

Nov. 12, 1963

H. B. MILLER
FOLDED TRANSDUCER

3,110,825

Filed Sept. 2, 1959

2 Sheets-Sheet 1

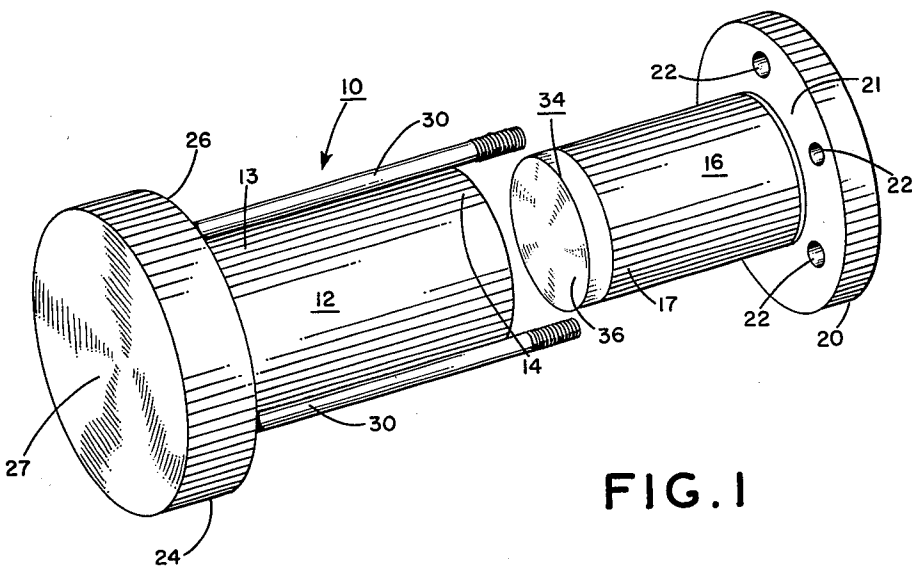


FIG. 1

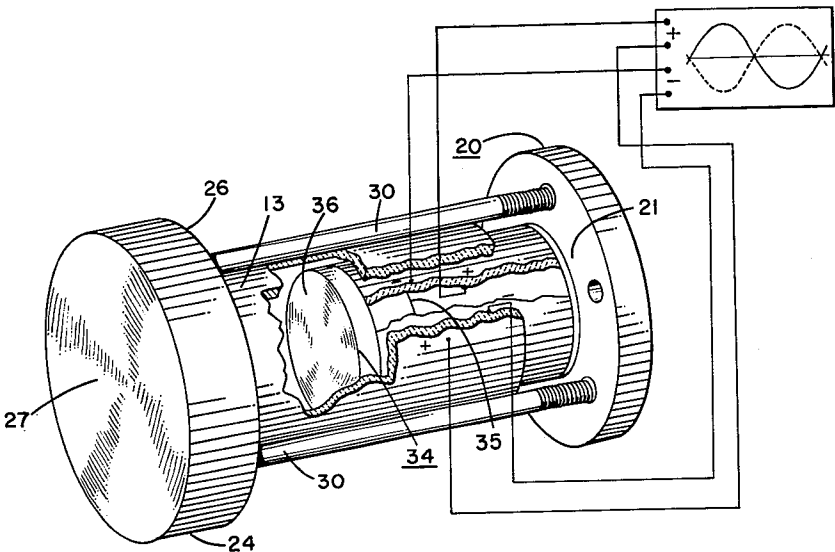


FIG. 2

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2 Sheets-Sheet 2

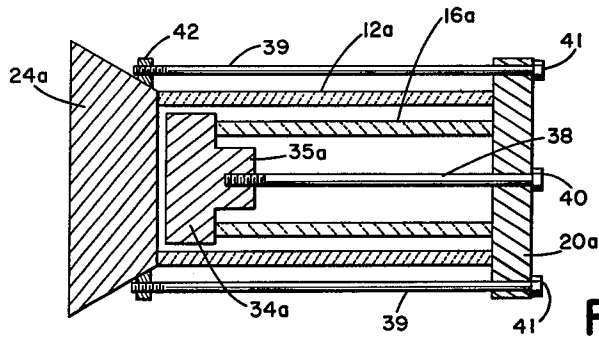


FIG. 3

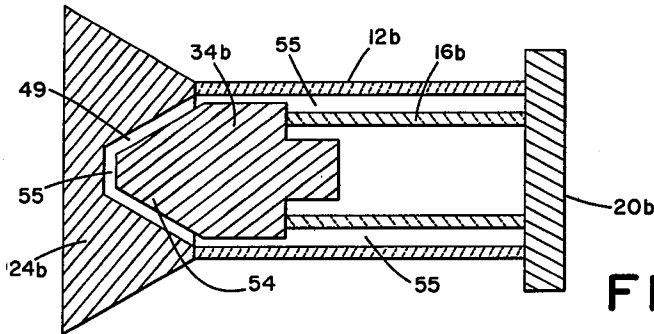


FIG. 4

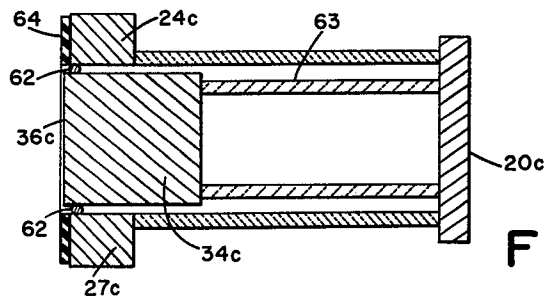


FIG. 5

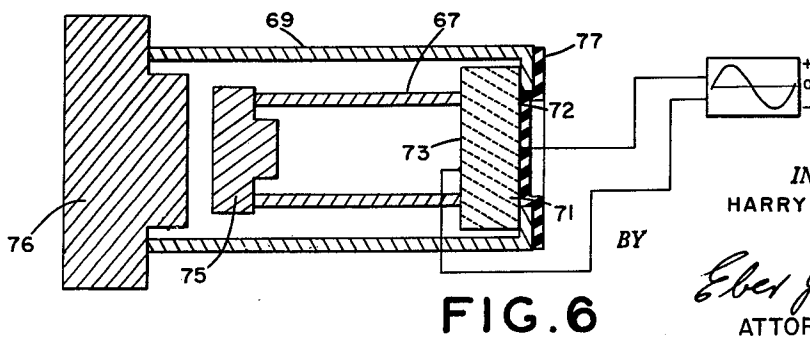


FIG. 6

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1

3,110,825

FOLDED TRANSDUCER

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19 Claims. (Cl. 310—8.7)

This invention relates to a transducer for operation in a medium such as water and more particularly concerns a half-wave electromechanical transducer structurally folded, thereby in size approximating substantially a quarter-wave length transducer element.

In the field of underwater signaling or detecting mechanical vibrations, transducers, including those comprising hollow cylinders with electromechanical transducing properties have been widely used. Such electromechanically responsive driver is fixedly disposed between tritic crystals, natural or synthetic. The latter may be formed by such chemical combinations as ammonium dihydrogen phosphate, or barium titanate, often used with a binder to form a ceramic or having an additive such as lead titanate to improve temperature stability, or other suitable materials.

The present invention is not concerned with any particular composition of such natural or artificial piezoelectric and electromechanically responsive elements. But rather the invention is directed towards a compact driver structure.

In the so-called sandwich type of construction for transducers, a single half-wave length type of electromechanically responsive drive is fixedly disposed between two generally rigid blocks which act as fronting and backing blocks or act as a means to translate the elongation and contraction of the driver in the longitudinal mode to the respective block into predetermined proportional radiation, which in turn is exposed to the medium in which the transducing is to take effect. Most commonly in practice, only the fronting block is required to radiate and hence the opposite block must be prepared by means of acoustical insulation, or the like, to act as a non-radiating or backing block.

