Aug. 21, 1951 A. L. W. WILLIAMS 2,565,158

HYDRAULIC ELECTROMECHANICAL TRANSDUCER

Filed Aug. 11, 1947

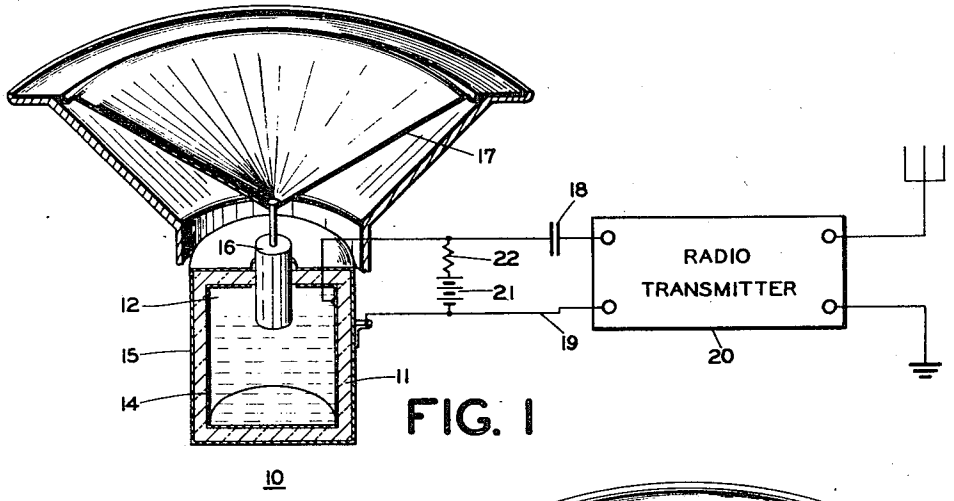


FIG. 1

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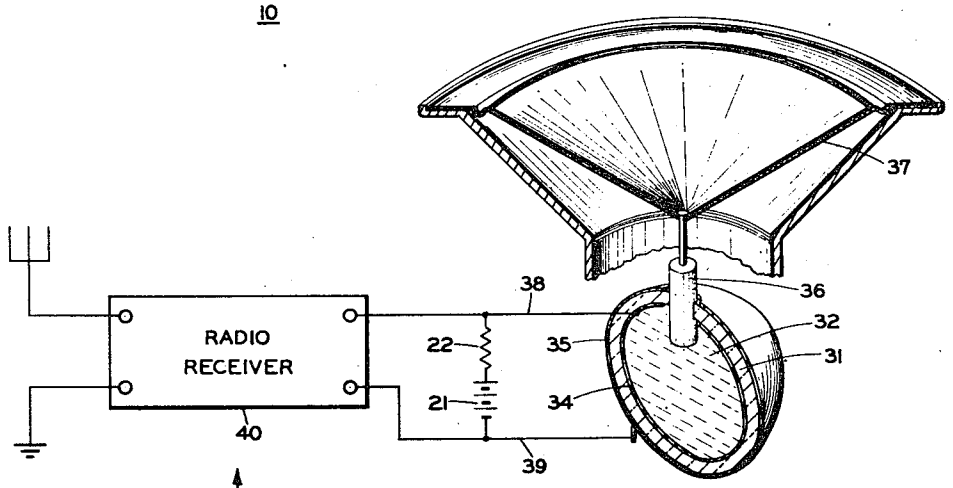


FIG. 3

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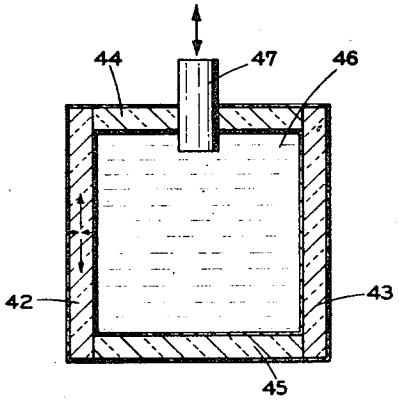


