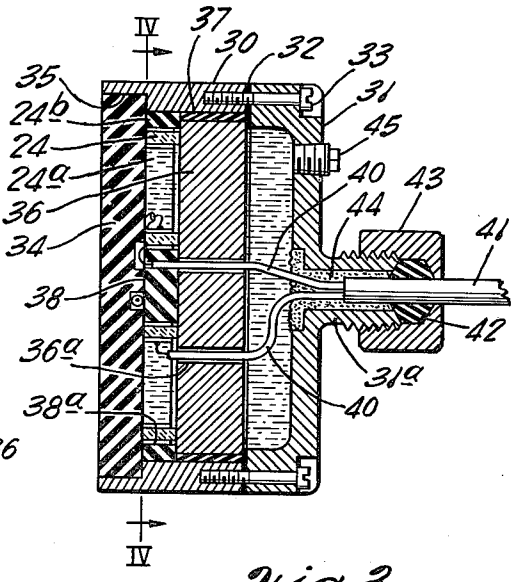
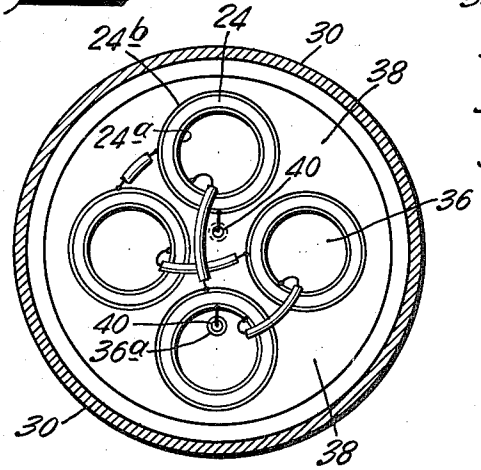


Fig. 3

Fig. 4



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CERAMIC TRANSDUCERS HAVING ANNULAR ELEMENTS

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6 Claims. (Cl. 340—10)

This invention relates to transducers for converting electrical oscillations into traveling compressional waves in fluids and vice versa, and has to do particularly with transducers for this purpose employing electro-mechanically responsive ceramics such as barium titanate.

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

This is a continuation in part of my application Serial No. 214,144, filed March 6, 1951, now abandoned and titled Ceramic Transducers for Underwater Sound Transmission and Reception.

An object of the invention is to provide ceramic transducer designs utilizing the special properties of electro-mechanically responsive ceramics to high advantage in converting traveling waves in fluids to electrical oscillations and vice wersa.

Other more specific objects and features of the invention will appear from the following description with reference to the drawing, in which:

Fig. 1 is a longitudinal sectional view of a transducer employing a short annular ceramic element.

Fig. 2 is a view similar to Fig. 1 showing a variation of the structure shown in Fig. 1.

Fig. 3 is a view similar to Fig. 2 showing a modified construction; and

Fig. 4 is a cross section taken in the plane IV—IV of Fig. 3.

The present invention is directed not to any particular ceramic composition, but to shapes and methods of mounting ceramic elements to obtain efficient transducers. Various compositions have been developed and are being developed, but for the purpose of the present invention it is merely necessary that the material be electro-mechanically responsive and be capable of being formed into the shapes disclosed. 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 a high unidirectional electric field in the direction of desired polarity, which is between the working electrodes, so that the latter can be used to apply the polarizing potential.

Barium titanate is a common basic ingredient of presently known ceramic electro-mechanically responsive elements, and for disclosures of compositions of some electro-mechanically responsive ceramics 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. For convenience, electromechanically responsive elements capable of being formed into the shapes disclosed herein will be referred to hereinafter 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 piezo-electric crystals in which the primary mechanical force is perpendicular to the field in most sonic and supersonic applications. The present invention utilizes this characteristic of ceramics to full advantage.

The transducers herein disclosed are particularly adapted for the transmission or reception of supersonic vibrations in water for use in depth sounding, underwater ranging, etc., but since they are not limited to any particular frequency range, the vibrations will be referred to, for convenience, as sound, which term as used herein includes both the sonic and supersonic range of frequencies.

Fig. 1 shows a transducer consisting of a fluid-tight case 20 closed at the front end by a sound transparent window consisting of a cap 21 of a rubber having substantially the same sound-transmitting properties as the water or other fluid in which the transducer is to be immersed, so that it transmits sound with substantially no reflection. The cap 21 is shown secured in place by a band clamp 23.

There is contained within the case 20 an electro-mechanically responsive radially vibratile annular transducing element consisting of a ceramic ring 24 having inner and outer electrodes 24*a* and 24*b* respectively, which may consist of thin silver films bonded to the internal and external surfaces of the ring. The ring 24 is backed by a solid member 25 of substantial size, which may be made of some material such as steel or aluminum having good sound transmission characteristics and a specific acoustic impedance much greater than that of water. The diameter of the backing member 25 is substantially the same as that of the ceramic ring 24, and both are supported within the casing 20 by a mass of some sound insulating material 26, such as Corprene or air-cell rubber. The entire space between the front end of the member 25 and the window 21 is filled with some fluid such as castor oil, which has substantially the same sound propagation characteristics as water and propagates sound between the window 21 and the annular inner surface of the ring (the surface to which the electrode 24*a* is attached).

The direct or primary mechanical motion produced in the ceramic ring 24 by potential between the electrodes 24*a* and 24*b* is radial, but there is a secondary circumferential movement which determines the resonant frequency, it being approximately equal to one wave length of sound in the material at the resonant frequency. The radial vibration of the outer face of the ceramic ring 24 is not utilized, it being reflected by the sound insulating material 26. The radial vibration of the inner surface of the ring 24 is transmitted to the fluid therewithin, developing sound waves which are transmitted through the fluid to the window 21, and through the window to the water or other fluid exterior thereof.

