May 14, 1968 J. V. BOUYOUCOS 3,382,841

FLEXURAL DISC TRANSDUCER

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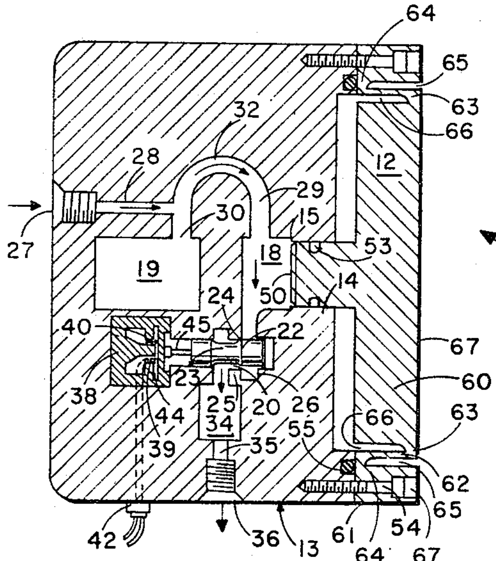

Fig. 1

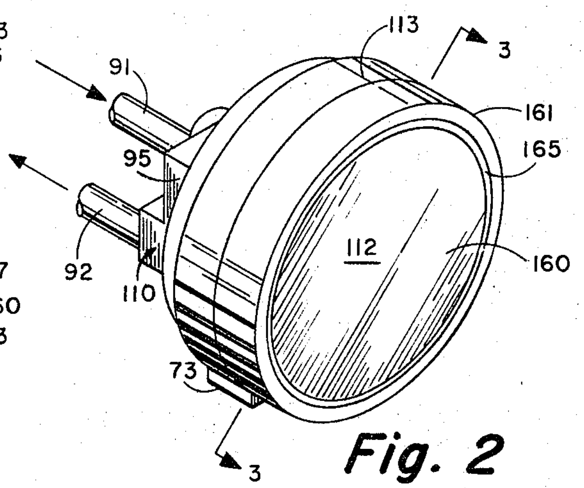

Fig. 2

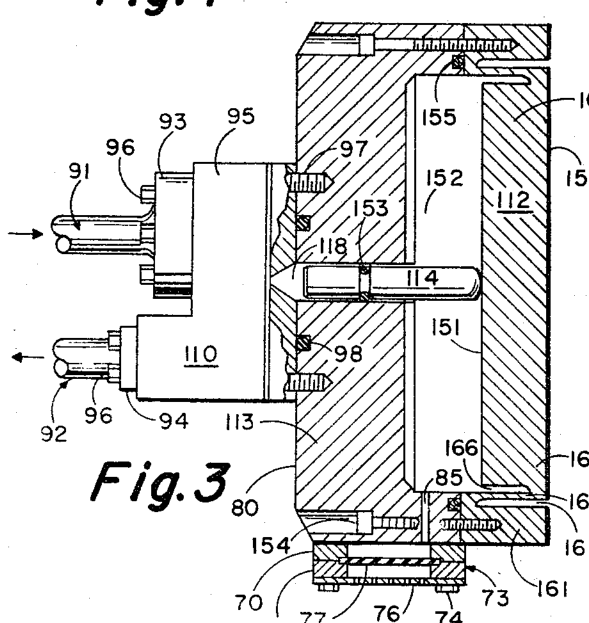

Fig. 3

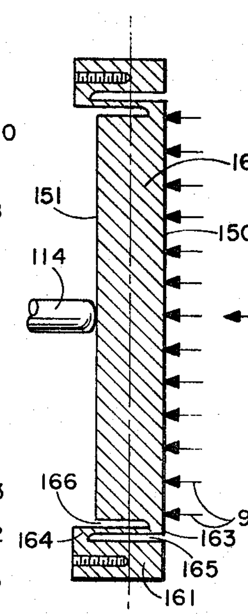

Fig. 4

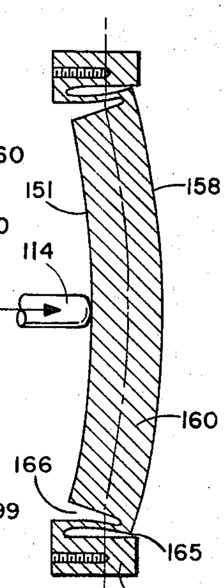

Fig. 4a

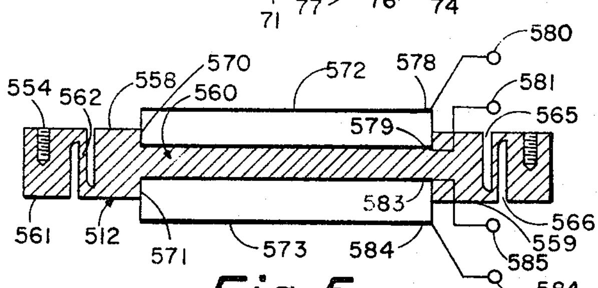

Fig. 5

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FLEXURAL DISC TRANSDUCER

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This invention relates to transducers for the generation and radiation of acoustic energy, and particularly to a flexural disc transducer. In a flexural disc transducer, the member which radiates acoustic energy is a disc or plate which exhibits an elastic, flexural mode of vibration rather than a rigid body piston-like motion.

Although the present invention is suited for more general applications, it is particularly adapted for use in deep underwater sound generators, as in the hydroacoustic transducers described in an application for a U.S. Letters Patent, Ser. No. 151,516 entitled, "Electro-Hydroacoustic Transducer," and filed by John V. Bouyoucos on Nov. 10, 1961 now U.S. Patent 3,212,473 and in U.S. Letters Patent No. 3,004,512 entitled, "Acoustic-Vibration Generator and Valve," issued Oct. 17, 1961, to John Bouyoucos.

There exists a need for underwater sound generators which can withstand high hydrostatic pressure and deliver high acoustic power into the surrounding water. In the above-mentioned U.S. patent application for "Electro-Hydroacoustic Transducers," there as described various hydroacoustic transducers wherein a radiating element constitutes a piston which moves as a rigid body connected to an elastic support which acts as a spring. While such transducers have the advantage of presenting a uniform velocity distribution across a face of the radiating element, they often are comparatively heavy because of the amount of solid material necessary to provide adequate piston rigidity.

