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FIG. 2

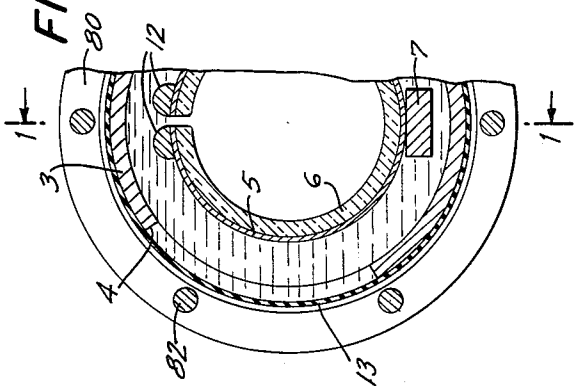
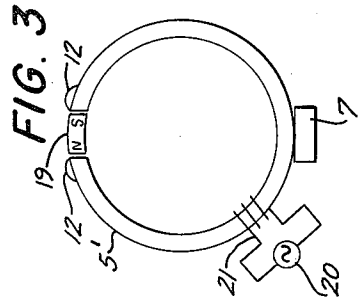


FIG. 3



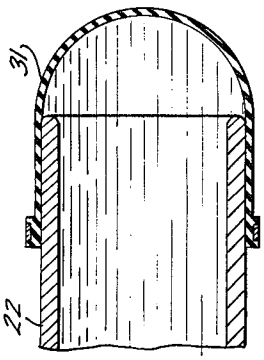


FIG. 1

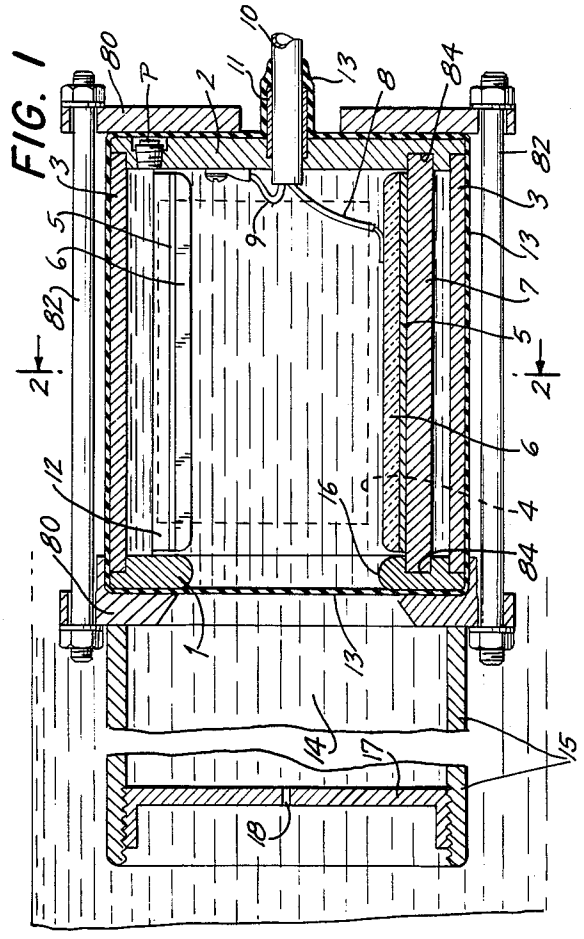
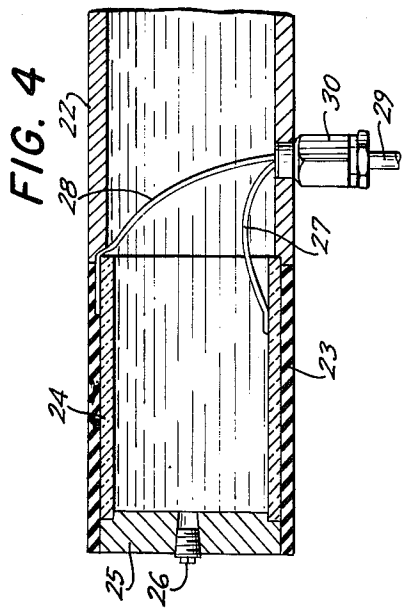


