

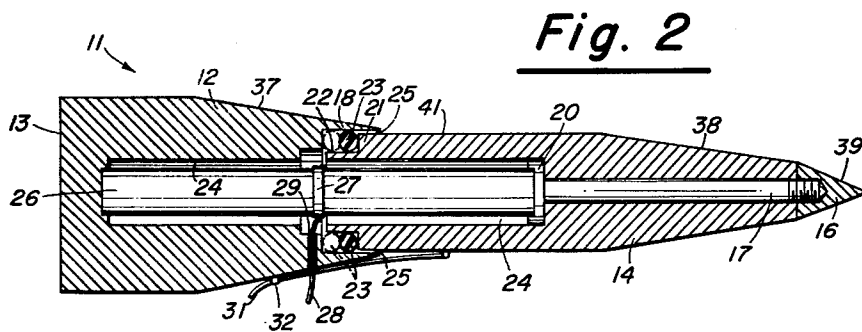
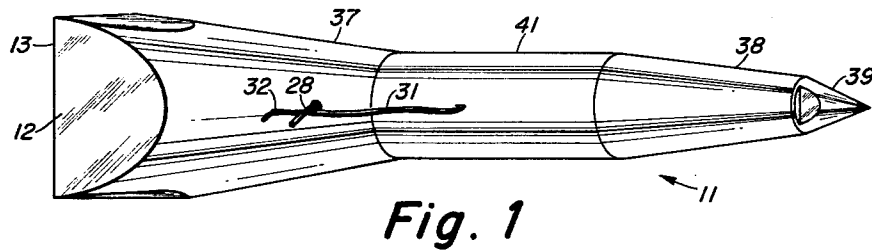
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ELECTROACOUSTIC TRANSDUCER

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ELECTROACOUSTIC TRANSDUCER

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to an electroacoustic transducer employing an electromechanical converter and more particularly to one which is characterized by low-frequency, broad-bandwidth operation, with directivity discrimination, and which is a complete watertight unit capable of use at deep-submergence levels of the medium.

There has been a pressing requirement for a simple, light, compact transducer capable of satisfactorily meeting the high static pressures encountered at deep-submergence levels of the acoustic medium. Previous deep-submergent transducers have required the use of pressure compensators to meet these high pressures. The presence of such prior-art compensating equipment adds to the weight and volume of such transducers and increases the complexity of their operation.

Concurrently there has been a continuing need for increasing the operating range of transducers.

The present invention produces a transducer capable of deep-submergence containing no acoustically compliant materials and which accordingly avoids the need for pressure compensating equipment. The transducer is a completely watertight unit comprising two end masses, each of rigid material, interconnected by an electromechanical converter. The end masses, in part, extend toward each other, one of them telescopically overlapping the other at a watertight connection between their ends to form an envelope for the converter, the third main element in the transducer. The nature of the connection at the area of "overlap-underlap" of the end masses is such that the converter is protected from the acoustic medium, such as water, for example, but the end masses are free to vibrate with respect to each other when driven by the converter which is actuated by an external power lead brought through a watertight opening in the envelope. The resulting structure is a transducer able to withstand deep-submergence pressures without the use of pressure compensators.

The transducer of the present invention is further characterized by its ability to be driven at a low frequency and over a broad bandwidth. The low frequency capability enables it to attain long ranges for it is axiomatic that the lower the frequency at which a transducer can be run the greater will be its range. It has been found that a certain shaping of the end masses will have a pronounced effect on the frequency and bandwidth at which the transducer can be run. By using end masses which are bored or turned back upon themselves, as seen herein (see FIG. 2 of the drawing), it has been found that the transducer can be run at a low frequency and over a broad bandwidth of frequencies yielding, among other advantages, substantially improved range.

Another feature of the present invention is the manner in which it attains directivity. The vibration of the end masses in anti-phase relative movement, i.e., each end mass vibrates 180° out of phase with respect to the vibration of the other end mass, produces in conjunction with the external surface configuration of said masses a resultant of substantially no propagation of energy from one end of the transducer and at the other end a resultant

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alternation of compression and rarefaction of the medium. The result is to provide a transducer with directivity.