Patent No. 3,004,512 describes a thin spherical shaped wall member that vibrates in response to fluid pressure variations in the acoustic generator. This wall member is adapted for transmitting or coupling acoustic energy into a surrounding body of water.

Bender plate or flexural disc transducers using piezoelectric materials are known. However these transducers generally have limited power handling capability owing to the stress limitation of the ceramic used therein, or have limited depth capability due to stress limitations in the plate or disc supporting member.

It is accordingly an object of the present invention to provide an improved sound generator having a flexural disc radiating element that transmits high acoustic power to a surrounding fluid medium and is light in weight and not subject to harmful stress levels.

It is another object of the present invention to provide an acoustic vibration generator which is adapted either to radiate acoustic energy uniformly at relatively high energy density from a large surface area or to couple to a load acoustic energy having high energy density.

Another object of the present invention is to provide an acoustic vibration generator having a relatively light coupling member which provides for efficient power transfer between a sound generator and a load.

It is a more specific object of the present invention to provide a transducer which can sustain high hydrostatic pressure and still handle high acoustic power.

It is another object of the present invention to provide a transducer having a large power handling capability without the need for sliding fluid seals.

It is still another object of the present invention to provide an improved edge support for acoustic coupling members.

It is yet another object of the present invention to

provide apparatus for decoupling an acoustic radiating element from its supporting structure.

