

Jan. 10, 1961

A. I. DRANETZ ET AL

2,967,956

TRANSDUCER

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2 Sheets-Sheet 1

Fig. 1.

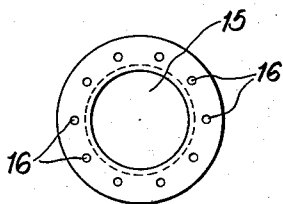


Fig. 3.

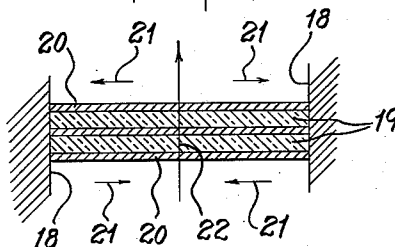


Fig. 2.

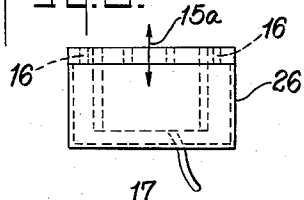


Fig. 4.

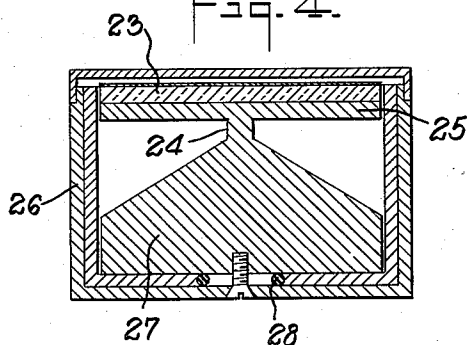


Fig. 5.

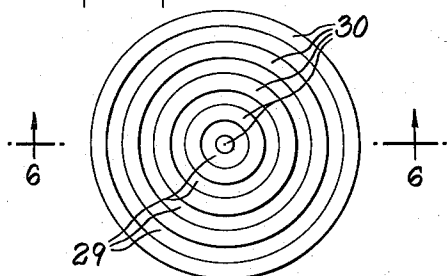


Fig. 6.

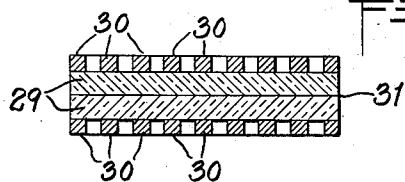


Fig. 7.

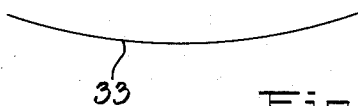
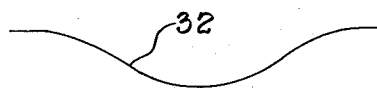


Fig. 8.