A further feature of the invention making another contribution to the directivity of the transducer is the use of a flat propagating face in the direction of propagation at the propagating end and a conic surface at the non-propagating end.

An object of the present invention is the provision of a deep-submergent electroacoustic transducer which does not require the use of pressure compensators.

An additional object is the provision of a light-weight, compact electroacoustic transducer.

Another object is to provide an electroacoustic transducer which can be run at low frequency and can be operated efficiently over a broad range of frequencies.

A further object is to provide an electroacoustic transducer having directional characteristic.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing which illustrates a preferred embodiment of the invention and in which like reference characters designate like or corresponding parts throughout the views and wherein:

FIG. 1 is a perspective view of the preferred embodiment of the invention; and

FIG. 2, a sectional view taken along the longitudinal axis of FIG. 1.

In general appearance the transducer 11 looks not unlike a missile. The one end of transducer 11 is a substantially truncated-conical head 12, of aluminum or like material, which in the embodiment shown has its base squared off so as to form a flat square outer face 13. Face 13 may be left circular or assume other configuration. The other end of the transducer is a tail 14, of lead or like metal, whose outer surface is cylindrical in part and truncatedly-conical at its outer portion. The outer portion of tail 14 is capped by a conical iron cap 16, threadedly fitted onto an iron bolt 17 which passes through a bore in the lead tail. The outer mating surfaces of cap and tail present a continuous surface. Head 12 telescopically overlaps tail 14 with portion 18 of the head overlapping portion 21 of the tail and spaced therefrom by a slight clearance.

Head 12 and tail 14 join each other at a watertight connection that prevents head and tail from frictionally binding together at the joining location with the result that a watertight envelope is formed and that head 12 and tail 14 are able to freely vibrate with respect to each other. To accomplish these purposes the parts are fitted together to receive an O-ring 23 of rubber, or other suitable material, which encompasses the annular portion 22 of tail 14 and radially extends to portion 18 of head 12. This O-ring 23 centers and holds head 12 and tail 14 apart so that they will not rub on each other and at the same time forms a barrier to prevent entry of water, or some like acoustic medium, into cavity 24 which extends into both head and tail sections. Thus the O-ring serves as a spacing member and as a seal to prevent water entry into the transducer. The minimal friction offered to vibratory movement of head and tail by O-ring 23 is negligible and can be considered as having no effect on the transducer action.

Located in cavity 24 is an electromechanical converter 26 which is bonded at its left end to head 12 and at its right end to the head 20 of bolt 17 which, in turn, is maintained in intimate contact with tail 14. This converter 26 in the preferred embodiment is a piezoelectric ceramic, but can equally well be a piezoelectric crystal or any other electromechanical element. Clamped around

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converter 26 at its midpoint is a band 27, of silver or like material, to which is led an electrical driver lead 28 which enters the transducer through a watertight hole 29 in head 12. Transducer head 12 and tail 14 are grounded, ground lead 31 being carried from tail 14 to conductive ring 32 on head 12 and from there leaves the transducer to go to "ground." The longitudinally-outmost ends of converter 26 are accordingly at "zero" potential and being symmetrically polarized from its longitudinally located midportion, to which driver lead 28 is connected by means of annular band 27, the converter 26 will alternately elongate and compress symmetrically about this medial section in response to a varying signal carried by driver lead 28 to vibrate, simultaneously, head 12 and tail 14 in opposite directions with respect to the midportion of converter 26. At optimum operation the entire system is driven at resonance.

This transducer is equally capable of acting as a pick-up device or as a radiator, lead 28 alternatively being led to a receiver or a transmitter.