FIG. 4

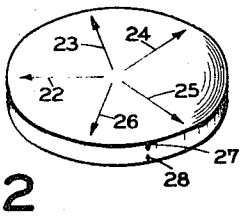


FIG. 2

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HYDRAULIC ELECTROMECHANICAL TRANSDUCER

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19 Claims. (Cl. 171—327)

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The subject matter of this invention relates generally to electro-mechanical devices for transducing between electrical and mechanical energy, or vice versa. The invention more particularly relates to transducers of the electro-mechanical type in which acoustical energy is utilized or produced by the transducer, and in a specific form the invention relates to transducers of the type under consideration in which are used levers of the hydraulic type. The acoustical or hydraulic energy which is transduced to or from electrical energy in the devices of the invention may be associated with displacements or vibrations of any suitable acoustical or hydraulic medium capable of transmitting elastic-wave energy or hydrostatic pressure. As used in the specification and in the accompanying claims, the term "acoustical" has the broad significance usual in the art and refers to ultrasonic as well as to audible sound phenomena.

Electro-mechanical devices for transducing between electrical and mechanical energy, or vice versa, are well known in the art. Thus transducers comprising an electro-mechanical actuating element of Rochelle salt have been widely used, both in microphones and in receivers. In transducers of the type under consideration, rather high forces but rather small movements are involved in the actuating element. Therefore, it has been the practice, in many such prior transducers, to provide a lever arrangement for converting the small movement involved in the actuating element to a large movement which is used, or for converting small forces which are available into large forces operating upon the actuating element of the transducer.

Also, actuating elements for electro-mechanical transducers which operate both in the transverse mode and in the longitudinal mode, with reference to the associated electrical field, are known in the art. Thus in the copending application for United States Letters Patent of Hans Jaffe, Serial No. 740,460, filed April 9, 1947, there is described and claimed a transducer element comprising a body of dielectric material which may, for example, be barium titanate. When properly polarized to respond in a linear manner to the fundamental component of an alternating field applied thereto, such a transducer element has associated with an applied electric field a motion in the direction of the electric field and a motion transverse to the electric field. The magnitudes of these effects are such as to render actuating elements of the type under

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consideration capable of many uses as the actuating elements of electro-mechanical transducers. However, in general, the way in which actuating elements of barium titanate, as well as substantially all other actuating elements of electro-mechanical transducers, have been used in commercial transducers has been such that only one of the above-mentioned modes inherent in the material has been utilized. It would be very desirable, therefore, to provide an electro-mechanical transducer in which each of the above-mentioned modes were utilized.

It is an object of the present invention to provide an improved electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical.

It is another object of the invention to provide an electro-mechanical transducer which is not subject to one or more of the above-mentioned disadvantages of prior such devices.

It is still another object of the invention to provide an electro-mechanical transducer in which more than one electro-mechanical transducing mode of the actuating element is utilized.

It is a further object of the invention to provide a new and improved electro-mechanical transducer utilizing the coupling between an electro-mechanically sensitive material and a contiguous acoustical or hydraulic medium for translating mechanical or mechano-acoustical energy.

In accordance with one feature of the invention, an electro-mechanical transducer comprises hollow means having an inside surface and an outside surface defining walls the major portions of which are of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields. The transducer also includes means for coupling only one of these surfaces effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between the afore-mentioned walls and the medium. Additionally the transducer comprises electrode means on each side of the wall portions of the polycrystalline dielectric material for translating the electrical currents associated with the transducing between acoustical energy in the medium and electrical energy in the wall portions.