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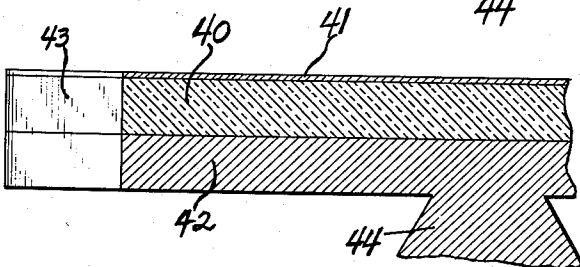
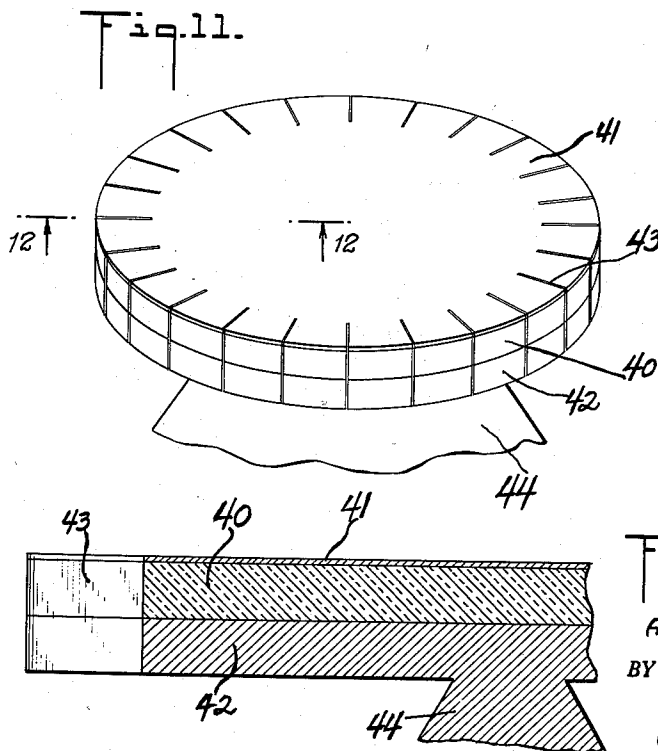
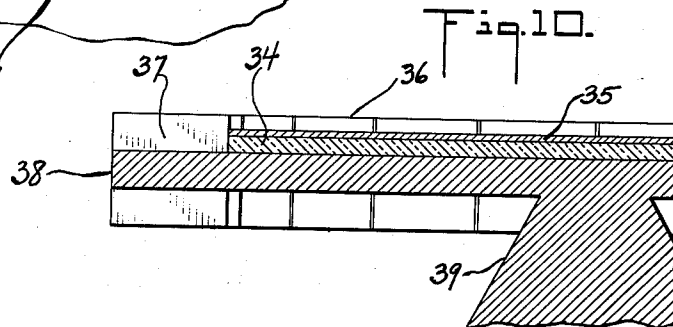
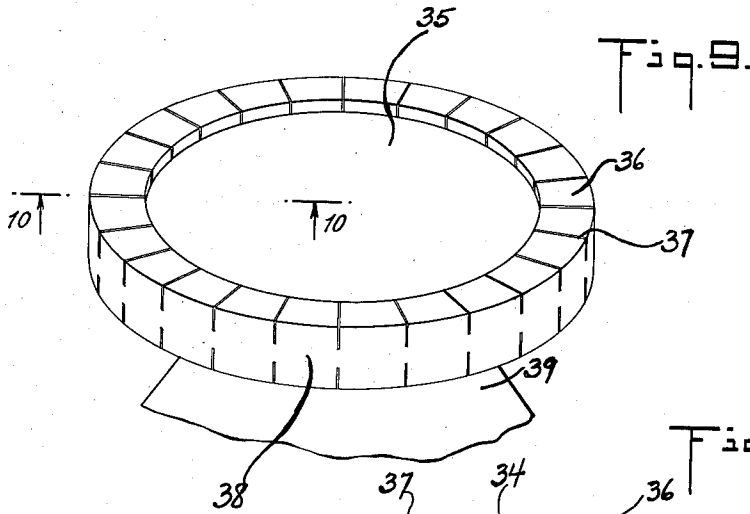
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2 Sheets-Sheet 2



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1

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4 Claims. (Cl. 310—9.1)

Our invention relates to electro-mechanical transducers and in particular to those ceramic electro-mechanical transducers which employ a vibrating disc which is excited in a bending mode of resonance.

Up to now, ceramic underwater sound transducers have been of the form of either flat discs or cylinders. These vibrating systems will vibrate at the largest amplitude when they are excited at one of their resonant frequencies (fundamental or harmonic). The common modes of resonance utilized in disc transducers are the radial and the thickness modes and those utilized in cylindrical transducers are the radial and length modes. Disc transducers vibrating in radial and thickness mode possess an inherently high Q, and cylindrical transducers increase in size as the resonant frequency is lowered. Since it is desirable to obtain transducers of reasonable size with low resonant frequencies, we propose to utilize the flexural vibrational modes of disc transducers.

