

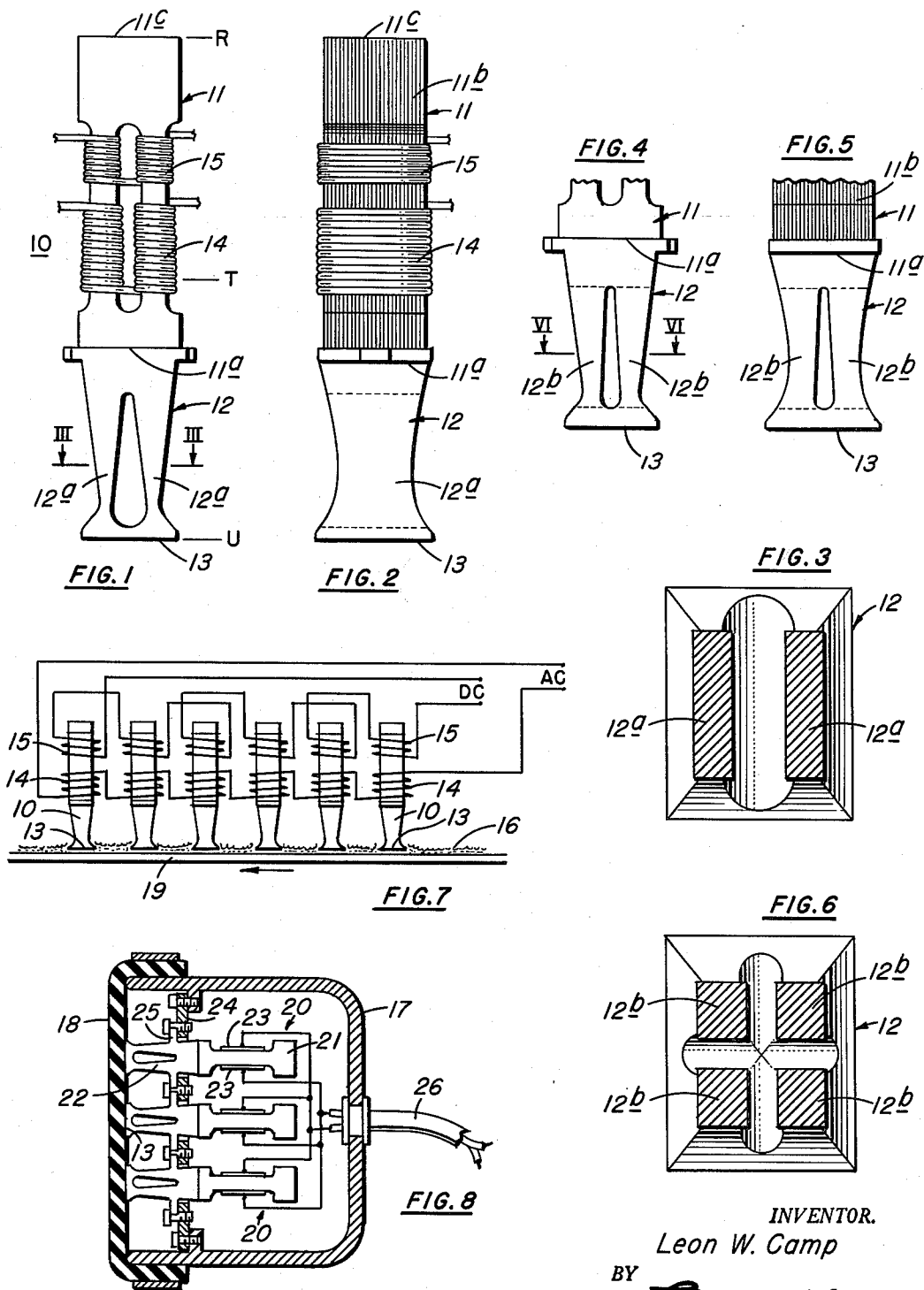
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SONIC TRANSDUCER WITH MECHANICAL MOTION TRANSFORMER

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SONIC TRANSDUCER WITH MECHANICAL
MOTION TRANSFORMER

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This invention relates to electromechanical transducers for generating or detecting sonic waves in fluid mediums. In this connection, the term "sonic" is intended to include waves of frequencies above the audible range, as well as those within it.