In the type of arrangement referred to, a driver, e.g. a tubular driver, is generally comprised of a continuous half-wave length type of tube. The word "driver" as used herein includes any electromechanically responsive element, whether to be used for "driving" or receiving sound waves. Similar satisfactory operating results are achieved when a double quarter-wave tubular driver is used, e.g., two quarter-wave tubes bonded to opposite sides of a common metal disc, inasmuch as the single element or combined one sets up a velocity node near the longitudinal center of the vibrating system. This fact is well known in the prior art. Similarly, in accordance with known procedures the nodal point may be moved from the center by changing certain characteristics of the electromechanical responsive elements.

It becomes very desirable in many applications to eliminate the effect of one back radiating block altogether and, of particular importance in a great many instances, to reduce the longitudinal dimension of the driver itself. The latter requirement is of particular importance when the transducer is part of underwater sound equipment. In such and similar applications space is a scarce commodity.

Briefly stated, one preferred embodiment of the present invention provides a transducer incorporating such desirable and advantageous features by providing a first and second quarter-wave driver having electromechanically responsive qualities adapted for longitudinal vibration along a given axis in response to the application thereto. These drivers are substantially concentrically disposed

2

with respect to each other forming in combination a double quarter-wave driver element having a total axial length less than a single half-wave driver, and these drivers are adapted to operate substantially 180° out of phase with respect to each other thereby causing at one mutual and co-extending end of the driver a velocity node.

Similarly, the invention may be constructed with the parts being arranged in reversed order. In such an alternative construction the tubular elements are electromechanically inactive and a disk or common mounting member is coupled to the tubes and constitutes the active element.

The invention is not restricted to any particular mode of application and the language herein must be construed to apply similarly to devices of a class such as hydrophones, wherein transducing takes place from mechanical to electrical energy, or projectors or loudspeakers wherein energy is transduced in reversed order, or reversible transducers, wherein the mode of transducing may be changed from a projector to a hydrophone type of operation or vice versa.

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

FIGURE 1 of the drawings illustrates a transducer in accordance with the invention showing a partially exploded view thereof;

FIGURE 2 is similar to FIGURE 1 showing the invention in assembled condition with parts partly broken away;

FIGURE 3 is a longitudinal sectional view of the invention in modified form;

FIGURE 4 is a longitudinal sectional view of the invention showing part of the internal structure protruding into the front radiating member;

FIGURE 5 is a longitudinal sectional view of the invention showing the previously internal structure member protruding through the front radiating member, the latter being shown now as having acoustical insulation, and constituting a mere fronting block;

FIGURE 6 is a longitudinal sectional view illustrating an arrangement in accordance with the principle of the invention, but in substantially reversed order. The common mounting member being the active member and the tubular members herein being inactive.

FIGURES 1 and 2 of the drawings illustrate a preferred embodiment of the invention. Herein a transducer 10 comprises a first electromechanically responsive driver 12 and a second similar though smaller driver 16 disposed between a common mounting plate 20 and a front radiating member 24.

The drivers 12 and 16 may be in the form of a hollow cylinder of electromechanically sensitive material, such as barium titanate as aforesaid or equivalent, the type of material depending upon generally well known factors. To improve piezoelectric qualities the hollow cylinder may be comprised of a plurality of rings stacked and rigidly bonded together.

The first driver 12 is rigidly secured at one end 13 to a rear surface 26 of the front radiating member 24 which forms a generally cylindrical disk of suitable rigid material such as for instance, brass, aluminum and magnesium.

The securing means used for bonding the first driver 12 to the front radiating member 24 may be by means of epoxy cement or its equivalent, or grease in conjunction with mechanical bias as disclosed in copending application S.N. 584,647, filed May 14, 1956, now Patent No. 2,930,912, issued March 29, 1960.

The general characteristics of the front radiating member 24 are suitably selected to avoid and/or reduce any nonuniform vibration. The forces acting upon the member 24, as a result of the excitation of the first driver 12, are circumferentially substantially uniform. The frequency and magnitude of these forces require that the shape of the structure is preferably in the form of a disk having substantially uniform width and the center of gravity thereof is preferably near the axial center of the tubular driver. Although uniform distribution of the mass is not essential for successful operation of the device, at least it should serve as a goal to be approached. Such an arrangement reduces unequal stresses which may cause shear action and could tear the tubular first driver 12 from the front radiating member 24.