Briefly described, a sound generator embodying the invention makes use of an improved flexural disc radiating element which provides large acoustic power handling capability without the aforesaid disadvantage of piston or thin spherical shaped wall members. This flexural disc radiating element also provides an acoustic transformer for transferring acoustic energy from a relatively small cross-sectional area to a relatively large cross-sectional area so that the impedances of an acoustic energy source and a load can be matched to each other.

The flexural disc radiating element in a preferred embodiment of this invention includes a unitary or monolithic structure having a flexural disc radiating portion, a peripheral mounting portion, and a thin shell or hollow, column-like structure connected between the radiating portion and the peripheral mounting portion. The flexural disc radiating element has two annular coaxial grooves located near the peripheral mounting portion of the disc, which grooves, in cooperation with the thin shell, separate and isolate the radiating portion from the peripheral mounting portion.

The two coaxial grooves are formed partway into the flexural disc radiating element from opposite sides and at different radii in a side by side relationship, so as to define the thin shell or hollow column-like structure between the radiating portion and the peripheral mounting portion. One end of the thin shell is fixed and integral with the peripheral mounting portion, while the other end of the shell is fixed and integral with the radiating portion. The thin shell is relatively flexible for lateral forces or movement at the ends thereof, but is substantially rigid for end thrust or longitudinal forces. The thin shell resists and is stiff to piston-like movement of the radiating portion, but is compliant to flexing or bending movement at the edge of the radiating portion. Thus, the radiating portion can be forced into a highly desirable edge-supported flexural mode of vibration for coupling acoustic energy from the generator to a surrounding fluid medium.

The monolithic structure eliminates the need for sliding hydrostatic seals. The flexural disc may be center-driven or driven in a distributed manner by various means such as a hydroacoustic or electroacoustic force generator. One advantage of the invention is that a center-driven all metallic flexural disc radiating element is simple in design and construction and presents an extremely rugged interface to the external environment. Another advantage resides in the fact that two flexural disc radiating elements may easily be mounted in a back to back relationship to provide a double end radiating element. A further advantage resides in the fact that the flexural disc radiating element may be flooded with a compliant liquid. In the latter case, the resonant frequency of the transducer is determined by the combined stiffness of the radiating portion and its backing fluid and the total effective mass of the moving system. Since a compliant liquid backed transducer is readily pressure equalized to ambient pressure, such as a transducer is suited for deep submergence application.

The invention itself, both as to its organization and method of operation, as well as additional objectives and advantages thereof, will become more readily apparent from a reading of the following description in connection with the accompanying drawing in which:

FIG. 1 is a cross-sectional view, along a vertical central plane, of a flexural disc transducer in accordance with the invention;

FIG. 2 is a perspective view of another flexural disc transducer also embodying the invention, the transducer having a flexural disc radiating element;

FIG. 3 is an elevational view, partially in section of the transducer shown in FIG. 2;

FIG. 4 is a sectional view, taken along a diametral plane, of the flexural disc radiating element shown in FIG. 2 in a rest or neutral position;

FIG. 4*a* is a view, similar to FIG. 4, of the flexural disc radiating element in an exaggerated position during a flexural mode of operation; and

FIG. 5 is a sectional view, taken along a diametral plane, of a flexural disc transducer employing electrostrictive ceramic elements for driving the flexural disc radiating element thereof in accordance with another embodiment of the invention.

FIG. 1 illustrates a hydroacoustic transducer **10** of the type described in U.S. patent application, Ser. No. 151,516 mentioned above, which includes a flexural disc radiating element **12** secured to one end of a stationary housing **13**. Flexural disc radiating element **12** includes a drive piston **14**. Drive piston **14** is contiguous to a drive cavity **18** of the housing **13** and moves axially in a cylindrical bore **15** in consequence of acoustic pressure signals generated within drive cavities **18** and **19**. These pressure signals are developed by a modulation of the flow of a hydraulic fluid through a variable area orifice **20** defined by a metering rim **22** of a movable valve **23** and the corresponding rim **24** of an inwardly extending portion **25** of a stationary port structure **26**. The hydraulic fluid enters under pressure at an inlet port **27** and passes through an inlet line **28** and through line branches **29** and **30** into drive cavities **18** and **19**. The direction of fluid flow is indicated in the various figures of the drawing by arrows.