When the static pressures of a medium to be met are extremely high the sealing action of O-ring 23 may be reinforced by filling cavity 24 with a suitable oil. As the transducer encounters an increase in such medium pressures such an increase acting upon the O-ring 23 through annular opening 25 will exert a thrust on the O-ring causing it to shift from right to left, as seen in FIG. 2, in its annular groove. As it does so the O-ring exerts a piston-like action upon the oil in cavity 24 causing it to be compressed to a certain degree. The leftward shift of O-ring 23 will continue until it reaches an equilibrium position where the thrust on the O-ring by the increased oil pressure balances the thrust on the O-ring by the medium pressure. When the medium pressure decreases the equilibrium position of the O-ring will shift to the right. The dotted-line showing of O-ring 23 indicates its position when the transducer is subjected to maximum pressures. It will be noted that the O-ring groove is made wide so as to provide for this position-shifting of O-ring 23 as the pressure change. The cross section of oil exposed to dynamic loading is very small compared to the rest of the surface area making it possible to dismiss the oil loading on the system.

The subject transducer fills the requirement for a lightweight, low-frequency, broad-band, deep-submergent, uni-directional transducer.

For the purpose of understanding the transducer's directional characteristic operation consider head 12 as mass M1 and the combination of tail 14 bolt 17 and cap 16 as mass M2. With converter 26 interconnecting masses M1 and M2 the transducer is symmetrically driven. The masses M1 and M2 optimally are driven in anti-phase movement with respect to each other but may also be driven in out-of-phase movements which are not exactly 180 degrees apart. As the converter contracts the head or mass M1 is moved to the right and water along the tapered surface 37 is placed under compression and water at the face 13 is placed under rarefaction. At the same time the tail-section-cap-and-bolt, or mass M2, moves to the left and the water along the tapered surface 38-39 is placed under tension or rarefaction. It will be noted that masses M1 and M2 are coaxially disposed with respect to one another. When the frequency is low and these two surfaces, 37 and 38-39, are within a fraction of a wave length of each other (measured along the common axis of said coaxially disposed masses M1 and M2) the tendency is for these opposing pressure energies along surface 37 and surface 38-39 to cancel each other, with a resultant rarefaction at the face 13 of head 12. When converter 26 expands and the masses M1 and M2 move in directions reverse to those noted above, at those places where there was rarefaction there is now compression and vice versa. Again the opposite effects along surface 37 on the one hand and along surface 38-39 on the other tend to cancel each

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other out with a net resultant of compression at the face 13 of head 12. In terms of net resultants then there is an alternation of compression and rarefaction at the face 13 of head 12. It will be noted that there is no compression or rarefaction along the cylindrical surface 41 of the tail section 14 where there is substantially laminar flow with no resultant energy propagation into the medium. The net result of outer surface configuration and anti-phase movement of the masses M1 and M2 is a transducer with directional characteristic.

When the transducers are placed in an array the directivity discrimination is heightened. The heads 12, or masses M1, present a solid front of radiating surface to the water and form a good acoustic match. The tails-caps-and-bolts, or masses M2, present a multitude of closely-knit points and in fact resemble an anechoic surface. Such a surface is a poor radiator and forms a poor acoustic match.

As noted previously it has been found that by using bored or turned-back-on-themselves masses as shown herein for M1 and M2 the transducer can be operated at a radically lower frequency and over a broad bandwidth. With this particular bored shaping, as portrayed by the FIG. 2 showing, the masses M1 and M2 act as if they were many times their actual weight as they relate to the frequency and mechanical Q of the transducer system. Another way of saying this is to state that with the particular bored/hollowed-out shaping used (as shown by FIG. 2) each of the masses M1 and M2 has an ("apparent") mass which is manyfold its ("actual") mass. It will be noted from FIG. 2 that each end mass has a substantial portion of its total mass extending alongside converter 26 (more or less in a direction parallel to the longitudinal axis of the converter) and that these backwardly-extending portions running alongside the converter 26 are radially spaced from the converter (an air gap being formed therebetween). It has been found that these backwardly-extending portions of the end masses, though made of rigid materials (here lead and aluminum, respectively), act as if they were what is referred to in this art as "compliant masses." If it is deduced that it is this "compliant mass" action of the end masses which causes them to present, for the purpose at hand, ("apparent") masses which are manyfold their ("actual") masses and enables the unexpected low-frequency (and thus high-range) operation available with the transducer. As a word of caution it should be noted that the radial spacing between these backwardly-extending portions of the masses M1 and M2 and the electromechanical converter must be preserved in any embodiment of the transducer, for, absent such spacing, these backwardly-extending portions of masses M1 and M2 obviously could not act as "compliant masses." Note from FIG. 2 that the backwardly-extending portion of head 12, as shown therein, represents more than half the total mass of this head 12. The result is a transducer capable of running at low frequency and over a broad bandwidth. Because the actual masses of M1 and M2 are small compared to the way they act the transducer also is deceptively light and compact.