FIG. 4



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FIG. 5

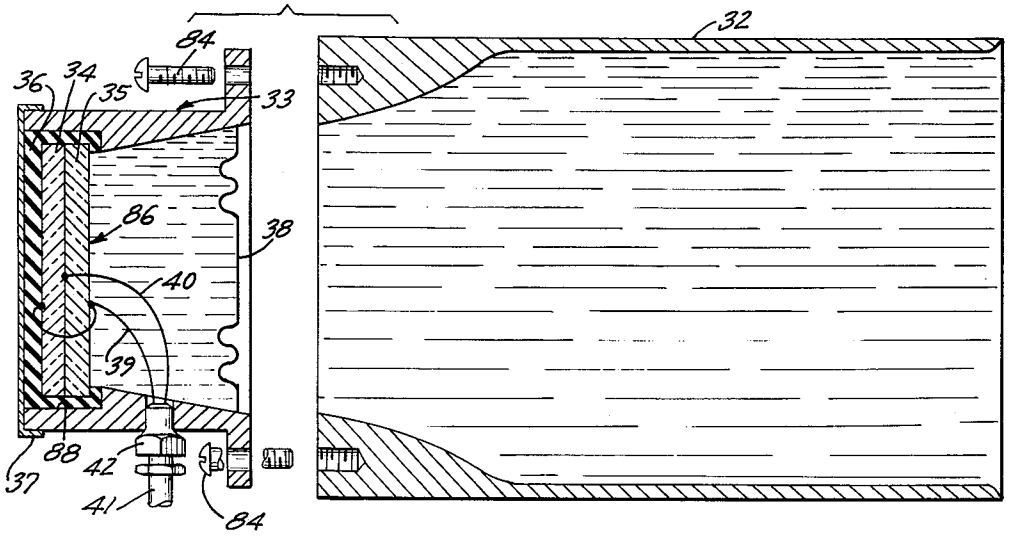


FIG. 6

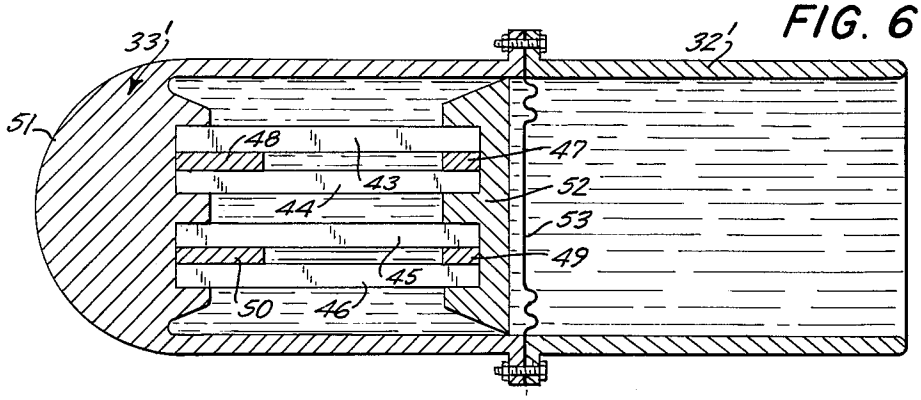
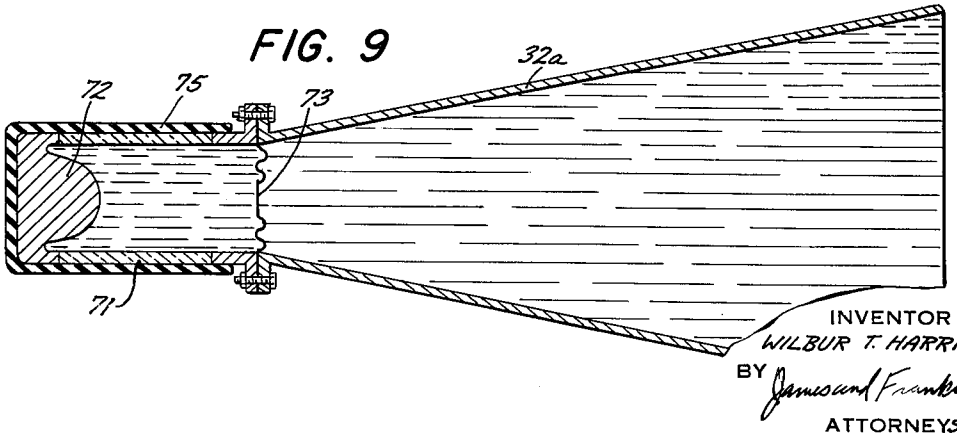