The branches **29** and **30** of FIG. 1 combine to form a loop **32** which provides an inertance in parallel with the acoustic compliance of cavities **18** and **19**. The fluid passes from cavity **18** through orifice **20** and thence at reduced pressure into discharge chamber **34** which communicates, through an outlet line **35**, with a fluid exit port **36**. The valve **23** is driven in a direction axially thereof along a path past the stationary port structure **26**. An electromechanical force generator **38** drives the valve **23**. The generator **38** includes a moving coil **39** free to move in magnetic field structure gap **40** when energized by an electrical control input signal supplied to the coil **39** by way of a pair of leads **42**. The coil **39** is wound upon a portion of a spider **44** and the movement of the coil **39** is communicated to the valve **23** through a connecting rod **45**. If the resonant frequency defined by the mass of the moving system and the stiffness of the spider is placed above the operating frequency range, the valve displacement will be directly proportional to and in phase with the input signal. In moving in reciprocal fashion within the port structure **26**, the valve **23** cyclically varies the size of the orifice **20**. A variational velocity disturbance or change in the velocity of the fluid generated by the size change at orifice **20** can give rise either to compression or expansion of the fluid within drive cavities **18** and **19** or to motion of the fluid within loop **32**. The combination of cavities **18** and **19** and the loop **32** thus constitutes an acoustic tank circuit.

As the pressure variations in the cavity **19** are 180° out of phase with the pressure variations in the cavity **18** at the nominal operating frequency, a point of zero pressure variation (acoustic ground) is found along the inertance loop **32**. This point is used as the feed-in point for hydraulic fluid, thereby reducing the possibility of coupling energy from the acoustic tank circuit of the transducer back into the unidirectional flow source. Thus the line **28** terminates at the zero pressure point. The cavity **19**, as shown in FIG. 1, is larger than the cavity **18**; consequently, the zero pressure point along inertance loop 32 will be nearer the larger cavity **19**. It should be understood that the drive cavities **18** and **19** may be of the same size in certain applications. Because of the presence of the inertance presented by a loop **32**, it is possible to tune and resonate, independently of each other, the acoustic tank circuit and the load coupling circuit. The load coupling circuit is made up principally of the effective mass of the flexural disc **12** and the flexural compliance of the disc **12** associated therewith. The injection of fluid from orifice **20** into the parallel tank circuit result in pressure variations therein which, in turn, operate on the surface **50** of the drive piston **14** to generate motion of the flexural disc radiating element **12** against an external load, such as a body of water.

The flexural disc radiating element **12** is made from a high strength elastic material such as aluminum alloy 7075–T6 having a composition of 5.5% Zn, 2.5% Mg, 1.5% Cu and 0.3% Cr. The flexural disc radiating element is driven by a piston **14** which may be an integral part of the flexural disc radiating element **12** or may be driven by various other ways as illustrated in FIGS. 3 and 5 and described hereinafter. The flexural disc radiating element **12** (FIG. 1) comprises a radiating portion **60** which includes the piston **14**, a peripheral mounting portion **61** and a hollow column-like portion which is in the shape of a thin cylindrical shell **62**. This shell **62** is defined by two coaxial circular grooves **65** and **66** located near the peripheral mounting portion **61** of the flexural disc radiating element **12**. The coaxial grooves **65** and **66** are blind, i.e. they extend only part way into the flexural disc radiating element **12** and from opposing sides. The grooves have different diameters; i.e., they are at different radii from the center of the disc. The grooves are in side-by-side relationship so as to define the thin cylindrical shell **62**. The thin shell **62** is connected to the radiating portion **60** at one end **63** and to the peripheral mounting portion **61** at the other end **64** of the thin shell **62**.