Accordingly, it is a principal object of our invention to provide a disc-shaped ceramic transducer capable of being excited in flexural modes.

It is a further object of our invention to provide a disc-shaped ceramic transducer which is easily manufactured and produced.

It is a still further object of our invention to provide an economical disc-shaped transducer of low resonant frequency and low Q.

It is a still further object of our invention to provide a mass-loaded disc-shaped ceramic transducer capable of being excited in flexural modes.

Other objects and advantages of our invention will be apparent during the course of the following description.

In the accompanying drawings, forming a part of this application, and in which like numerals are employed to designate like parts throughout the same,

Figure 1 is a plan view of an embodiment of our invention,

Figure 2 is a side elevation of the embodiment of Figure 1,

Figure 3 is utilized to illustrate the stresses in a transducer which is excited in flexural mode,

Figure 4 is a cross-sectional view of a further embodiment of our invention,

Figure 5 is a plan view of a further embodiment of our invention,

Figure 6 is a cross-sectional view along the line 6—6, Figure 7 is a stress curve of an edge-clamped disc transducer,

Figure 8 is a stress curve of an edge-supported or center-supported disc transducer,

Figure 9 is a perspective view of a further embodiment of our invention, illustrating a method of mass loading,

Figure 10 is a cross-sectional view along the line 10—10,

Figure 11 is a perspective view of a further embodiment of our invention, illustrating another method of mass loading, and

2

Figure 12 is a cross-sectional view along the line 12—12.

In the drawings, wherein for the purpose of illustration, are shown preferred embodiments of our invention, the numeral 15 designates the active element of a ceramic transducer, 16 designates the clamping screws, and 17 designates the electric cable. The numeral 18 designates clamping surfaces, 19 designates ceramic transducer active elements, 20 designates the electrodes, 21 designates the directions of element stress, and 22 designates the resultant direction of motion.

The numeral 23 designates the active element of a ceramic transducer, 24 designates the center support, 25 designates the metal element of the ceramic-metal sandwich and serves as the lower electrode, 26 designates the case and 27 designates the mass backing. The numeral 28 designates the sealing ring, 29 designates the active elements of a ceramic transducer, 30 designates the electrodes, and 31 designates the separation surface. The numeral 32 designates the stress curve of an edge-clamped disc transducer, 33 designates the stress curve of an edge-supported disc transducer, 34 designates the ceramic transducer element, 35 designates the upper electrode and 36 designates the outer mass ring. The numeral 37 designates the slits in outer mass ring 36, 38 designates the lower metal element of the ceramic-metal sandwich and 39 designates the center support. The numeral 40 designates the ceramic transducer element, 41 designates the upper electrode, 42 designates the lower metal element of the ceramic-metal sandwich, 43 designates the slits in the outer rim, and 44 designates the center support.

The embodiments of our invention described and illustrated utilize ceramic transducers of the titanates and in particular those which are made largely of barium titanate. However, our invention applies equally as well to flat-plate transducers of any shape, such as squares, rectangles, ellipses, etc. which are capable of being excited in flexural mode. Materials which are either piezoelectric, magnetostrictive, electrostrictive or the like are suitable to carry out our invention and may be employed as the active material of transducers produced in accordance with the invention.

The embodiment of our invention illustrated in Figures 1 and 2 may utilize either the two active elements in the sandwich construction of Figure 3 or an active piezoelectric element backed by a piezoelectrically inert disc such as are illustrated in Figures 4, 9 and 11. All the embodiments of our invention may be constructed of either type of transducer. The electrical connections to the active element 15 of the transducer are contained in cable 17 and the active element 15 is clamped by clamps 16 around the edge of 15. When the unit is excited at the resonant frequency of the flexural modes, the center of active element 15 will move in the direction 15a as illustrated in Figure 2.