FIG. 9



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FIG. 8

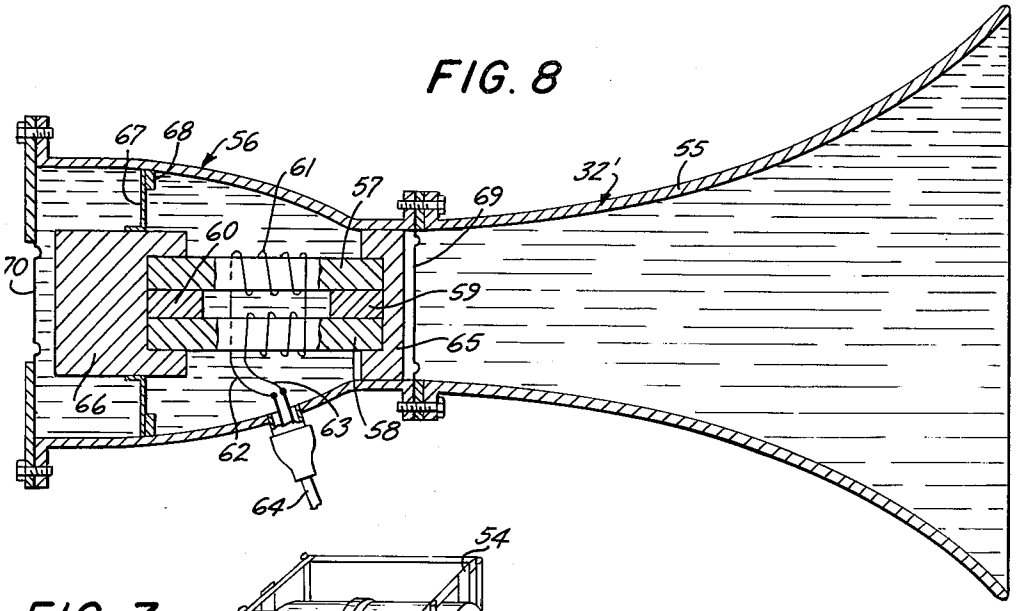


FIG. 7

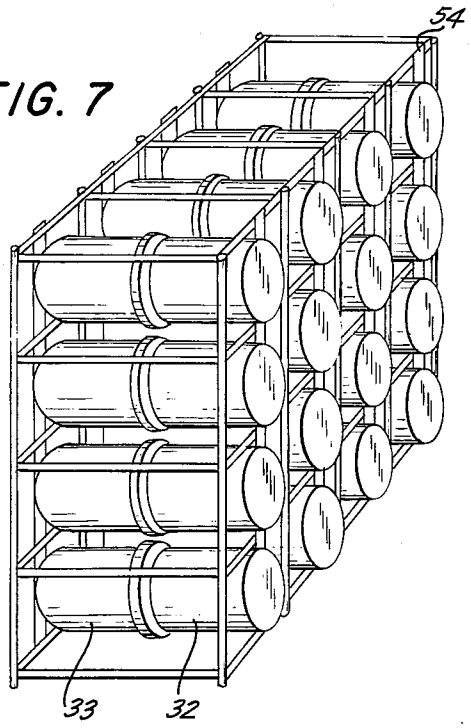
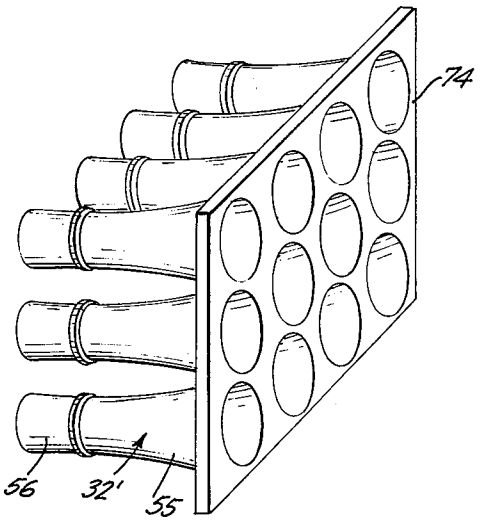


FIG. 10



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FIG. 11

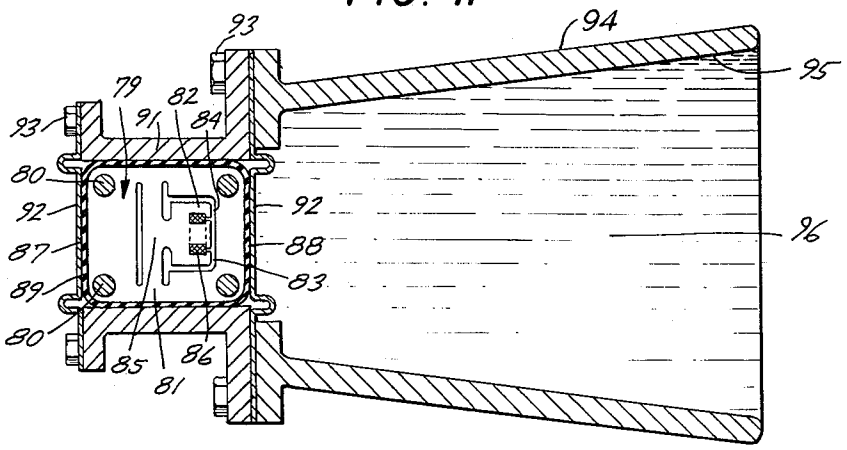


FIG. 12

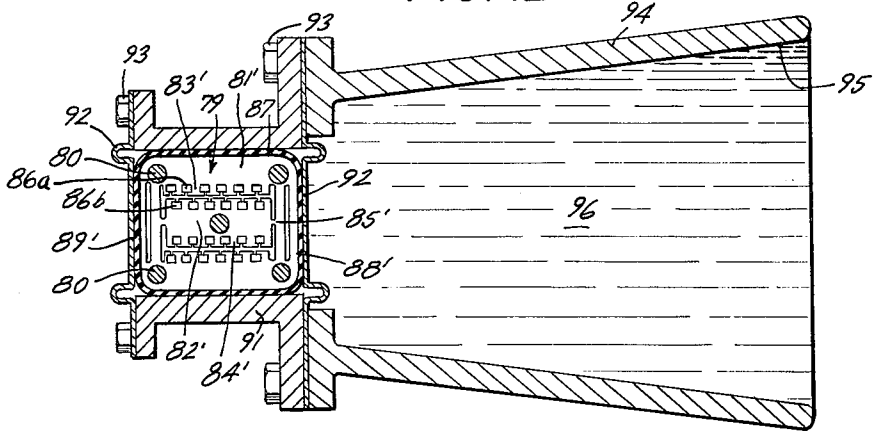
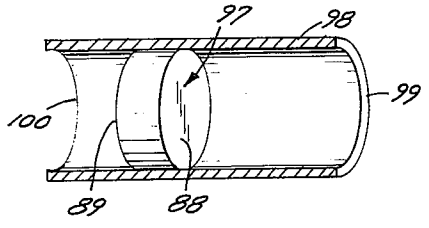


FIG. 13



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United States Patent Office 3,233,213 Patented Feb. 1, 1966

3,233,213

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Wilbur T. Harris, Woodbury, Conn., assignor to The Harris Transducer Corporation, Woodbury, Conn., a corporation of Connecticut

Filed Apr. 15, 1960, Ser. No. 22,646
18 Claims. (Cl. 340—8)

This application is a continuation-in-part of my prior application having the same title, Serial No. 7,940, filed Feb. 10, 1960, now abandoned.

This invention relates to an electro-acoustic transducer for underwater application, and more specifically to such a transducer which employs a liquid column as an essential part of the resonating mechanism.