The thin shell **62** provides an improved cylindrical edge support for the radiating portion **60**. The wall of the thin cylindrical shell **62** is substantially perpendicular to a radiating face **67** of the radiating portion **60**; i.e., the axis of the shell **62** is perpendicular to the face **67**. The thin shell **62** behaves in accordance to the physical laws governing thin cylindrical shells when subjected to end thrust and lateral forces applied to the ends **63** and **64**; that is, the thin shell **62** is stiff and highly resistive to end thrust or to piston-like movement of the radiating portion **60**. The thin shell **62** however is free to bend in response to lateral forces exerted at its ends **63** and **64**. The thin shell **62** is particularly compliant to lateral forces generated at the end **63** when the radiating portion **60** is vibrated in a flexural mode.

The radiating portion **60** has a disc-like body similar to the radiating portion **160** shown in perspective view in FIG. 2. The radiating portion **60** has a diameter to thickness ratio which may be in the order of approximately 8:1. A flexural radiating disc element **12** has been built and operated with a radiating portion **60** having a diameter of approximately 17.5 inches and a thickness of approximately 2 inches. The dimensions just given are for illustrative purposes only.

The peripheral mounting portion **61** is securely clamped to the housing **13** by bolts **54**. The peripheral mounting portion is shown as ring-like in cross sectional area. However, the mounting portion **61** may have other shapes. An O-ring **55** provides a seal between the flexural disc radiating element **12** and the housing **13**. The peripheral mounting portion **61** includes a series of mounting holes **67** for the bolts **54**. The mounting holes **67** are uniformly spaced so as to provide an even clamping between the mounting portion **61** and the housing **13**.

When vibratory fluid forces are applied on the face **50** of drive piston **14**, the radiating portion **60** flexes in a flexural mode of vibration as though that portion were supported along its circular edge. The radiating portion **60** is forced into this flexural mode of vibration, since the edge support provided by the thin shell **62** is stiff to extension and compression and therefore offers a high impedance to piston-like movement of the radiating portion **60** or to axial translation of the edge of radiating portion **60**. The thin shell **62**, however, offers comparatively negligible impedance to bending or to lateral movement of the edge of radiating portion **60**. Freedom for bending yet high impedance to piston action or axial translation provided by the ends **63** and **64** and by the thin shell **62** respectively, enables the flexural disc radiating element **12** to exhibit an edge-supported flexural mode of vibration rather than a piston-like mode of virbation. This edge-supported mode of vibration is characterized by an axial displacement of the radiating portion **60**, which starts at the end **63** of the thin shell **62** and reaches a maximum at the center of the radiating portion **60**. The manner in which the radiating portion **60** and the thin shell **62** bends or flexes is shown in more detail in another embodiment of the flexural disc radiating element in FIGS. 4 and *4a*, and will be described more in detail hereinafter.

In FIGS. 2 and 3 there is shown a single embodiment of a modification of the device of FIG. 1. Elements of the device of FIGS. 2 and 3 corresponding to those of FIG. 1 are indicated by the same reference numeral plus **100**. The device of FIGS. 2 and 3 aside from certain mechanical assembly details differ essentially in that the flexural disc radiating element **112** is backed with a compliant liquid instead of air. The drive piston **114** is shown as a free piston which is biased against the radiating portion **160** by a pressurized fluid in the chamber **118**. The drive piston **114** includes an O-ring **153**.

The transduced **110** of FIGS. 2 and 3 is particularly useful for transducers which are submerged to a considerable depth in sea water. The pressure of the backing liquid within cavity **152** may be equalized to the pressure of the sea in which the transducer **110** is submerged by means including a rubber diaphragm **77** trapped between two anchor members **70** and **71** of an assembly **73** and attached by screws **74** to the portion **80** of the housing **113**. The rubber diaphragm **77** is exposed on one side to ambient sea water passing through a perforated cover **76** which also forms a portion of the assembly **73**. The rubber diaphragm **77** is also exposed to the fluid in the interior of the cavity **152** by means of a narrow passage **85** in the portion **80** of the housing **113**.