A ceramic ring 24 suitable for operation at 37.5 kilocycles may have an axial dimension of one centimeter, a radial thickness of 3.2 centimeters, and a mean diameter equal to

$$\frac{\lambda}{\pi}$$

where λ is the wave length of sound in the ceramic at the stated frequency. The length of the backing member 25 (if of steel) may be 3.3 centimeters, which is approximately one-fourth of the wave length of sound in steel.

Fig. 2 shows a modification of the structure shown in Fig. 1, in which the backing member 27 is made of larger diameter, and has an integral forward extension defining a plurality of recesses 27*a* to receive a plurality of radially vibratile annular transducing elements consisting of ceramic rings 24. The recesses 27*a* are preferably of substantially the same depth as the rings 24 so that

when the bases of the rings are resting against the bottom of their recesses, their outer faces are approximately flush with the front face of the backing member **27**. The base portion of member **27** rearward of the recesses **27***a* constitutes a solid sound-reflective wall member, and the portions forward of the base portion constitute an integral forward extension thereof for supporting the rings **24**.

Any desired number of rings may be employed in a single transducer, as shown in Fig. 2. This multiple construction is not limited to the particular design of Fig. 2, but can also be applied to that of Fig. 1.

However, the use of the block **27** having the recesses **27***a* for receiving the ceramic rings **24** is particularly advantageous for multiple unit transducers, in that practically all surfaces exposed to the oil that fills the space back of the rubber cap **21** are sound reflective. This substantially increases the efficiency. Tests on comparable multiple units corresponding to Figs. 1 and 2 respectively have shown an efficiency approximately 3½ db higher for the construction of Fig. 2 than for that of Fig. 1.

To permit radial movement of the outer face of each ceramic ring **24**, in the construction of Fig. 2, the internal diameter of the recess in which the ring fits is made somewhat greater than the outside diameter of the ring, and the ceramic ring is supported clear of the recess wall in sound insulated relation therewith by a ring **28** of some sound absorptive insulating material such as air-cell rubber.

There is shown in Figs. 3 and 4 a modication of the structure shown in Fig. 2. In the construction of Fig. 3 the case consists of a front cylindrical case **30** and a rear closure cap **31** secured together in fluid tight relation by means of a gasket **32** and screws **33**. The front wall member or sound window **34** is set into a counterbore **35** in the front end of the case **30** and bonded thereto. A flat faced solid sound-reflective wall member or plate **36** is mounted in the case **30** with its rear face flush with the rear face of case **30**. Plate **36** is supported at its peripheral face from the case **30** by a ring **37** of Corprene or the like. The Corprene ring **37** and case **30** constitute means joining the solid wall member or plate **36** and the front wall member **34** together at their edges to form an enclosure containing the ceramic rings **24**. The peripheral portion of the closure cap **31** is thicker than the case **30**, so that it extends inwardly to engage the rear face of the plate **36** and support it against rearward movement.

These ceramic rings **24** are positioned in apertures **38***a* in a disc **38** of air cell rubber or Corprene, and the assembly of disc **38** and rings **24** is sandwiched between the sound window **34** and the plate **36**. Leads **40** from the electrodes of the ceramic rings are brought back through holes **36***a* in the plate **36** to a cable **41** which enters the cap **31** through a neck **31***a* thereon. The cable is sealed by a packing ring **42** compressed by a packing gland **43**, and by a potting compound **44** poured into the neck **31***a*. All free space within the case is filled with a suitable oil, which is supplied through a filler opening **45** in the cap **31**.

Whereas the rings **24** are shown spaced from the sound window in Fig. 2, they are shown in contact therewith in Fig. 3. However, this does not appear to affect the efficiency of the transducer, and from a manufacturing standpoint the structure of Fig. 3 is more practical than that of Fig. 2. It is to be understood that at least a film of oil will separate the inner surface of the sound window **34** from the disc **38** and the front surfaces of the ceramic rings **24**. Also, sufficient oil may be introduced to slightly bulge the window **34** away from the disc **38** except at the edges of the latter.

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 solid wall member of sound-reflective material 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 transducing elements positioned in said enclosure, each element 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 compressional 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 means interposed between said elements comprises an integral forward extension on said solid wall member defining cylindrical recesses in which said elements are individually positioned, said recesses being of larger diameter than said elements, and a ring of sound-absorptive material separating the said outer surface of each element from the inner surface of its recesses.

3. A transducer according to claim 2 in which the depth of said recesses is substantially the same as that of said elements.

4. A transducer according to claim 1 in which said means interposed between said elements comprises a sheet of sound-absorptive insulating material substantially coextensive with and lying against said solid wall member and of thickness substantially equal to the axial thickness of said elements, said sheet having cylindrical apertures extending therethrough individually containing said elements.

5. A transducer according to claim 4 in which said front wall member is substantially in contact with said elements and said sheet.

6. A transducer according to claim 5 in which said means joining said wall members together at their edges comprises a peripheral case secured to and extending rearwardly from the edge of said front wall member and dimensioned internally to loosely receive therewithin the peripheral face of said solid wall member; a layer of solid sound-absorptive material filling the space between the peripheral face of said solid wall member and the inner face of said peripheral case; and a closure cap secured to and closing the rear end of said peripheral case, said closure cap having a shoulder engaging the rear face of said solid wall member for preventing rearward movement thereof.

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