In transducers such as have been employed heretofore the transducer energizing unit itself, sometimes together with its housing or mounting assembly, and sometimes together with structural appurtenances such as resonating metallic tubes, constituted the primary operative vibratory mechanism which generated (or sensed) the vibrations and determined the characteristics of those vibrations. Some transducers have in the past been liquid-filled in whole or in part, but the liquid did not function as an essential part of the vibratory mechanism. The liquid was variously used for cooling, insulation, ambient pressure equalization, or acoustic transmission through a cover. The resonant characteristics of that liquid were not directly utilized as a factor determining to any appreciable degree the vibratory or resonant characteristics of the transducer or of the vibrations produced or sensed thereby.

It is an important object of the present invention to produce a liquid-filled transducer so designed that the filling liquid will itself contribute in significant fashion to the acoustical characteristics of the transducer. Some of the filling liquid may be drawn from the sea or other liquid medium in which the transducer is immersed.

Broadly considered, the chamber in wihch the liquid is received is in communication with the transducer energizing unit itself and causes the liquid to define a loading column which effectively modifies the resonant characteristics of the transducer. In its preferred form the liquid column has an acoustical length which is essentially a quarter wave length of the optimum frequency of the vibrations produced. There are various ways, some of which are here specifically disclosed, in which this loading column may be combined with transducer energizing units and housings in order to give rise to the efficient and effective generation of vibrations and the transmission of those vibrations into the medium in which the transducer is immersed.

One major result of this type of acoustical loading of what may be essential conventional transducer units is that the size of the overall transducer assembly for a given vibration frequency is greatly reduced over that which was inevitable when essentially half-wave length metallic or water resonators were employed, as in the prior art. This invention permits, for the first time, relative miniaturization in the context of sonar technology. Since transducer size becomes greater, and hence more of a problem, as the vibration frequency decreases, transducers of the present invention are particularly applicable to relatively low frequency generation or sensing.

It is particularly noteworthy that this marked decrease in size and weight is accomplished by means of a structure which has a comparatively low Q and which operates at high efficiency.

It is a feature of the invention to provide a transducer having the above mentioned advantages and which does not contain any soft pressure release material, therefore

being substantially immune to damage or loss of efficiency caused by hydrostatic pressure. The invention is therefore particularly applicable for use in deep sea installations.

It is still a further object of the invention to provide a novel transducer which employs a liquid resonating column as part of its resonating mechanism.

It is another object of the invention to provide a transducer utilizing liquid-filled loading horns of various shapes, e.g., cylindrical, conical or exponential.

It is still another object of the invention to provide a liquid column resonator, including provision for adjustably varying the length of the column resonator.

It is another feature of the invention to provide a plurality of resonator designs which may use different types of exciter units, whether of the magnetostrictive, piezoelectric electrostrictive or variable position types.

It is still another feature of the invention to provide a transducer design which has useful directional characteristics, and which is amenable to array disposition for more highly directional propagation.

More specifically, there is provided a transducer for underwater acoustic propagation comprising a housing defining a liquid-filled chamber, and means for exciting the liquid in that chamber at its resonant frequency. The housing includes an acoustic window to the external water medium, whereby the resonating motion of the liquid is projected into the medium. In one type the exciter means is separate from and in direct acoustical connection with said chamber. In another type the liquid-filled chamber is in two parts, the first chamber part containing said exciter means together with liquid and the second chamber part containing a liquid column in free vibration-transmission connection with said first chamber part, a quarter-wave length effect being produced thereby. Said second chamber part may take the form of a cylindrical or tapered loading horn. The two chamber parts may be separated by a vibratable partition or may be in direct fluid communication with one another.

The vibrations may be transmitted to the surrounding medium from the chamber proper or, when the chamber is in several parts, from the first chamber part, the second chamber part, or both. In all cases the chamber proper, including the two chamber parts when present, define a liquid column which controls the overall characteristics of the device. The housing ordinarily will not be readily vibratable at the frequencies involved, thereby acoustically containing the resonant liquid column. It is preferred that both the liquid column and the exciter means itself should resonate at the same frequency.

To the accomplishment of the above, and to such other objects as may hereinafter appear, the present invention relates to transducer structure, as defined in the appended claims, and as described in this specification, taken together with the accompanying drawings, in which:

FIG. 1 is a longitudinal sectional view of one embodiment of the novel transducer, taken along the line **1—1** of FIG. 2;

FIG. 2 is a fragmentary view taken along line **2—2** of FIG. 1;

FIG. 3 is a schematic showing of an alternative arrangement of the exciter unit utilized in the embodiment of FIGS. 1 and 2;

FIG. 4 is an alternative embodiment of the transducer comprising a quarter-wave pipe with a "squeezer" piezoelectric cylinder at a closed end of the pipe;

FIG. 5 is a longitudinal sectional view, partly exploded, of another embodiment of the transducer, comprising a cylindrical horn and a piezoelectric exciter unit;

FIG. 6 is a diagramamtic view of an alternative embodiment of the transducer including a cylindrical horn and employing a magnetostrictive exciter unit;

FIG. 7 is a diagrammatic view of an array of cylindrical-horn transducers;

FIG. 8 is a longitudinal sectional view of a transducer comprising an exponentially tapered horn and employing a magnetostrictive exciter unit;

FIG. 9 is an alternative embodiment of FIG. 8, in which the horn is conically tapered and the exciter unit comprises piezoelectric material;

FIG. 10 is a perspective view of an array of transducers shown in FIG. 9;

FIG. 11 is a longitudinal sectional view of an alternative embodiment of the transducer comprising a variable position type exciter unit;

FIG. 12 is a view similar to FIG. 11 but showing a specifically different kind of variable position type exciter unit; and

FIG. 13 is a longitudinal sectional view of yet another embodiment of the present invention.