The flexural disc radiating element **112** is attached to the periphery of the portion **80** of the housing **113** by bolts **154**.

The transducer **110** also includes a hydraulic input port assembly **91** and an output port assembly **92**, which include flanges **93** and **94** connected to a portion **95** of the housing **113** by bolts **96**. The portion **95** of the housing **113** is bolted to the enlarged housing portion **80** by bolts **97**. Acoustic pressure variations produced within cavity **118** of the hydroacoustic amplifier **110** produces vibratory hydraulic forces on the drive piston **114** which causes movement of the flexural disc radiating element **112** in a manner similar to that shown and described in FIG. 1, except, of course, the piston **114**, while biased to remain in contact with radiating portion **160**, is not an integral part of the radiating portion **160**. The fluid within cavity **152** is isolated from the acoustic amplifier drive cavity **118** by means of the O-ring **153** cooperating with drive piston **114**. Similarly, fluid leakage from cavities **118** and **152** to the exterior of housing **113** is prevented respectively by O-rings **98** and **155**.

In the operation of the device shown in FIGS. 2–*4a* inclusive, the hydroacoustic amplifier **110** produces acoustic pressure variations in the cavity **118** in a similar way as described for the device of FIG. 1. The average pressure in the cavity **118** biases the free piston **114** against the radiating portion **160** with sufficient force so that piston **114** will remain in intimate contact with radiating portion **160** throughout the cycle of vibration. The alternating pressure variations in the cavity **118** are transmitted thru the free piston **114** to the radiating portion **160**. The free piston **114** exerts a dynamic force on the radiating portion **160**, which force is equal to the product of the alternating pressure variations in cavity **118** and the cross-sectional area of piston **114**.

The radiating portion **160** is shown in FIG. 4 in a neutral or rest position. Shown at **99** are a plurality of uniformly distributed force arrows representing a uniform load such as the hydrostatic ambient sea pressure acting on a front face **158** of the radiating portion **160**, when the back face **151** is, for example, in contact with air at atmospheric pressure, as might be the case in the structure o FIG. 1. The axis of the thin shell **162** and the grooves **165** and **166** are substantially perpendicular to the front face **158** of the radiating portion **160** so as to withstand high axial forces and yet be relatively compliant to bending moments acting at the end **163**, as described previously for the flexural disc radiating element **60** of FIG. 1. The axial forces acting on the thin shell **162** are a summation of all the forces **99** acting normal to the face **158**.

The static axial stress in the thin shell **162** is equal approximately to the net axial static force exerted on radiating portion **160** divided by the cross-sectional area of the thin shell **162**, as established by its diameter and wall thickness. Once the axial force has been specified, as for example, by specifying the maximum depth of operation, a cross-sectional area of the thin shell **162** can be selected to achieve a satisfactory stress level. The bending moment exerted by the thin shell **162** on the edge of radiating portion **160**, as well as the bending stress in thin shell **162**, can then be controlled by the choice of the length of the thin shell **162**. The ability to choose independently the shell thickness to contral axial stress, and the shell length to control bending stiffness and bending stress is a particularly attractive and important feature.

When the hydroacoustic amplifier **110** is operated, the drive piston **114** is responsive to the alternating pressure in the cavity **118** and drives the radiating portion **160** into a flexural mode of vibration as previously described for the radiating portion **60** of FIG. 1. FIG. *4a* shows the radiating portion **160** in an exaggerated flexural deflection to show the displacement of the radiating portion **160** across its faces **158** and **159** and to show at the same time the displacement of the thin shell **162**. The radiating portion **160** flexes about its neutral axis while the thin shell **162** flexes in a cylindrical plane which is substantially perpendicular to the neutral axis of the radiating portion **160**. Effectively, it appears that the radiating portion **160** flexes substantially about its neutral axis along a line substantially midway between the ends **163** and **164** of the thin shell **162**.