A general object of the invention is to improve the over-all efficiency of electromechanical sonic transducers.

Another object is to provide an electromechanical transducer of the mechanically resonant type having a good impedance match with the fluid medium with which it works.

Another object is to provide a practicable method of controlling the band width of a resonant electromechanical transducer.

Other more specific objects and features of the invention will appear from the description to follow.

Electromechanical transducers for use in water at sonic and ultrasonic frequencies commonly employ a body of solid electroresponsive material which expands and contracts when subject to an alternating magnetic or electric field and is so dimensioned as to be mechanically resonant at its operating frequency. The most commonly used materials are magnetostrictive substances such as nickel; piezoelectric crystals; and ceramics containing barium titanate. It is characteristic of all such materials that they are relatively rigid and vibrate with very small amplitude, although producing relatively large forces. Stated another way, they have high mechanical impedance, usually quite radically different from the acoustic impedances of liquids such as water, and have an undesirably low efficiency of energy transfer when coupled directly thereto. In this connection, it is to be understood that a perfect impedance match which would give maximum energy transfer between the transducer and the liquid is usually undesirable with a mechanically resonant transducer, as it would reduce the efficiency of conversion of the electrical energy to mechanical vibratory energy within the transducer. However, it is highly desirable to be able to control the mechanical impedance, and it is done in accordance with the present invention by a novel solid horn construction.

It is known that if a solid horn has its large end secured to the working face of a vibrating body, the amplitude of longitudinal oscillation at the small end of the horn can be increased to an extent inversely proportional to the ratios of the square roots of the areas at the large and small ends. Such devices are used in ultrasonic drilling, testing, etc. Contrariwise, solid expanding horns have been suggested in underwater transducers to obtain a large area of contact with the water. Neither device produces a perfect coupling to a liquid. The contracting horn has large amplitude of oscillation at its working end, which is desirable, but has too small an area acting against the fluid to be fully effective. The expanding horn has the desirable larger working face, but its amplitude of vibration is reduced as compared to that of the vibrating body.

In accordance with the present invention, I employ

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a plurality of small contracting horns extending in parallel relation from the electromechanical vibrator and connected at their outer (small) ends to a unitary diaphragm having a continuous working face of area which may be as large or larger than the face of the vibrator. It is sometimes possible to obtain satisfactory results by using only a single contracting horn between the vibrator and the diaphragm, but usually a single arrangement is unsatisfactory, because the diaphragm flexes and all portions thereof do not vibrate together as a rigid member. In this connection, the diaphragm should be as light as possible, and perfect rigidity cannot be achieved in practice. However, by using a plurality of horns or legs to drive the diaphragm at a plurality of points, it is practicable to obtain a diaphragm face all portions of which vibrate at high amplitude in phase with each other, and still keep the mass of the diaphragm desirably low. By virtue of the low mass and large amplitude of vibration of the diaphragm, the resistance to motion applied to the small ends of the horns is in the main determined by the motional resistance of the liquid in contact with the diaphragm. Hence, the coupling between the transducer and the liquid is efficient, which is another way of stating that the impedance match is good. An important advantage is that the mechanical impedance of the transducer can be regulated within a wide range by properly selecting the taper of the horns or legs. This makes it practicable to design a resonant transducer of any desired band width within a wide range. Other advantages of the construction will appear from the following detailed description.

In the drawing:

Fig. 1 is a side view of a magnetostriction transducer incorporating the invention.

Fig. 2 is a side view looking at either side of Fig. 1.

Fig. 3 is a cross section in the plane III—III of Fig. 1.

Fig. 4 is a side view of an alternative horn construction.

Fig. 5 is a side view looking at either side of Fig. 4.

Fig. 6 is a cross section in the plane VI—VI of Fig. 4.

Fig. 7 is a schematic diagram showing a plurality of units in accordance with Fig. 1 used for sonic cleaning.