Referring now to FIGS. 1 and 2, there is disclosed a longitudinal sectional view of a transducer comprising a housing in the form of a cylinder having end walls 1, 2 and a side wall 3, held together by end caps 80 and bolts 82. The side wall 3 is provided with longitudinally extending openings 4, one of which is shown in FIG. 2. Another symmetrically disposed opening 4 is located in the opposite side wall, which for simplicity is omitted in the view of FIG. 2. The openings 4 constitute radiative windows.

The exciting unit of the transducer of this embodiment is cylindrical in form and is adapted to be driven to vibrate simultaneously circumferentially and radially. This type of exciting unit is well known, and may take a variety of forms. As here specifically disclosed by way of exemplification it comprises a split cylinder 5 of metallic material capable of being driven in the combined radial and circumferential mode of vibration as described. The split cylinder 5 is excited by a split piezo electric cylinder 6 which is mounted on one side, e.g., the inside, of the split cylinder 5 is excited by a split piezoelectric cylinder mounted on a metal supporting rod 7, which is secured in socket-type openings 84 in the opposite end walls 1, 2 of the housing.

Electrical energy is applied to excite the split cylinder assembly 5, 6 over leads 8 and 9. Lead 8 is connected to the inside of the piezoelectric cylinder 6. The opposite surface of the piezoelectric cylinder 6 is activated by energy applied through lead 9, end wall 2, supporting rod 7 and split cylinder 5. As shown, the ends of the piezoelectric cylinder 6 and the split metal cylinder 5 are spaced from the end walls 1 and 2 of the housing in order to prevent short circuiting of the piezoelectric element. The leads 8 and 9 are brought in through a cable 10 entering the end wall 2. A watertight sealing ring 11 seals the space between the end wall 2 and the cable 10.

Thes resonant frequency of the piezoelectric-split cylinder assembly 5, 6 is accurately adjusted by weights 12 (FIG. 2) securely mounted on the opposite ends of the piezoelectric-split cylinder assembly. For a detailed discussion of the split cylinder transducer, reference may be had to my Patent No. 2,812,452 of November 5, 1957, entitled, "Split Cylindrical Transducer." For a description of a different type of cylindrical transducer, reference may be made to my copending application Serial No. 6722, filed Feb. 4, 1960, and entitled, "Transducer," now Patent No. 3,142,035.

The entire housing is sealed, preferably by a rubber or other elastic cover 13, which is acoustically transparent at the operating frequencies. The internal volume of the housing 1, 2, 3, defining the first chamber part, within which part is housed the exciting unit 5, 6, is filled with a high dielectric and compressible liquid, such as naphtha, through a filler plug P.

A liquid column 14 is confined within a cylinder 15, that cylinder being secured to end cap 80 in any appropriate manner and constituting a part of the overall

housing for the device. The interior of the cylinder 15 defines a second chamber part, and the liquid therewithin is acoustically coupled to the exciter unit 5, 6 of the transducer via window 16 in the end wall 1 of the housing. The liquid column 14 is preferably filled with the water from the external medium, i.e., sea water, and is separated from the interior of the housing 1, 2, 3 by a partition defined by a portion of the elastic cover 13, through which liquid cannot pass but which, because of its ready vibratability, permits vibration transmission from one side thereof to the other. The cylinder 15 is closed by a plug 17 at one end thereof which preferably includes a bleed orifice 18, whereby the pressure inside the cylinder 15 is continuously equalized to the ambient pressure. As shown in FIG. 1, the length of the liquid column measured from the effective plane of radiation of the exciter unit 5, 6 ideally is one-quarter wave length; an idealized effective plane of radiation is assumed along an axial plane of symmetry of the exciter unit 5, 6 represented by the cross-section line 2—2 of FIG. 1.

The radiations are emitted through the acoustic windows 4 on opposite sides of the housing. The frequency of the propagated energy is that of the resonant frequency of the liquid column. Preferably, although not necessarily, the liquid column and the exciter unit 5, 6 resonate at the same frequency.

Thus, if we assume that the emitted waves originate along the plane 2—2, a wave passing along the liquid column is reflected by the end wall or plug 17 and returned so that the reflected wave reinforces the incident wave of the exciter unit 5, 6. Hence the overall size of the unit approximates that of one-quarter of the wave length in sea water of vibrations of the frequency generated, with a very high radiation efficiency. The device operates like a closed end quarter wave length line, velocity excited at its open end.

The length of the liquid column may be selectively varied by providing means for adjustably positioning the plug 17 within the cylinder 15. One means for accomplishing this variable positioning is by threading the inside wall of the cylinder 15 and the engaging surface of the plug 17, as shown.

In place of the piezoelectric-split cylinder exciter unit 5, 6 illustrated in FIGS. 1 and 2, an electromagnetic exciter means, such as illustrated in FIG. 3, may be employed. In this embodiment the split cylinder 5′ comprises a ferromagnetic material polarized by a magnet 19. By applying alternating current from a source 20 over winding 21 to the cylinder 5, the cylinder 5 may be caused to vibrate as described.

In FIG. 4 there is illustrated another embodiment of the novel transducer employing a quarter-wave liquid column as part of the basic resonating mechanism. The transducer comprises a metal cylinder 22 connected at one end to an exciter unit 24 externally covered by a rubber sheath 23. The exciter unit 24 comprises, preferably, a piezoelectric "squeezer" type cylinder. The cylinder 22 is closed at the exciter end by a mass 25 which is essentially non-vibratable at the frequencies involved and which is equipped with a plug 26 for filling the interior of the transducer wtih an insulating liquid. The piezoelectric cylinder is excited by an alternating current which is applied via leads 27, 28 to the opposite surfaces of the cylinder 24. The leads 27, 28 are brought into the interior of the transducer through a cable 29 which is sealed to the tube 22 by a watertight cable gland 30. The open end of the tube 22 is covered by a protective covering, such as a rubber or neoprene boot 31, which is acoustically transparent. The space inside the exciter unit 24 constitutes the first chamber part and the space inside the cylinder 22 constitutes the second chamber part.