FIG. 5 shows a flexural disc radiating element and electroacoustic drive means for driving the flexual disc radiating element into a flexural mode of vibration. Elements of the flexural disc radiating element of FIG. 5 corresponding to those of FIG. 1 are indicated by the same reference numeral plus **500**. The flexural disc radiating element **512** comprises a radiating portion **560**, a peripheral mounting portion **561**, and a thin shell **562**. The peripheral mounting portion **561** is substantially similar to the mounting portion **161** of the flexural disc radiating element **112** of FIG. 3. Mounting holes are provided at **554**. The thin shell **562** is encircled by two proximal grooves **565** and **566**.

The radiating portion **560** includes two cavities **570** and **571** on faces **558** and **559** respectively. Disposed in the cavities **570** and **571** are piezoelectric members, such as electrostrictive ceramic discs **572** and **573** respectively. The discs **572** and **573** are loaded tightly within the cavities **570** and **571** so that any radial expansion or contraction of the electrostrictive ceramic discs **572** and **573** will be translated into flexural motion of the radiating portion **560**. Electrostrictive ceramic disc **572** includes flat electrodes **578** and **579** connected to input terminals **580** and **581** respectively. Electrostrictive ceramic disc **72** is polarized so as to expand and contract in a radial direction in response to a varying AC signal applied to input terminals 580 and 581.

Electrostrictive ceramic disc 573 includes electrodes 583 and 584 connected to terminals 585 and 586 respectively. Electrostrictive ceramic disc 573 is also polarized to expand and contract in a radial direction, in response to a varying AC signal applied to the input terminals 585 and 586.

In the operation of the device of FIG. 5, and AC electrical input signal is applied to input terminals 580 and 581 of the electrostrictive ceramic disc 572 and to input terminals 584 and 585 of electrostrictive ceramic disc 573 in a manner well known to those skilled in the art so that electrostrictive ceramic disc 572 will expand and contract while electrostrictive ceramic disc 573 will contract and expand alternately during each cycle of the AC electrical signal. In response to the phase opposed radial expansion and contraction of electrostrictive ceramic discs 572 and 573 respectively, the radiating portion 560 is urged into a flexural mode of vibration. The frequency of the vibrations is a function of the frequency of the electrical input signal applied across electrostrictive ceramic discs 572 and 573.

The device of FIG. 5 is particularly advantageous over prior art devices since the flexural disc radiating element 512 incorporates an edge support for the electrostrictive ceramic discs 572 and 573 which may be exceptionally stiff for axial translation of the edge, yet which provides a low bending moment for the radiating portion 560 at its edge. The low stress inherent in the design of the peripheral mounting portion 561 enables the electrostrictive discs such as 572 and 573 to be used for transducers which are subjected to high hydrostatic pressures.

Whereas the above examples have illustrated the use of hydroacoustic and electrostrictive means as force generators to drive the flexural disc radiating element of the invention, other force generators are equally applicable, such as moving coil, magnetostrictive, and purely mechanical generators. Accordingly, the foregoing description should be taken as illustrative and not in any limiting sense.

What is claimed is:

1. A transducer comprising
(a) a disc radiating element of elastic material having a peripheral mounting portion and a disc-like radiating portion,
(b) said disc radiating element including coaxial grooves on opposite faces thereof encircling said radiating portion to define a thin cylindrical shell therebetween connected,
(c) said thin cylindrical shell providing at one end thereof a lateral compliant edge support for said one edge of said radiating portion, and
(d) means coupled to said radiating portion to excite said radiating portion into vibration.