The second driver 16 is rigidly secured, in the same aforescribed manner, to an inwardly facing surface 21 of the common mounting member 20. The latter is preferably so arranged that the axial center of the member 20 is in substantial alignment with the axial center of the front radiating member 24. Such an arrangement is not necessarily essential; however as longitudinal vibration in the longitudinal mode occurs, any substantial off-center alignment will tend to increase the factors contributing to the non-uniform vibration of either the radiating or common mounting member, resulting in undesired flexural modes over these faces.

The common mounting member forms a solid circular disk made of a suitable rigid material such as metal and provides a plurality of apertures 22 which are extended in circular array around the axial center of the mounting member 20. A supporting rod 30 is projected at one end through one of the apertures 22 of the common mounting member 20 and secured thereto by means of a nut (not shown) or the like. The opposite end of the supporting rod 30 is threadedly disposed (not shown) into the front radiating member 24. All other remaining apertures 22 similarly receive a supporting rod 30, therewith providing in combination additional structural rigidity.

The end portion 17 of the second driver 16, adjacent to the front radiating member 24, is securely coupled to a structure member 34 which may be of similar suitable material as the front radiating member 24 and common mounting member 20. As a further space saving means the back portion 35 of the structure member 34 may protrude into the hollow confine of the tubular second driver 16. The outside diameter of the structure member 34 substantially corresponds with the outside diameter of the second driver 16 so that the second driver, including the structure member 34, may be concentrically extended into the hollow cylindrical space of the first driver 12, thereby leaving only a nominal clearance between the outside diameter of the second driver 16 and the inside diameter of the first driver 12. The axial length of the first driver 12 is slightly greater than the corresponding length of the second driver 16, so that in assembled condition the end portion 14, of the first driver 12 adjacent to the common mounting member, engages this common member 20. In one mode of operating the device the first driver 12 is in pressure-tight engagement with the common mounting member 20 and the peripheral end 14 of the driver 12 is well bonded onto the common mounting member 20 so as to prevent substantially any escape of air from the internal space of the first driver 12. This sealing provides within the hollow cylinder of the first driver a substantially pressure-tight air chamber. Upon excitation of the drivers the front portion 36 of the structure member 34 will vibrate within the air chamber. The increased air pressure serves as an air cushion having a similar effect as an acoustical insulation means.

To put the device into operation alternating current is supplied from an oscillator-amplifier combination suitably connected to a transformer (not shown) and the output thereof comprises two secondaries of different turns ratio and substantially 180° out of phase, arranged to provide

equal mechanical amplitudes but substantially opposite phases. The current is supplied by a double set of lead wires. One set thereof is connected to the piezoelectric substance of the first driver 12, and the other set is connected in similar fashion to the second driver 16. The wiring connection is made by means of some bonding material such as solder.

It is understood that the aforesaid method of providing currents which are approximately 180° out of phase, is well known in the art and a number of different approaches may be used to obtain the desired end.

After the generating unit is energized and in turn supplies two currents 180° out of phase onto the drivers, the drivers will as a result of their transducing qualities excite and cause vibratory motion in the longitudinal mode along a given axis. This vibratory motion in both drivers is in the form of substantially uniform longitudinal contraction and expansion along the cylinder walls. The effect of having the two currents approximately 180° out of phase, causes the expansion cycle to start in one driver exactly when the other driver starts the contraction cycle. Similarly, when the maximum contraction in one driver occurs, the maximum expansion in the other driver is also occurring. Broadly then, the mechanical amplitude of contraction and expansion in each respective driver is equal in magnitude at all times but in opposite direction, to its partner.

Thus when the aforescribed unit is assembled and current is supplied, the first driver 12 will longitudinally expand and contract in accordance with its single wave pattern, thereby producing forces at certain intervals against the common mounting member 20 at the opposite end against the front radiating member 24. The second driver 16 acts similarly but oppositely with respect to the first driver against the common mounting member 20, setting up its own single wave pattern which is equal but opposite to that of the first driver. The resulting vibratory wave pattern sets up at the common mounting member a velocity node. Expressed in mechanical terms the vector forces being opposite and equal in magnitude produce a state of equilibrium at the common mounting member 20.