At the operating frequency, the acoustic resonance of the quarter-wave liquid column formed within the exciter unit 24 and the tube 22 by the first and second chamber parts together constitute the resonating mechanism. The

transducer has resonances or efficiency maxima at a fundamental frequency of one-quarter wave length, etc. Actually, the tube length is slightly less than one-quarter of the filler liquid wave length because of end loading. The mechanical resonances of the transducer metal structure are at a substantially higher frequency than the acoustic resonance of the liquid column, so that the tube is radially stiff at the operating frequency. It operates like a closed end quarter wave length line, pressure excited at the closed end.

The remaining FIGS. 5–10 illustrate embodiments of the invention which utilize open-ended liquid columns contained within cylindrical or tapered loading horns, those horns defining within themselves the second chamber parts.

In FIG. 5 an open-ended cylindrical horn **32** is coupled at one end, by screws **84**, or in any other appropriate manner, to housing **33** containing an exciter unit **86**, the horn **32** constituting a part of the overall housing for the device. The exciter unit **86** may be any one of several well known types, but by way of example is illustrated as a bilaminar ceramic disk comprising laminations **34** and **35**. The housing **33** is provided with a recessed portion **88** fitted with a resilient socket sleeve **36** which accommodates the bilaminar ceramic disk **34**, **35**. The exciter end of the housing **33** is closed by a cover **37** made either of accoustically transparent or acoustically stiff material, depending on the particular design of the transducer which may be desired. The end of the housing **33** coupled to the horn is mechanically closed by an acoustic window diaphragm **38** through which liquid cannot flow.

The interior of the housing **33** is filled with an insulating liquid, preferably having high compressibility. The bilaminar ceramic disk **34**, **35** is formed and energized to provide a push-pull effect on the liquid, bowing back and forth in the direction of the axis of the housing **33**. This may be accomplished by using similar materials for the laminations **34**, **35** and applying an electrical charge of like polarity to the outside surfaces of the laminations and a charge of opposite polarity to the adjoining surfaces thereof. This connection is illustrated by leads **39** and **40** connecting the several surfaces, the leads being brought in through a cable **41**, which is sealed by a gland **42** to the housing **33**. The exciter unit **86** is a high amplitude, low mechanical impedance device suitable for velocity excitation at the column mouth.

If desired, the cylindrical horn **32** may be provided with means for adjusting its length, diameter and exciter location, so that radiation occurs only at one end of the horn, or so that radiation from each end is in such relation to radiation from the other end that radiation from the two ends may combine to produce a uni-directional output from an individual transducer.

If the cover **37**, together with the resilient socket material **36**, constitutes an acoustic diaphragm then the rear end of the transducer (the left hand end as viewed in FIG. 5) drives the medium as an unbaffled piston. In this arrangement, the relationship between weighting, phasing and length should be chosen so that radiation from both ends combine to produce a uni-directional output from the transducer. If the left hand end of the transducer is acoustically stiff, the transducer will function in a manner similar to that of FIG. 4.

FIG. 6, in which primed reference numerals similar to those used in FIG. 5 are employed for similar parts, illustrates another arrangement of a cylindrical horn transducer in which the exciter unit comprises pairs of magnetostrictive sections **43**, **44**, **45** and **46**. The magnetostrictive sections are preferably polarized by magnetic couplers **47**, **48**, **49** and **50**. In the interest of simplicity, the windings around each of the sections have been omitted from the drawings. However, the windings are preferably arranged so as to produce complementary motions in the magnetostrictive sections. The magnetostrictive assemblies are fixed at one end to end wall **51**. Driving piston **52**, which is freely axially slidable inside housing **33'**, is provided with sockets for receiving the other ends of the magnetostrictive assembly. The right hand end of the interior of the housing **33'** is closed by diaphragm **53**, which is acoustically transparent and liquid-impermeable. The housing **33'** is filled by some appropriate fluid, preferably insulating in character.

FIG. 7 shows an array of transducers of the type shown in FIG. 6, mounted within a framework **54**. In the array, the entire housing **33** becomes part of the transducer tail weight. The effect of high acoustically resistive loading on the pistons **52** resulting from the properties of the liquid columns confined in the horns **32** assures that the radiations from the mouths of the horns **32** will be highly predominant. In closely spaced large array such as those shown, unidirectional radiation patterns may therefore be obtained without reflectors.

The exponentially tapered horn **32'** shown, for example in FIG. 8, comprises a flared portion **55** mounted at its narow end on a housing **56**. In this embodiment the exciter unit comprises a magnetostrictive assembly similar to the exciter unit in FIG. 6. By way of example, the magnetostrictive assembly in FIG. 8 may comprise laminated magnetic cores **57**, **58** coupled together preferably by permanent magnets **59** and **60**. The magnetostrictive assembly is excited by energizing winding **61**, which is connected to a pair of leads **62**, **63** extending from a cable **64**. The magnetostrictive assembly **57–60** is supported in front and tail weights **65** and **66** respectively. The front weight **65** is a piston mounted for free axial vibration thereof in the front end of the housing **56**. The tail weight **66** is supported, also to permit axial vibration, by a framework **67** secured to a flange **68** extending circumferentially inside the housing **56**. Each end of the housing **56** is equipped with an acoustic window diaphragm **69** and **70** respectively. As in the previous embodiment, the interior of the housing **56** is filled with an insulating liquid. The horn **32'**, of course, is filled with water from the external medium. The window diaphragm **70** could be eliminated, and the tail end of the housing **56** could be rendered non-vibratory, if vibration transmission only from one end of the assembly was desired.