In accordance with another feature of the invention, an electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprises

a container having at least one wall portion which is provided with means for translating electrical currents associated with an electric field across that wall portion and which has the property of transducing energy between the two above-mentioned types. The device also includes a fluid in the container and a mechanical-acoustical coupling extending through a wall of the container and acoustically coupled to the fluid; this coupling ordinarily takes the form of a piston acting upon the fluid in the container. Means also are provided, including the above-mentioned means for translating electrical currents and the piston, for applying energy of one of the above-mentioned types to the wall portion and for deriving energy of the other of the above-mentioned types therefrom.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

Referring now to the drawings, Fig. 1 illustrates an electro-mechanical transducer in accordance with the invention which is utilized as a microphone; Fig. 2 illustrates the electro-mechanical transducing properties of a wall portion of the transducer of Fig. 1; Fig. 3 illustrates a modified form of the transducer arrangement of the invention which is utilized to actuate a speaker; and Fig. 4 illustrates a modification of the invention in which the transducer actuating elements are electroded flat plates.

Referring now to the drawing, in Fig. 1 there is illuustrated an electro-mechanical device 10 for transducing between the types of energy which are classified as electrical and mechanical. As shown, the device is such as to transduce mechanical energy to electrical energy. The device comprises an inclosing means or container 11, which has at least one wall portion provided with means for translating or conducting electrical currents associated with an electric field across the wall portion, and which has the property of transducing mechanical energy to electrical energy. Specifically, the container 11 is in the form of a hollow cylinder and a half section of the container is illustrated. The aforesaid wall portion, and preferably the entire cylindrical container, is of a polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields. The container is preferably comprised of barium titanate including a substantial portion of strontium titanate in its composition. The container 11 includes therein a fluid 12 which may, for example, be oil. Extending through the upper wall portion of the container is a mechanical-acoustical coupling in the form of a piston 16 the bottom of which is acoustically coupled to the liquid medium 12. The piston 16 acts upon the fluid for translating mechanical energy to the wall portions of the container. The wall portions of the container are provided with an inside electrode 14 and an outside electrode 15 which are adjacent the inside surface and the outside surface respectively of the cylinder. The electrodes 14 and 15, adjacent these two surfaces on the opposite sides of the walls of the container 11, are separated or electrically insulated from each other at all points. A diaphragm 17, which is shown schematically, is utilized as the diaphragm of a microphone in order to apply mechanical energy to a piston 16 operating on the liquid in the

container. The electrical currents, which are developed by the actuating material of the transducer are applied, by a conductor 18 connected to electrode 14 and by a conductor 19 connected to electrode 15, to the input circuit of a radio transmitter 20.

In order to polarize the titanate material, in the manner fully described in the above-mentioned copending application of Hans Jaffe, a uni-directional source of potential 21 is coupled across electrodes 14, 15 through a resistor 22. However, in some cases, materials such as titanates have the property of retaining polarization after a uni-directional field has been applied thereto so that the material responds in the fundamental mode, that is, in an essentially linear manner, to an alternating field applied thereto and, in case material of this type is utilized, the source of voltage 21 may be omitted. A coupling condenser 18 is utilized to isolate the source 21 from the input circuit of radio transmitter 20. The container 11 is mounted upon some stationary object (not shown) which is fixed relative to the mounting member to which the rim of diaphragm 17 is affixed.

Considering now the operation of the embodiment of the invention described in Fig. 1, it will be seen that vibratory forces are applied to the piston 16 when the diaphragm 17 is actuated and that the piston 16 acts upon the fluid 12 in the container 11 to apply mechanical forces to the walls of the container. Thus the mechanical energy applied to the piston is translated through the bottom of the piston into the fluid 12, which translates the energy as acoustical energy to the walls of the container. The fluid 12 inside the container and the fluid-tight closure provided by the walls of the container and around the piston constitute means for coupling only the inside surface of the container effectively to a medium capable of transmitting hydrostatic pressure. Due to the transducing properties of the material 11 of the container, corresponding electrical signals are developed and applied to the input circuit of transmitter 20, the electrical currents associated with the transducing being translated by electrodes 14 and 15. In Fig. 2 is illustrated one portion of the container 11. This may, for example, comprise the bottom of the cylindrical container. If a portion of properly polarized barium titanate material of the type illustrated in Fig. 2 has an electrical potential of a certain polarity applied between the upper and lower faces thereof, the material tends to expand in all radial directions as illustrated by the arrows 22, 23, 24, 25, and 26 and tends to contract in its thickness direction as indicated by the arrows 27, 28. Referring to Figure 1, it will be seen that forces of the type represented by the arrows 22 to 28 inclusive are applied to the bottom section of the container 11 when the piston 16 is actuated in a downward direction. This means that the forces which are so applied to the walls of the container are accumulatively effective in causing corresponding electrical potentials to appear at electrode 14, 15 since the effect described above is visible. It is for this reason that the present invention is of particular utility when utilized with transducers including actuating elements of titanate material.