Hence, the invention herein provides a transducing means similar in techniques to a single half-wave transducing element, whose length equals the sum of the two quarter-wave drivers, but by means of operating the two quarter-wave drivers approximately 180° out of phase, one active element thereof can be co-extensively arranged with the other element without causing any change in the basic operating characteristic. Yet, with my invention the longitudinal total length of the electromechanical drivers can be halved for a given resonant frequency.

However, if the two drivers are in phase agreement (i.e., substantially 0° out of phase), then the resonant frequency will increase by one octave. This is also true if one driver is not activated. In these cases, the two folded quarter-wave drivers act like two independent half-wave drivers, and hence, the system resonates an octave higher as compared with the arrangement in accordance with this invention. It should be noted that my invention is operable either way.

The other aspects of the device proceed in the conventional manner, that is to say, the structure member 34 and the front radiating member 24 have potential radiating surfaces and the forwardly facing radiating surface 27 of the front radiating member 24 is in contact with the medium, such as water, to send and receive wave patterns.

The device as illustrated in FIGURE 3, resembles the device as shown in FIGURES 1 and 2, except herein some of the structural aspects have been changed to provide for additional strength and stability. The latter is a contributory factor in reducing non-uniform vibratory motion.

Hereinafter, all main components, or surfaces thereof,

resembling aforescribed in FIGURES 1 and 2, have been designated with the same reference number. A small letter has been added, where applicable, to distinguish same.

The additional strength of stability is realized by providing a rod 38, in substantially concentric relation with a first and second driver 12a and 16a respectively and rigidly disposed on one end into a structure member 34a at about the axial center thereof. The rod 38 extends longitudinally from the end adjacent to the back portion 35a of the structure member 34a towards and projecting through the axial center of the common mounting member 20a. A nut 40 secures the rod 38 rigidly in position.

A front radiating structure 24a as employed herein, resembles the form of a frustum of a circular cone or of a rectangular-base pyramid and one end thereof engages the cylindrical wall portion of the driver 12a. A supporting shoulder 42 extends radially from the member 24a providing a plurality of threaded bore portions each to receive a rod similar to 39. The rods 39 run parallel with the other rod 38 and extend toward the common mounting member 20a; thereabout they protrude axially through the member 20a and are secured by a nut 41.

In FIGURE 4, I also illustrate the general principle of my invention, except that for greater compactness a structure member 34b protrudes substantial into a front radiating member 24b.

More particularly, the front radiating member 24b forms a cavity 49 on one side, which is adjacent to the first and second drivers 12b and 16b, respectively. The cavity 49 describes substantially the same form, although geometrically opposite, as protruding portion 54 of the structure member 34b. The protruding portion 54 does not come into direct contact with the internal surface of the radiating member cavity, but rather the portion 54 is so disposed as to leave a substantial air space therebetween. The air space, in operation, is utilized as an air cushion suitable for acoustical insulation as aforescribed.

The aforesaid air space, as well as a region 55, as described, which is between the first and second driver 12b and 16b respectively, may be filled with water which would then act as a deterrent against any expansion of the vibrating bodies whether this be in the longitudinal or radial mode. However, region 55, extending all around the external surface of the second tubular driver 16b and structure member 34b, may then be partially filled with a resilient compound such as cellite rubber, or the like, providing a cushioning effect.

In FIGURE 5, the basic principle of the invention is retained, except herein the compactness of my invention is carried to the ultimate. That is to say, a structure member 34c protrudes nearly beyond the forwardly facing surface 27c of the front radiating member 24c which functions herein as a mere fronting block. In this type of arrangement the choice is given to select either one of the aforementioned members as the radiating member exposed to the medium. FIGURE 5 illustrates the structure member 34c as being the one used as the active or radiating member and the front radiating member or fronting block 24c is suitably provided with an acoustical insulating means 64. Obviously, this arrangement can be reversed and the acoustical insulation 64 would then be applied to the forwardly facing surface 36c of the structure member 34c.