Figure 3 serves to illustrate this action wherein the transducer is comprised of two active elements 19 with electrodes 20 on each outer face and between the two separate active elements 19 suitably bonded or otherwise fixedly attached to the surfaces of 19. The electrodes are electrically connected so that an applied voltage will cause the active elements to stress in the directions indicated by arrows 21. If the stresses as indicated by arrows 21 are so produced, the resultant motion of the transducer will be in the direction shown by arrow 22. When the directions of arrows 21 are reversed, the direction of arrow 22 will likewise be reversed. The flexing of the transducer along the line of arrow 22 will occur at the frequency of the applied voltage. In like manner, if the transducer is mechanically or acoustically flexed along the line of arrow 22, the voltage produced will be of the same frequency or time dependence as the applied stress.

If the two active elements 19 are polarized in the same direction, then they should be driven in parallel. While if the two active elements 19 are polarized in opposite directions, then they should be driven in series.

In water, utilization of the flexural mode of vibration produces a broad peak if output is plotted against frequency whereas the other modes of vibration produce much sharper peaks. The optimum figure of merit, Q , for a transducer of a given size may be attained by suitable mass-loading of the transducer. This may be accomplished by varying the loading masses in size, position or both. Control over the acoustic coupling of the transducer may also be attained by selective isolation of portions of the transducer face which are operating out of phase with the major portion of the face.

Figure 4 illustrates a unit produced in accordance with our invention wherein the active element 23 is backed by a piezo-electrically inert backing 25 to which it is securely and uniformly bonded, the whole assembly being center-supported by support 24 which is mass backed by 27. The complete unit is enclosed in case 26 and sealed by sealing ring 28. When the active element 23 is energized by a potential, the plane surface of 23 tends to shrink and grow in accordance with the frequency of the applied exciting potential. This motion of the active element 23 is resisted by inert disc 25, thus causing the combined unit 23—25 to vibrate in the flexural mode. The output of this type of transducer is lower than the output of a similarly sized unit containing two active elements such as is illustrated in Figure 3 but it is simpler to machine and construct especially since the mounting arrangement and mass backing may be constructed of the same piece as the inert backing.

If center supporting is desired, such as is illustrated in Figure 3, the metal may be turned so that the disc portion resembles the head of a mushroom supported on a stem. When this is backed with sufficient mass 27, the disc is free to vibrate with a fixed center point. If edge clamping is employed, the metal disc is made so that clamping space is provided on the outside rim and the center is free to vibrate.

The unit illustrated in Figures 5 and 6 utilizes rings of electrodes 30 on the active elements 29. The spacing between these electrode rings 30 should be larger than the thickness of the active elements 29. The embodiment illustrated shows electrodes on both surfaces of active elements 29 but this is not necessary to excitation of the elements in flexural mode; the electrodes may be mounted on one surface only or a single active element may be employed in lieu of the two active elements illustrated. In Figure 6, the active elements are bonded together or suitably affixed along the separation surface 31.

The curve 32 of Figure 7 illustrates the stress of a transducer, produced in accordance with our invention, which is edge-clamped and the curve 33 of Figure 8 illustrates the stress of a transducer, produced in accordance with our invention, which is edge-supported.

Figures 9 and 10 illustrate a further embodiment of our invention wherein ceramic element 34 is suitably bonded to electrode 35 and is backed by piezoelectrically inert metallic element 38 which is center-supported by center support 39. These elements 38 and 39 may be of the forms described in the description of the embodiment of Figure 4. Outer ring 36 serves to mass-load the transducer and may be of the same material and turned from the same piece as 38 and 39 or all three elements may be of different materials or the same material individually fabricated and suitably and appropriately attached or fastened together. The slots 37 serve to relieve the compression in outer ring 36 when the transducer vibrates flexurally.

Figures 11 and 12 illustrate a further embodiment of our invention wherein a ceramic-metal sandwich comprising ceramic element 40 which is suitably bonded to elec-

trode 41 and to metallic element 42, center-supported on center support 44 and with slots 43 around the periphery of the ceramic-metal sandwich 40—42. These slots serve to relieve the compressional effect in the transducer when the transducer is vibrated flexurally.