In Fig. 3 there is illustrated an embodiment of the invention in which the transducer is utilized to convert electrical energy into mechanical energy. Specifically, the transducer of Fig. 3 is used to cause the electrical output of a radio receiver

to drive a diaphragm acting as a loudspeaker. Circuit elements of Fig. 3 which are similar to those of Fig. 1 bear similar reference numerals in the 30-series. Thus the Fig. 3 arrangement comprises a container 30 which is in the form of a hollow sphere having wall portions 31 and filled with a liquid 32. An inside electrode 34 and an outside electrode 35 are provided for the container and a piston 36, operating through the wall of the sphere upon the liquid 32, is effective to apply mechanical movements of the wall portions of the sphere 31 to the diaphragm 37. Conductors 38 and 39 are utilized to connect the inside electrode 34 and the outside electrode 35 to the output terminals of the radio receiver 40. As in the case of Figure 1, the battery 21 and resistor 22 may be utilized in cases where it is necessary to polarize the material of the sphere 31 in order to provide a linear response in the manner explained in full in the above-identified Jaffe application.

The operation of the element of Fig. 3 will be readily apparent from the description which has been given above with reference to the operation of the Fig. 1 arrangement. Specifically, however, radio signals which are received by the receiver 40 are detected in order to obtain the audio components of the received signals which are applied, through conductors 38 and 39, to the electrodes 34 and 35. These varying audio signals cause variations in the pressure which the wall portions of sphere 31 apply to the piston 36 through the liquid 32 which fills the entire container. These pressure variations upon piston 36 are applied through the drive member to the diaphragm 37 where they are converted into audible sounds.

In Fig. 4 is illustrated an embodiment of the invention in which the liquid-filled container is formed by a construction consisting of a number of electroded slabs of material effective to transduce mechanical energy to electrical energy, or vice versa. Thus the container may be constructed of slabs 42, 43, 44, and 45 enclosing the left-hand and right-hand sides, the top and the bottom of the container as illustrated, and additional slab 46 and another slab (not shown) may be utilized to enclose the back and front end portions, respectively. The piston 47, represented schematically by the reference numeral 47, operates through the wall portion of the container formed by the slab 44. The operation of the embodiment of Fig. 4 as the actuating element of a microphone will be readily understood with the description which is given above with reference to Fig. 1 and its operation as an actuating element of a speaker will be readily understood from the description which has been given above with reference to the Fig. 3 embodiment of the invention.

The actuating element which has been described with reference to each of the arrangements of Figs. 1, 3 and 4 is such that substantially all wall portions of the container are electroded and are thereby effective as transducer portions of the element. It will be understood, however, that it is not necessary that all the wall portions of the container be electroded inasmuch as a useful output may be derived from the actuating element from any electroded portion of the container. In general, however, it is advantageous to electrode all available wall portions for the reason that the transducing capabilities of the device are thereby increased.

While there have been described what are at present considered to be the preferred embodiments of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising; a container having at least one wall portion provided with means for translating electrical currents associated with an electric field across said wall portion and which has the property of transducing energy between the two above-mentioned types; a fluid in said container; a piston acting upon said fluid in said container; and means, including said means for translating said electrical currents and said piston, for applying energy of one of said types to said wall portion and for deriving energy of the other of said types therefrom.