FIG. 9 shows an alternative embodiment of the tapered horn wherein the exciter unit comprises a ceramic cylinder **71** of the squeezer type provided with a non-vibratory end mass **72** and covered with rubber boot **75**. A diaphragm **73** located at the throat of the horn **32***a* constitutes an acoustic window at the resonant frequency of the liquid column.

FIG. 10 shows an array of tapered loading horns of the type shown in FIG. 8 supported by a front frame plate **74**. As in the embodiment of the cylindrical horn array, the housing **56** of the tapered horn also becomes part of the transducer element tail weight and the light weight piston **65** becomes the driving element for the medium. The front surface of the diaphragm **69** drives the liquid column and the rear diaphragm **70** drives the medium as an unbaffled piston. For this arrangement, the radiation resistance associated with the rear surface would be in the order of .1 to $.2Z_0$ and for the front surface about $8Z_0$; hence substantially unidirectional radiation patterns may also be obtained with elements of this type without reflectors in closely spaced large arrays.

FIG. 11 discloses an embodiment of the present invention in which an exciter unit of the variable position type, generally designated **79**, is employed. This specific exciter unit **79** is constructed as disclosed in my Patent 2,713,127 of July 12, 1955, entitled, "Variable Position Transducer." It comprises a laminated assembly, held together by bolts **80**, which defines a stator area **81** enclosing an armature area **82**, the areas **81** and **82** having opposed pole faces **83** and **84** respectively and being yieldably joined to one another remote from the pole faces by connecting means **85**. An exciting winding **86** is provided as shown. The laminated assembly is encased

by an acoustically transparent rubber boot 87. The unit in question has radiating faces 88 and 89, all as described in greater detail in the aforementioned Patent 2,713,127. In accordance with the present invention this type of exciter unit, together with its sheathing boot 87, is snugly received within housing portion 91 which has a rectangular cross-section corresponding to the peripheral shape of the exciter unit 79, the unit 79 being held in place by flexible metal straps 92 secured to the housing portion 91 by means of bolts 93. Tubular horn-like housing portion 94 is secured to the housing portion 91 by the bolts 93, the radiating face 88 of the exciter unit 79 being directed toward the interior of the horn 94 and separated therefrom only by the strap 92, which is acoustically transparent at the frequencies involved. The housing portions 91 and 94 are stiff and acoustically opaque at those frequencies. The horn 94 is open both physically and acoustically at its end 95, and therefore is adapted to be filled with the liquid medium in which the transducer is adapted to be immersed, that liquid filling being designated 96. The liquid 96 will therefore be seen to constitute a column extending essentially from the radiating face 88 of the exciter unit to the open horn end 95. This liquid column corresponds to the liquid columns in the embodiments of the present invention described above. As in those embodiments, the length of the liquid column 96 is a minor fraction, and preferably nominally on the order of one-quarter, of the wave length in the liquid of the vibrations produced by the exciter unit, and the diameter of the open end 95 is on the same order of magnitude, and preferably is somewhat less than the length of the liquid column. Also as in the preceding embodiments, the length of the exciter unit is less than the overall length of the housing 91, 94.

Since both of the straps 92 are acoustically transparent at the frequencies involved, the exciter unit 79 in the embodiment of FIG. 11 will tend to propagate vibrations from both of its radiating surfaces 88 and 89, to the right and to the left respectively as viewed in the drawings. Radiation to the left, from the face 89, this corresponding to the back of the overall assembly, will be relatively negligible because of the poor loading at that area, that loading sometimes being less than $1\rho C$ per cm.^{2}. The presence of the liquid column 96 at the right hand end of the exciter unit will, however, load that end much more highly, and a liquid-filled horn 94 which has a Q of less than 4 may result in a loading of as high as $8–10\rho c$ per cm.^{2}. As a result the unit will have a high radiative output from the mouth of the horn and will exhibit efficient transducing properties over a relatively broad band of frequencies.

The embodiment disclosed in FIG. 12 is essentially the same as that disclosed in FIG. 11, and reference numerals as used in FIG. 11 are also applied to FIG. 12 to designate comparable structural parts. However, the variable position exciter unit of FIG. 12 is specifically that disclosed in my Patent 2,822,482 of February 4, 1958, entitled, "Variable-Position Transducer," that exciter unit comprising the stator mass area 81' and the armature mass area 82' having opposed pole faces 83' and 84' respectively and connected by resilient connecting means 85'. Biasing and energizing windings 86*a* and 86*b* are provided. As is described in more detail in my aforementioned Patent 2,822,482, the faces designated 88' and 89' are the radiating faces of the unit.

FIG. 13 discloses in semi-schematic manner the positioning of an exciter unit generally designated 97 within an acoustically opaque elongated housing tube 98, that tube having acoustically transparent open ends 99 and 100. The exciter unit 97, which may well comprise the variable position type of unit shown in FIGS. 11 and 12, is located with its radiating surfaces 88 and 89 spaced respectively from the open housing ends 99 and 100, thereby, when the ends of the housing tube 98 become flooded with water, producing loading liquid columns at both sides of the exciter unit 97. By varying the position of the unit 99 within the tube 98 and by varying the length of the tube 98 in accordance with the well recognized weighting and phasing properties the amount of radiation propagated both to the right and to the left as viewed in FIG. 13 may be controlled and adjusted.