In embodiments of both Figures 9 and 11, the lower metallic elements 38 and 42 may be replaced by active ceramic elements such as is illustrated in Figure 3. When ceramic-ceramic sandwiches are employed, a second electrode must be employed on the lower face of the ceramic element which replaces either of the metallic elements 38 or 42. If 42 is metallic, as illustrated, it may be machined from the same piece as 44 or the two elements 42 and 44 may be of separate pieces and suitably affixed together.

Sufficient mass backing such as is shown in Figure 4 must also be employed in the embodiments of Figures 9 and 11 and the support structures 39 and 44 should be similar to but need not be identical to 24 of Figure 4.

While we have described our invention by means of specific examples and in specific embodiments, we do not wish to be limited thereto, for obvious modifications will occur to those skilled in the art without departing from the spirit of our invention or the scope of the subjoined claims.

Having thus described our invention, we claim:

1. An electro-mechanical transducer comprising, a substantially disc shaped member including at least one substantially disc shaped piezo-sensitive element provided with electrodes, a support secured at right angles to the center of the substantially disc shaped member and having transverse dimensions appreciably less than the planar dimensions of the substantially disc shaped member for supporting the center only of the substantially disc shaped member, a housing therefor, means within the housing connected to the support and having a mass greater than the mass of the support for substantially preventing longitudinal movement of the support so as to provide a substantially stationary center support for the substantially disc shaped member, and means for applying flexing forces directly to the substantially disc shaped member for flexing the same substantially uniformly about its substantially stationary center, as into and out of umbrella shape.

2. An electro-mechanical transducer for converting mechanical energy into an electrical signal comprising, a substantially disc shaped member including at least one substantially disc shaped piezo-sensitive element provided with electrodes, a support secured at right angles to the center of the substantially disc shaped member and having transverse dimensions appreciably less than the planar dimensions of the substantially disc shaped member for supporting the center only of the substantially disc shaped member, a housing therefor, means within the housing connected to the support and having a mass greater than the mass of the support for substantially preventing longitudinal movement of the support so as to provide a substantially stationary center support for the substantially disc shaped member, and means for applying mechanical flexing forces directly to the substantially disc shaped member for flexing the same substantially uniformly about its substantially stationary center, as into and out of umbrella shape, for producing corresponding electrical signals at said electrodes.

3. An electro-mechanical transducer for converting electrical energy to mechanical energy comprising, a substantially disc shaped member including at least one substantially disc shaped piezo-sensitive element provided with electrodes, a support secured at right angles to the center of the substantially disc shaped member and having transverse dimensions appreciably less than the planar dimensions of the substantially disc shaped member for supporting the center only of the substantially disc shaped member, a housing, means within the housing

5

connected to the support and having a mass greater than the mass of the support for substantially preventing longitudinal movement of the support so as to provide a substantially stationary center support for the substantially disc shaped member, and means for applying electrical energy to said electrodes for flexing the substantially disc shaped member substantially uniformly about its substantially stationary center, as into and out of umbrella shape, for producing corresponding mechanical energy.

4. An electro-mechanical transducer comprising, a substantially disc shaped member including at least one substantially disc shaped piezo-sensitive element provided with electrodes and having a peripheral mass, a support secured at right angles to the center of the substantially disc shaped member and having transverse dimensions appreciably less than the planar dimensions of the substantially disc shaped member for supporting the center only of the substantially disc shaped member, a housing therefor, means within the housing connected to the support and having a mass greater than the mass of the support for substantially preventing longitudinal move-

6

ment of the support so as to provide a substantially stationary center support for the substantially disc shaped member, and means for applying flexing forces directly to the substantially disc shaped member for flexing the same substantially uniformly about its substantially stationary center, as into and out of umbrella shape.

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