The bored masses M1 and M2 in another way add to the compactness of the transducer. When the two masses M1 and M2 are driven by the converter 26 the maximum amplitude available to masses M1 and M2 is dependent upon the tensile strength and length of the converter. Accordingly, within the limit set by its tensile strength, it is advantageous to have converter 26 as long as possible. The boring of masses M1 and M2 allows converter 26 to fit into the end masses M1 and M2 with a shortening of the overall dimensions of the transducer.

Through use of the enveloping construction with its O-ring joinder described above there is produced a transducer having a closed, watertight body capable of deep submergence without the need for pressure compensating equipment.

It should be understood, of course, that the foregoing

disclosure relates to only a preferred embodiment of the invention and that numerous modifications or alterations may be made therein without departing from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. An electroacoustic transducer, adapted to be submerged in sound-propagating liquid media, comprising a pair of bored, coaxially-disposed radiator masses, adapted to be acoustically exposed to said sound-propagating media, the greater portion of said respective radiator masses being in juxtaposition with respect to each other and one of said radiator masses telescopically overlapping the other of said radiator masses at their mutually-nearest respective ends so that the combined bores of said radiator masses form an envelope, the overlap of said one radiator mass being radially spaced, with respect to the common axis of said coaxially-disposed radiator masses, from the underlap of said other radiator mass; electrically-actuable electromechanical converter means disposed within said envelope and vibratile in longitudinal mode for driving said respective radiator masses in anti-phase vibratory relative movement with respect to each other, each of said radiator masses having a substantial portion of its total mass extending alongside said electromechanical converter means in a direction substantially parallel to the longitudinal axis of said converter means and spaced from said converter means, said electromechanical converter means being bonded, at its respective longitudinally-outermost ends and solely along a path substantially normal to the longitudinal axis of said electromechanical converter means, to each of said radiator masses; electrically-conductive means, connected to said electromechanical converter means, for conveying an actuating electrical signal to said electromechanical converter means; and means disposed between said radiator masses at the area of overlap for concurrently presenting a seal to prevent external fluid media from entering said envelope and maintaining the radial spacing between said radiator masses in the area of overlap so that said radiator masses may freely move back and forth with respect to each other in a substantially frictionless manner.

2. An electroacoustic transducer, adapted to be submerged in sound-propagating liquid media, comprising a pair of hollowed-out, coaxially-disposed radiator masses, adapted to be acoustically exposed to said sound-propagating media, the greater portion of said respective radiator masses being in juxtaposition with respect to each other and one of said radiator masses telescopically overlapping the other of said radiator masses at their mutually-nearest respective ends so that the combined hollows of said radiator masses form an envelope, the overlap of said one radiator mass being radially spaced, with respect to the common axis of said coaxially-disposed radiator masses, from the overlap of said other radiator mass; electrically-actuable electromechanical converter means disposed within said envelope and vibratile in longitudinal mode for driving said respective radiator masses in anti-phase vibratory relative movement with respect to each other, each of said radiator masses having a substantial portion of its total mass extending alongside said electromechanical converter means in a direction substantially parallel to the longitudinal axis of said converter means and radially spaced from said converter means, said electromechanical converter means being bonded, at its respective longitudinally-outermost ends and solely along a path substantially normal to the longitudinal axis of said electromechanical converter means, to each of said radiator masses; electrically-conductive means, connected to said electromechanical converter means, for conveying an actuating electrical signal to said electromechanical converter means; and means disposed between said radiator masses at the area of overlap for concurrently presenting a seal to prevent external fluid media from entering said envelope and maintaining the radial spacing

between said radiator masses in the area of overlap so that said radiator masses may freely move back and forth with respect to each other in a substantially frictionless manner.