An O-ring 62 is disposed between the structure member 34c and the front radiating member 24c whereby the space 63 is protected from being filled with a fluid which would prevent or reduce radial expansion and contraction.

The transducer shown in FIGURE 6 has an electromechanically active common mounting member 71. Upon longitudinal excitation thereof the member sets up a nodal plane near the longitudinal center and causes respective faces 72 and 73 to vibrate substantially 180° out of phase. The tubular structures 67 and 69 are not electromechanically active, and are concentrically disposed

with respect to each other to serve as mechanical drivers. The tubular structures are connected to respective fronting blocks 75 and 76 by cement, or the like. Herein, the tubular structure 69 is mechanically coupled to the common mounting member at one end face 72 as shown in the drawing, and tubular structure 67 engages the other end face 73 of the mounting member 71. The nodal plane herein is about halfway between face 73 and face 72, face 72 will try to radiate sound waves and hence may be covered with acoustic insulation material 77.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made 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 as my invention:

1. A transducer for operation in a medium and for transducing therein and between electrical and mechanical energy, comprising: first and second quarter-wave length elongated structures adapted to vibrate in the longitudinal mode along a given axis, said elongated structures being substantially coextensively disposed with respect to each other forming in combination a folded one half-wave member comprised of said two quarter-wave structures, said combination having a total overall axial length less than a single half-wave elongated structure; means for mechanically coupling said structures at one common end to establish a nodal plane at said end; and means for inducing said elongated structures to vibrate longitudinally 180° out of phase with respect to each other.

2. A transducer similar to that in claim 1, wherein said elongated structures are vibratable in the longitudinal mode by an electromechanically active common mounting member.

3. A transducer similar to that in claim 1, wherein said elongated structures are themselves electromechanically active.

4. A transducer similar to that in claim 1, wherein said elongated structures are substantially tubular.

5. A transducer for operation in a medium and for transducing therein and between electrical and mechanical energy, comprising: first and second quarter-wave length tubular drivers having electromechanically responsive qualities and being adapted to vibrate in the longitudinal mode along a given axis, said tubular drivers being substantially concentrically disposed with respect to each other forming in combination a double quarter-wave tubular driver having a total axial length less than a single half-wave tubular driver; means for mechanically coupling said drivers at one common end; said drivers being adapted to operate substantially 180° out of phase with respect to each other thereby causing at said common end a velocity node.

6. A transducer for operation in a medium and for transducing therein and between electrical and mechanical energy, comprising: first and second hollow cylindrical electromechanical drivers adapted to vibrate in the longitudinal mode, each of said drivers having first and second ends; a front radiating member; a structure member; a common mounting member oppositely spaced with respect to said members; said second ends of said drivers being secured to said common mounting member, said first end of said first driver being secured to said front radiating member, said first end of said second driver being secured to said front structure member; and said drivers being adapted to operate substantially in phase opposition to each other thereby cooperating to set up a velocity node at said common mounting member.

7. A transducer for operation in a medium and for transducing therein and between electrical and mechanical energy, comprising: a front radiating member having a generally forwardly facing surface; a common mounting

member oppositely spaced from said members; a structure member; first and second hollow cylindrical electromechanical drivers adapted to vibrate in the longitudinal mode along a given axis, each of said drivers having first and second ends, said second ends of said drivers being secured to said common mounting member, said first end of said first driver extending rearwardly secured from said forwardly facing front radiating surface, said first end of said second driver being secured to said structure member and extending rearwardly therefrom; said drivers being adapted to operate substantially in phase opposition to each other thereby co-operating to set up a velocity node at said common mounting member.

8. A transducer for operation in a medium and for transducing therein and between electrical and mechanical energy, comprising: first and second hollow cylindrical electromechanical drivers adapted to vibrate in the longitudinal mode along a given axis, each of said drivers having first and second ends; a front radiating member; a structure member; a common mounting member oppositely spaced with respect to said members; said second ends of said drivers being coupled to said common mounting member, said first end of said first driver being coupled to said front radiating member, said first end of said second driver being coupled to said structure member and the longitudinal axis of said first driver being in substantially parallel alignment with that of the second driver; and said drivers being adapted to operate substantially 180° out of phase in their relationship to each other co-operating to set up a velocity node at said common mounting member.