Fig. 8 is a schematic diagram showing the use of a plurality of transducer elements in accordance with the invention in an underwater transducer.

Referring to Figs. 1 and 2, there is shown a transducer element 10 comprising an electromechanically responsive body 11 having a front face 11a joined to the rear end of a motion-transforming member 12, the front end 13 of which constitutes a sound-absorptive or radiating diaphragm.

The body 11, as shown, is a magnetostriction vibrator consisting of laminations 11b of nickel and having an A. C. winding 14 and a D. C. polarizing winding 15. The magnetostriction vibrator is of the type shown in my Patent 2,530,244 and, as heretofore used, would have its front face 11a directly coupled to the sound-conveying medium.

The motion-transforming member 12 is preferably of metal and may be brazed or welded directly to the face 11a so that it is firmly affixed thereto. The member 12 is divided longitudinally into two legs or horns 12a 12a, which are rectangular in cross section (Fig. 3) throughout their length but gradually taper from a maximum cross section at their rear ends to a minimum cross section at a neck closely adjacent the front end. In front of its neck each leg expands smoothly but rapidly into the diaphragm 13 which, as shown, is of only slightly smaller area than the face 11a.

Because of the smooth and relatively gradual reduction in the cross sectional area of each leg 12a up to the neck, a true horn action is obtained which results in an increase in amplitude of particle movement at the neck substantially inversely proportional to the square

root of the ratio of the area of the rear end of the leg to the area at the neck. However, because of the short distance from the necks to the diaphragm face 13 and the rapid expansion of the area between these points, the horn action (which, if present, would greatly reduce the amplitude in the face 13 as compared to the neck) is relatively slight, and the amplitude of motion of the diaphragm face is very nearly as great as that in the necks of the legs.

Various modes of vibration may be obtained with the structure in Fig. 1, depending upon the frequency of excitation.

As usually constructed for use alone, a magnetostriction element corresponding to element 11 is made one-half wave length long, under which condition it vibrates with maximum motion at its opposite ends and with minimum motion in a plane intermediate the ends.

If the total length of the transducer 10 from the plane R of the rear face to the plane U of the front face is a half wave length, it likewise will have maximum motion at its ends and minimum motion in a plane intermediate its ends. This is its lowest or fundamental frequency of operation.

An advantage of the present construction is that it will also function efficiently at double its fundamental frequency, under which condition the over-all length of the transducer is one wave length. When the total length is one wave length, maximum motion occurs at opposite ends in the planes R and U and in an intermediate plane T, and minimum motion occurs at two planes intermediate the planes R and T, and the planes T and U, respectively.

The half wave construction has the advantage that for a given frequency the minimum amount of electromechanically responsive material is required (some materials, such as nickel, are relatively expensive). It is sometimes objectionable, because the plane of maximum stress is adjacent the junction of the body 11 and the member 12, but with many materials it is practicable to bond the parts together with sufficient strength to resist the forces involved.

Since the same structure can be operated at high efficiency either at its fundamental frequency or the first harmonic thereof, the invention is particularly suitable for use in systems where it is desired to signal at either of two frequencies.

To indicate the increase in energy transfer obtained by the use of the motion transformer 12, the band width of a 10,000-cycle transducer in accordance with Fig. 1 can easily be made 2,000 cycles per second, whereas a 10,000-cycle transducer like element 11 with its face 11a coupled directly into water has a band width of only about 250 cycles per second.

It is perfectly practicable to operate a magnetostriction transducer of the type shown in Fig. 1 at its first harmonic frequency, because the major portion of the length of the magnetostrictive body 11 is on one side of the plane T and is being stressed the same at any instant, so that all the resultant magnetic forces are in phase. If the entire length of the transducer were made up of magnetostrictive material, half of it would be in tension while the other half was in compression, and the resulting magnetic forces would not all be in phase with each other.

It is to be noted further that it is not necessary that the body 11 and the transforming member 12 be of the particular relative lengths shown in Fig. 1, although those lengths are well suited to operation at the fundamental frequency. When the frequency of operation is the first harmonic, it may be preferable in some instances to make both units of equal length or make the transformer member 12 of greater length than the magnetostriction element 11, in order to separate the junction between the two elements from the plane of maximum stress.