2. An electro-mechanical device for transducing mechanical energy to electrical energy comprising; a container having at least one wall portion provided with means for translating electrical currents associated with an electric field across said wall portion and which has the property of transducing mechanical energy to electrical energy; a fluid in said container; a piston acting on said fluid in said container for applying mechanical energy to said wall portion; and means, including said means for translating said electrical currents and said piston, for applying mechanical energy to said wall portion and for deriving electrical energy therefrom.

3. An electro-mechanical device for transducing electrical energy to mechanical energy comprising; a container having at least one wall portion provided with a means for applying an electric field thereto and which has the property of transducing electrical energy to mechancal energy; a fluid in said container; a piston acting upon said fluid in said container for receiving mechanical energy from said wall portion; and means, including said means for applying an electric field to said wall portion and said piston, for applying electrical energy to said wall portion and for receiving mechanical energy therefrom.

4. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising; a cylinder having wall portions provided with means for translating electrical currents associated with an electric field across said wall portions, which wall portions have the property of transducing between the two above-mentioned types; a fluid in said cylinder; a piston in said cylinder acting upon said fluid and means, including said means for translating said electrical currents and said piston, for applying energy of one of said types to the wall portions of said cylinder and for deriving energy of the other of said types therefrom.

5. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising; a hollow sphere provided with means for translating electrical currents associated with an electric field across the wall thereof, which wall has the property of transducing energy between the two above-mentioned types; a fluid in said sphere; and a piston in a wall portion of said sphere and acting upon said fluid and means, including said

means for translating said electrical currents and said piston, for applying energy of one of said types to the wall of said sphere and for receiving energy of the other of said types therefrom.

6. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising; a container having at least one wall portion of barium titanate material provided with means for translating electrical currents associated with an electric field across said wall portion and which has the property of transducing energy between the two above-mentioned types; a fluid in said container; a piston acting upon said fluid and means, including said means for translating said electrical currents and said piston, for applying energy of one of said types to said wall portion and for deriving energy of the other of said types therefrom.

7. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising; a container having at least one wall portion of barium titanate which includes a substantial amount of strontium titanate and provided with means for translating electrical currents associated with an electric field across said wall portion, said wall portion having the property of transducing energy between the two above-mentioned types; a fluid in said container; a piston acting upon said fluid and means, including said means for translating said electrical currents and said piston, for applying energy of one of said types to said wall portion and for deriving energy of the other of said types therefrom.

8. An electro-mechanical transducer comprising: hollow means having an inside surface and an outside surface and substantially all wall portions of which are of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields, means for coupling only one of said inside and outside surfaces effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said one surface and said medium, and electrode means on each side of substantially all of said wall portions of dielectric material for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portions.

9. An electro-mechanical transducer comprising: inclosing means of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields and having a generaly cylindrical inside surface and a generally cylindrical outside surface substantially concentric with said inside surface, means for coupling effectively only one of said generally cylindrical inside and outside surfaces of said inclosing means to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said one surface and said medium, and electrode means on each of said inside and outside surfaces for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said dielectric material.

10. An electro-mechanical transducer comprising: inclosing means having an inside surface and an outside surface and having at least one wall portion of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields, means for coupling only said inside surface effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said inside surface and said medium, and electrode means on each side of said wall portion for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portion.

11. An electro-mechanical transducer comprising: inclosing means having an inside surface and an outside surface and having at least one wall portion of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields, means for coupling only said inside surface effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said inside surface and said medium, electrode means on each side of said wall portion for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portion, and a mechanical-acoustical coupling extending through a wall portion of said inclosing means and acoustically coupled to said medium.

12. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising: inclosing means having an inside surface and an outside surface and having at least one wall portion of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields; means for coupling only said inside surface effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said inside surface and said medium; electrode means on each side of said wall portion for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portion; a mechanical-acoustical coupling extending through a wall portion of said inclosing means and acoustically coupled to said medium; and means, including said electrode means and said mechanical-acoustical coupling, for applying energy of one of said types to said wall portion and for deriving energy of the other of said types therefrom.

13. An electro-mechanical transducer comprising: inclosing means having an inside surface and an outside surface and substantially all wall portions of which are of material having the property of transducing between electrical and mechanical energy, means for coupling only said inside surface effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said inside surface and said medium, electrode means on each side of substantially all of said wall portions for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portion, and a mechanical-acoustical coupling extending through a wall portion of said inclosing means and acoustically coupled to said medium.

14. An electro-mechanical transducer comprising: a container having an inside surface and an outside surface and having at least one wall portion comprising a piezoelectric material which has the property of transducing between electrical and mechanical energy, a fluid in said con-

tainer and coupled effectively to only said inside surface thereof for translation of acoustical energy between said inside surface and said fluid, electrodes on each side of said wall portion for translating the electrical currents associated with the transducing between acoustical energy in said fluid and electrical energy in said wall portion, a mechanical-acoustical coupling extending through a wall portion of said container and acoustically coupled to said fluid, and means connected to said mechanical-acoustical coupling externally of said container and effectively uncoupled from said outside surface thereof for translating the mechanical energy associated with motion of said mechanical-acoustical coupling.

15. An electro-mechanical device for transducing between the types of energy which are classified as electrical and mechanical comprising: a container having an inside surface and an outside surface and having at least one wall portion which is provided with electrodes and which has the property of transducing energy between the two above-mentioned types; a fluid in said container for acoustical contact with only said inside surface thereof; a piston acting upon said fluid; and means for applying energy of one of said types to said wall portion and for deriving energy of the other of said types therefrom, said last-mentioned means including said electrodes, said piston, and energy-translating means connected to said piston externally of said container and effectively uncoupled from said outside surface thereof for translating the mechanical energy associated with motion of said piston.

16. An electro-mechanical transducer comprising: hollow means having an inside surface and an outside surface defining walls the major portions of which are of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields, means for coupling only one of said surfaces effectively to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said walls and said medium, and electrode means on each side of said wall portions of said polycrystalline dielectric material for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portions.

17. An electro-mechanical transducer comprising: a hollow structure having an inside surface and an outside surface defining walls the major portions of which are of titanate-type polycrystalline dielectric material electrically polarized in directions differing over said wall portions and everywhere substantially normal to one of said surfaces, means for coupling only said one of said surfaces effectively to a medium capable of transmitting acoustical energy for translation of such energy between said one surface and said medium, and electrode means on each side of said wall portions of said polycrystalline dielectric material for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said wall portions.

18. An electro-mechanical transducer comprising: inclosing means having an inside surface and an outside surface defining walls the major portions of which are of polycrystalline dielectric material of the type capable of developing substantial mechanical strains when subjected to electrostatic fields, means for coupling effectively only one of said two surfaces of said inclosing means to a medium capable of transmitting hydrostatic pressure for translation of acoustical energy between said walls and said medium, and electrode means on said wall portions for translating the electrical currents associated with the transducing between acoustical energy in said medium and electrical energy in said dielectric material.

19. An electro-mechanical transducer comprising: inclosing means having an inside surface and an outside surface defining walls in which, in the event of an application of hydrostatic pressure against only one of said surfaces, such pressure is transformed into stresses in peripheral directions generally parallel to said surfaces, and having at least one substantial portion of said walls composed of polycrystalline dielectric material of the type capable of developing substantial mechanical strains in said peripheral directions when subjected to electrostatic fields; means for coupling effectively only one of said two surfaces to a medium capable of transmitting hydrostatic pressure; and electrode means on said wall portion for translating the electrical currents associated with transducing between mechanical energy in said medium and electrical energy in said wall portion.

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