2. An acoustic vibration transducer comprising
(a) a flexural disc radiating element having a peripheral mounting portion and a disc-like radiating portion,
(b) said disc-like radiating portion having two substantially parallel edges,
(c) said flexural disc radiating element including relatively deep proximal coaxial grooves on opposing faces thereof encircling said radiating portion to define a thin cylindrical shell therebetween, said shell having an axis substantially normal to at least one surface of said radiating portion,
(d) said thin cylindrical shell providing at one end thereof an edge support for said one of said edges of said radiating portion,
(e) said shell having less impedance to lateral forces than to longitudinal forces applied at said one edge, and

(f) means coupled to said radiating portion to excite said radiating portion into vibrations.

3. An acoustic vibration transducer comprising
(a) a disc-like radiating element of elastic material having a peripheral mounting portion and a disc-like radiating portion,
(b) means coupling the outer periphery of said mounting portion for providing less impedance to a force in a direction along the surface of said disc than to a force transverse to said surface, and
(c) means coupled to said radiating portion to excite said radiating portion into vibrations.

4. An acoustic vibration transducer comprising
(a) a flexural disc radiating element having a peripheral mounting portion and a disc-like radiating portion,
(b) said flexural disc element including relatively deep proximal coaxial grooves on opposing faces thereof in a side by side relationship to define a thin short cylindrical shell substantially normal to said radiating portion,
(c) said shell being connected at one end to said peripheral mounting portion and at the other end to one edge around one face of said radiating portion,
(d) said thin cylindrical shell providing a circular edge support for said radiating portion having less impedance to flexing of said radiating portion than to piston-like movement of said radiating portion, and
(e) means coupled to said radiating portion for exciting said radiating portion into vibrations.

5. An acoustic vibration transducer comprising
(a) a housing including annular support means, at least a portion of said housing defining a path for the steady flow therethrough of a fluid medium under pressure,
(b) fluid chamber means,
(c) fluid flow switching means including a movable valve interposed in said path for modulating repetitively the flow of fluid through said chamber means, the movement of said valve converting a portion of the steady flow energy into acoustic vibrations within said chamber means,
(d) a drive member set in motion in response to said acoustic vibrations,
(e) a flexural disc radiating element having a peripheral portion rigidly secured to said support means,
(f) said disc element also including a radiating portion and a thin cylindrical shell portion integral with said disc,
(g) said thin shell portion being connected to said peripheral portion at one end thereof and being connected to said radiating portion at the other end thereof,
(h) said drive member operatively engaging said radiating portion of said disc, and
(i) said radiating portion being set into vibration in consequence of the motion of said drive member.

6. An acoustic vibration transducer comprising
(a) a housing including annular support means, at least a portion of said housing defining a path for the steady flow therethrough of a fluid medium under pressure,
(b) fluid chamber means,
(c) fluid flow switching means including a movable valve interposed in said path for modulating repetitively the flow of fluid through said chamber means,
(d) the movement of said valve converting a portion of the steady flow energy into acoustic vibrations within said chamber means,
(e) a drive element driven in response to said acoustic vibrations,
(f) a flexural disc radiating element having a peripheral portion rigidly secured to said support means,
(g) said disc further including a radiating portion and a thin cylindrical shell integral with said disc element,
(h) said radiating portion and said thin cylindrical shell

being disposed within said peripheral portion of said flexural disc radiating element and formed by closely spaced oppositely directed coaxial grooves within said disc element,

(i) said grooves being disposed along different radii on said disc element,

(j) said drive element operatively engaging said radiating portion of said disc element, and

(k) the diameter of said radiating portion being long compared to the thickness dimensions of said radiating portion.

7. A transducer comprising

(a) a flexural radiating element having peripheral mounting portions and a radiating portion,

(b) said flexural radiating element including spaced apart grooves on opposite faces thereof encompassing at least a part of said radiating portion to define thin columns interconnecting said radiating portion to said peripheral mounting portions,

(c) said thin columns providing at one end thereof an edge support for said radiating portion, and

(d) means coupled to said radiating portion to excite said radiating portion into vibrations.

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