For all of the illustrated embodiments it is preferred that none of the structure except the exciting unit (vibration-causing means) and the liquid column resonate except at frequencies much higher than those of the produced vibrations. Hence the fluid in the chamber, including first and second chamber parts when present, will be acoustically contained within the surrounding structure with a high degree of effectiveness.

There has now been described a basic and wholly novel concept of a transducer designed for underwater applications. In addition to the advantages described above concerning small size and low Q, the novel transducers do not contain any soft pressure-release material and, therefore, their operating characteristics are not substantially altered by high ambient pressure variations. In the embodiments utilizing an insulating liquid, the exciter unit housing is small relative to the liquid column, so that the resonant frequency is only sightly varied by variations in ambient pressure. High efficiency and power handling capabilities are obtained, comparing favorably with, and often exceeding, those characteristics in previously available structures.

While the foregoing description sets forth the principles of the invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation of the scope of the invention as set forth in the following claims.

I claim:

1. A transducer for underwater acoustic energy propagation comprising a housing having a chamber with first and second parts, each of said chamber parts being substantially filled with a liquid, means in said first chamber part for causing the liquid therein to vibrate at a given frequency, means for operatively connecting the liquid in each of said chamber parts for vibration transmission therebetween, and means for transmitting the liquid vibrations in said chamber to the exterior of said housing, said housing structure being essentially acoustically opaque to vibrations at said given frequency.

2. The transducer of claim 1, in which said second chamber part has an acoustical length such in conjunction with said first chamber part as to form a liquid column having an effective acoustical length relative to said vibration-causing means which is substantially one-quarter of the wave length in said chamber of vibrations at said given frequency.

3. The transducer of claim 2, in which the same liquid is in said first and second chamber parts.

4. The transducer of claim 2, in which an insulating liquid is in said first chamber part and liquid from the medium surrounding said housing is in said second chamber part, said liquid in said first and second chamber parts being separated by a partition impermeable to the flow therethrough of either of said liquids, which partition comprises said means for operatively connecting the liquid in each of said chamber parts.

5. The transducer of claim 2, in which the liquid in said first and second chamber parts are separated by a fluid-impermeable partition substantially freely vibratable at said given frequency, which partition comprises said means for operatively connecting the liquid in each of said chamber parts.

6. The transducer of claim 5, in which said vibration causing means comprises a vibrated driving part operatively connected to said partition by the liquid in said first chamber part.

7. The transducer of claim 2, in which said first chamber part is acoustically opaque to the exterior of said

housing except via said second chamber part, said vibration-transmitting means being located in said second chamber part.

8. The transducer of claim 2, in which said first chamber part is acoustically opaque to the exterior of said housing except via said second chamber part, said vibration-transmitting means being located in said second chamber part as the end thereof remote from said first chamber part.

9. The transducer of claim 2, in which said vibration-transmitting means comprises a portion of said first chamber part.

10. The transducer of claim 2, in which said vibration transmitting means comprises a portion of said first chamber part and a portion of said second chamber part at the end thereof remote from said first chamber part.

11. The transducer of claim 2, in which said second chamber part comprises a horn having an open end remote from said first chamber part.

12. The transducer of claim 2, in which said second chamber part comprises a horn having an open end remote from said first chamber part, and a freely vibratable diaphragm separating said first and second chamber parts, said diaphragm being operatively connected to said vibration-causing means and comprising said means for operatively connecting the liquid in each of said chamber parts.

13. The transducer of claim 1, in which an insulating liquid is in said first chamber part and liquid from the medium surrounding said housing is in said second chamber part, said first and second chamber parts being separated by a partition impermeable to the flow therethrough of either of said liquids, which partition comprises said means for operatively connecting the liquid in each of said chamber parts.

14. The transducer of claim 1, in which said first chamber part is acoustically opaque to the exterior of said housing except via said second chamber part, said vibration-transmitting means being located in said second chamber part at the end thereof remote from said first chamber part.

15. The transducer of claim 1, in which said vibration-transmitting means comprises a portion of said first chamber part and a portion of said second chamber part at the end thereof remote from said first chamber part.

16. The transducer of claim 1, in which said second chamber part comprises a horn having an open end remote from said first chamber part, and a freely vibratable diaphragm separating said first and second chamber parts, said diaphragm being operatively connected to said vibration-causing means and comprising in said means for operatively connecting the liquid in each of said chamber parts.

17. A transducer for underwater acoustic energy propagation comprising a housing having a chamber with first and second parts, each of said chamber parts being substantially filled with a liquid, means in said first chamber part for causing the liquid therein to vibrate at a given frequency which is the resonant frequency of said means, means for operatively connecting the liquid in each of said chamber parts for vibration transmission therebetween, and means for transmitting the liquid vibrations in said chamber to the exterior of said housing, said housing structure being essentially acoustically opaque to vibrations at said given frequency.

18. The transducer of claim 17, in which said second chamber part has an acoustical length such in conjunction with said first chamber part as to form a liquid column having an effective acoustical length relative to said vibration-causing means which is substantially one-quarter of the wave length in said chamber of vibrations at said given frequency.

References Cited by the Examiner

UNITED STATES PATENTS

1,472,558	10/1923	Fessenden et al.	340—8
1,686,901	10/1928	Culver	340—8
1,733,718	10/1929	Biondel.	
2,405,226	8/1946	Mason	340—10
2,411,541	11/1946	Hayes	340—8
2,448,365	8/1948	Gillespie.	
2,522,389	9/1950	Mason	340—8
2,552,970	5/1951	Horsley et al.	

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