Figs. 4, 5 and 6 show a construction identical with

that of Figs. 1 and 2 except that four horns or legs 12b are provided in the motion transformer 12 instead of two. Increasing the number of legs provides a better distribution of the driving force on the diaphragm and facilitates vibration of all portions of the diaphragm in phase. The extent to which the horn should be subdivided in any particular case depends on the wave length or frequency employed and the area of the diaphragm.

Fig. 7 shows an application of transducers in accordance with the invention to the cleaning of a plate 19 which is moved past an array of transducers 10 having their vibrating faces 13 in a common plane very close to the path of movement of the plate 19 and immersed in a liquid 16 on the plate. Intense compressional waves can be set up in the liquid 16 which are very effective in cleaning the plate.

In a system such as shown in Fig. 7, the action between each diaphragm 13 and the plate 19 is independent of the others, and it is not necessary that they be in phase with each other. Under these conditions it is desirable to reverse the connections to half of the polarizing windings relative to the A. C. windings, to neutralize the A. C. potentials induced in the polarizing circuit by the A. C. in the A. C. windings. This is done in Fig. 7 by inverting the connections to alternate polarizing windings 15. It could equally well be accomplished by inverting the connections to alternate A. C. windings 14, or reversely connecting either the A. C. or D. C. connections on half the transducers wherever located.

Fig. 8 shows one application of the invention to an underwater transducer. Here a plurality of elements 20 are positioned in an array within a case 17 having a sound window 18 to which the diaphragms 13 of elements 20 are bonded.

In this instance each element 20 is shown as consisting of a titanate ceramic body 21 bonded at its front end to a motion transforming member 22 generally similar in shape to the member 12 in Fig. 1. The ceramic body 21 has a reduced midsection to opposite sides of which electrodes 23 are bonded. The motion transforming member 22 may be of metal or a suitable non-metallic material of relatively good tensile strength and elasticity.

Since it may not be possible to produce as strong a bond to a titanate ceramic as to a metallic material, the vibrator 20 may preferably be energized at its first harmonic frequency so that the bond between the body 21 and the member 22 is located near the plane of minimum stress, i. e., a vibrational loop.

Since the diaphragms 13 are bonded to the sound window 18, the units or elements 20 are in part supported by the diaphragm. Additional support may be provided by a frame 24 in the casing to which the members 22 are joined at or near a vibrational node therein. To this end, flanges or ears 25 may be formed on the members 22 and secured by screws to the frame 24. The electrodes 23, 23 of each element are shown connected in parallel to those of the other elements and to the conductors of a cable 26.

Although for the purpose of explaining the invention a particular embodiment thereof has been shown and described, obvious modifications will occur to a person skilled in the art and I do not desire to be limited to the exact details shown and described.

I claim:

1. A transducer for high-frequency compressional waves in fluids comprising: a longitudinally expandible and contractible electromechanically responsive body having a front end face of substantial area; a diaphragm longitudinally spaced from said end face and having a front working face of substantial area; a motion-transforming member interposed between and interconnecting said body and diaphragm; and comprising a plurality of legs extending alongside each other, each leg tapering gradually from a maximum cross section at each end to a neck of

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minimum cross section at an intermediate point located substantially closer to the front end than the rear end.

2. A transducer according to claim 1 in which said legs are integrally formed and merge into each other adjacent their rear ends.

3. A transducer according to claim 2 in which said legs merge into each other adjacent their front ends.

4. A transducer according to claim 1 in which said body, diaphragm and legs are all of rectangular cross section throughout.

5. A transducer according to claim 1 in which the lengths of said body and said transforming member are each a quarter wave length at the operating frequency.

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6. A transducer according to claim 1 in which said body and said transforming member are each a half wave length at the operating frequency.

5 7. A transducer according to claim 1 in which the said neck of each leg is spaced approximately an integral number of half waves from the rear end of said electromechanically responsive body and substantially less than a quarter wave from said diaphragm face.

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