3. The transducer of claim 2 wherein one of said radiator masses constitutes a head and the other of said radiator masses constitutes a tail; said head having at its longitudinally-outermost end a flat, planar external surface normal to the longitudinal axis of said electromechanical converter means, and therefore normal to the direction of vibration of said head, and having for the balance of its external surface a generally tapered surface; said tail having at its outer end a generally similarly-tapered external surface and at its inner end a cylindrical external surface whose axis lies in the direction of the longitudinal axis of said converter means and therefore in the direction of vibration of said tail; the respective tapered surfaces of said head and said tail being within a fraction of a wavelength of each other for any given operating frequency of said transducer; the hereinbefore defined external shaping of said head and said tail in conjunction with the hereinbefore defined spacing between the respective tapered external surfaces of said head and said tail and the anti-phase vibratory relative movement of said head and said tail producing, in a given medium in which said transducer is submerged, a net resultant of rarefaction of the medium solely in the region of the planar surface of said head as said head and said tail are vibrated toward one another and a net resultant of compression of the medium solely in the region of the planar surface of said head as said head and said tail are vibrated away from one another.

4. The transducer of claim 2 wherein said radiator masses have external surfaces so shaped that one of said radiator masses presents at its longitudinally-outermost extremity a flat planar surface, normal to the longitudinal axis of said electromechanical converter means and therefore normal to the direction of vibration of said radiator masses, and is substantially truncatedly conical in the balance of its outer surface, the cone base being coincident with said flat planar surface and that the other of said radiator masses at its inner portion has a cylindrical external surface and at its outer portion has an external surface which is substantially conical with the apex of this outer portion conical surface located at the longitudinally-outermost extremity of said other of said radiator masses, the respective conically-shaped external surfaces of said radiator masses having substantially the same slope and being within a fraction of a wavelength of each other for any given operating frequency of said transducer.

5. An electroacoustic transducer, adapted to be submerged in a sound propagating fluid medium, comprising a pair of hollowed-out coaxially disposed radiator masses, adapted to be acoustically exposed to said sound-propagating medium, the greater portion of said respective radiator masses being in juxtaposition with respect to each other and one of said radiator masses telescopically overlapping the other of said radiator masses at their mutually-nearest respective ends so that the combined hollows of said radiator masses form an envelope, the overlap of said one radiator mass being radially spaced, with respect to the common axis of said coaxially-disposed radiator masses, from the underlap of said other radiator mass; electrically-actuable electromechanical converter means disposed within said envelope and vibratile in longitudinal mode for driving said respective radiator masses in anti-phase vibratory relative movement with respect to each other, said electromechanical converter means being bonded at its respective longitudinally-outermost ends to each of said masses; electrically-conductive means, connected to said electromechanical converter means for conveying an actuating electrical signal to said electromechanical converter means; and means disposed between said radiator masses at the areas of overlap for concurrently presenting a seal to prevent the external fluid

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medium from entering said envelope and maintaining the radial spacing between said radiator masses in the area of overlap so that said radiator masses may freely move back and forth with respect to each other in a substantially frictionless manner; one of said radiator masses constituting a head and the other of said masses constituting a tail; said head presenting at its longitudinally-outermost extremity a flat planar surface, normal to the longitudinal axis of said electromechanical converter means and therefore normal to the direction of vibration of said radiator masses and being substantially conical in the balance of its outer surface, the cone base being coincident with said flat planar surface and said tail at its inner portion having a cylindrical external surface and at its outer portion having a substantially conical external surface with the apex of this outer portion conical surface located at the longitudinally-outermost extremity of said

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tail, the respective conically-shaped external surfaces of said head and said tail having substantially the same general slope and being within a fraction of a wavelength of each other, as measured along the common axis of said respective radiator masses, for any given operating frequency of said transducer.

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