9. A folded transducer comprising: inner and outer tubular members, concentrically arranged, piezoelectrically responsive, and adapted to vibrate in the longitudinal mode along a given axis; a common mounting member connected to one axial end of each of said tubular members; a structure member mounted to the other axial end of said outer tubular member; a radiating member mounted to the other axial end of said outer tubular member and inclosing said structure member and said inner tubular member; said tubular member being adapted to operate substantially 180° out of phase to each other whereby a velocity node is set up at said common mounting member.

10. A transducer according to claim 9, and resilient means within the space defined by said outer tubular member and said radiating member.

11. A transducer according to claim 9, and water within the space defined by said outer tubular member and said radiating member.

12. A transducer according to claim 9 wherein at least one of said tubular members is comprised of a plurality of rings, piezoelectrically responsive, stacked, and rigidly bonded together.

13. A transducer according to claim 9 wherein said radiating member has rearwardly a cavity and said structure member protrudes at least partly into said cavity.

14. A transducer according to claim 9 and a plurality of bolt-like rods disposed to adjustably secure said radiating member and said structure member in spaced relation to said common mounting member.

15. A folded transducer comprising: inner and outer tubular members, concentrically disposed, piezoelectrically responsive, and adapted to vibrate in the longitudinal mode along a given axis; a common mounting member connected to one axial end of each of said tubular mem-

bers; an annular member having a forward and a rearward surface, the latter surface of said annular member being connected to the other axial end of said outer tubular member; acoustic insulating means on said forward surface; a radiating structure member concentrically arranged relative to said annular member and connected to the other axial end of said inner tubular member; said tubular members being adapted to operate substantially 180° out of phase to each other whereby a velocity node is set up at said common mounting member.

16. A folded transducer comprising: inner and outer tubular members, concentrically disposed, piezoelectrically responsive, and adapted to vibrate in the longitudinal mode along a given axis; a common mounting member connected to one axial end of each of said tubular members; an annular radiating member having a forward and a rearward surface, the latter surface being connected to the other axial end of said outer tubular member; a structure member concentrically arranged relative to said radiating member and having a forward and rearward surface, the latter surface being connected to the other axial end of said inner tubular member; acoustic insulating means on said forward surface of said structure member; said tubular members being adapted to operate substantially 180° out of phase to each other whereby a velocity node is set up at said common mounting member.

17. A transducer according to claim 15 and sealing means for sealing said radiating member to said structure member.

18. A folded transducer comprising: inner and outer tubular members concentrically arranged and adapted to vibrate in the longitudinal mode along a given axis; a common mounting member, piezoelectrically responsive, connected to one axial end of each of said tubular members for driving said member 180° out of phase; a structure member mounted to the other axial end of said inner tubular member; a radiating member mounted to the other axial end of said outer tubular member and inclosing said structure member and said inner tubular member.

19. A folded transducer comprising: inner and outer tubular members, concentrically arranged, piezoelectrically responsive, and adapted to vibrate in the longitudinal mode along a given axis; a common mounting member connected to one axial end of each of said tubular members; a structure member mounted to the other axial end of said inner tubular member; a radiating member mounted to the other axial end of said outer tubular member and inclosing said structure member and said inner tubular member; means for selectively inducing said tubular members to vibrate longitudinally 180° out of phase or to operate in phase agreement whereby the resonant frequency will be increased by one octave as compared to the former condition.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,110,825

November 12, 1963

Harry B. Miller

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 18, for "driver is fixedly disposed between" read -- elements are made of piezoelec- --; line 32, for "drive" read -- driver --; column 4, line 44, for "techniques" read -- technique --; line 45, for "two-" read -- two --; column 5, line 26, for "substantial" read -- substantially --; column 6, line 75, after "surface;" insert -- a structure member; --; column 7, lines 1 and 2, strike out "a structure member;".

Signed and sealed this 28th day of April 1964.

(SEAL)

Attest:

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Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents