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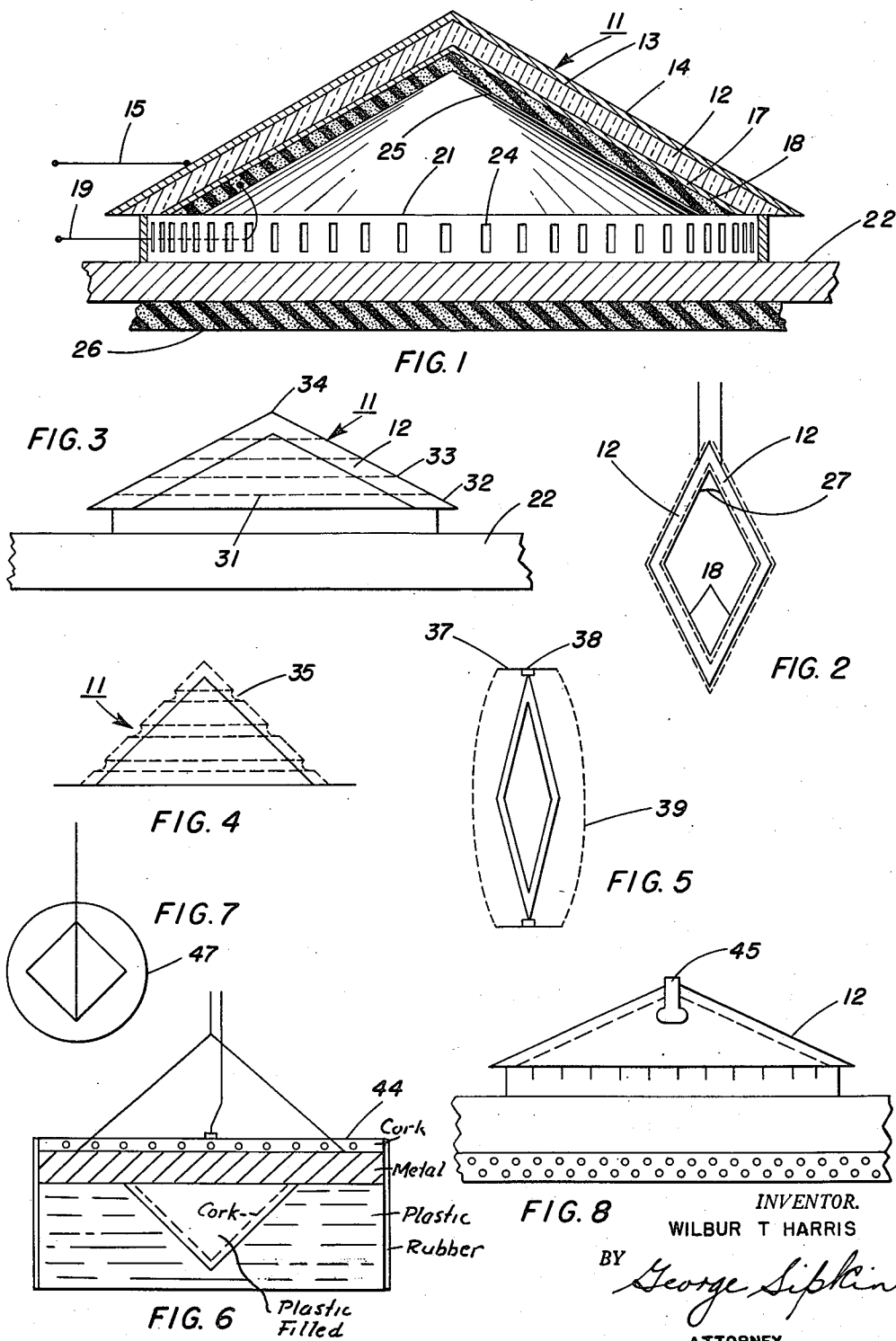


FIG. 8

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

This invention relates to transducers and more particularly to electromechanical transducers for use in either water or air and for a wide variety of frequency ranges and preferably having a sensitive element of electrostrictive material.

In the prior art electromechanical transducers embodied piezoelectric crystal or magnetostrictive sensitive elements in forms which did no allow for matching the mechanical impedance of the transducer to the sound medium in which the transducer was used. Furthermore the transducers did not have high efficiency over broad frequency ranges. Crystals were usually employed in the form of blocks suitably assembled in the transducer structure. In magnetostrictive transducers in the form of wound cylinders, rod, laminated rings, or the like of magnetostrictive materials were employed in suitable assemblies. In general, mechanical and electrical considerations dominated transducer designs so that many desirable features could not be conveniently incorporated.

In order to obtain high efficiency in a transducer, it is necessary that it be mechanically resonant. This mechanical resonance in prior art transducers occurs normally at one discrete frequency, so that highly efficient transducers normally possess this high efficiency in a very narrow frequency range. At other frequencies, their efficiencies are low. It has been generally considered impossible to attain high efficiencies in broadband transducers.

The conical transducer structure of this invention provides more efficient broadband performance in two important ways. In the first place it makes it possible for the mechanical impedance to be matched to the sound medium and in the second place the structure has inherent in it a distributed resonant effect for efficient broadband response.

An object of this invention is to provide an electromechanical transducer which can be used efficiently in either water or air.

A further object is to provide an electromechanical transducer which can be used efficiently in either air or water for a wide variety of frequency ranges.

A further object is to provide an electromechanical transducer in which the mechanical impedance can be controlled as desired by choosing dimensions favorably, while still maintaining other advantages.

A further object is to provide an electromechanical transducer of general applicability, using a very simple and economically manufactured type of basic sensitive element.

A further object is to provide an electromechanical transducer element which can be easily incorporated into a directional array assembly, possessing good directional characteristics.

A further object is to provide a basic electromechanical transducer which is more versatile as to medium, fre-

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quency, range, and manufacture, while also possessing improved efficiency and performance characteristics.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a view in cross-section of a preferred embodiment of the transducer of this invention,

Fig. 2 is an outline showing of an omnidirectional transducer including the basic structure of the device shown in Fig. 1,

Fig. 3 is an outline showing of the transducer of Fig. 1 and including parallel dividing planes shown in phantom lines,

Fig. 4 is an outline showing a modification of the transducer of Fig. 1,

Fig. 5 is an outline showing of an omnidirectional transducer,

Figs. 6 and 7 are two further modifications of the transducer shown in Fig. 1, and

Fig. 8 is a further modification of a transducer shown in Fig. 1.

In Fig. 1 there is shown a transducer 11 adaptable for underwater use. The sensitive element 12 is a hollow cone of electrostrictive material, or more precisely, a piezoelectric ceramic such as a barium titanate composition, the conical outer surface 13 of which is coated with a thin metal electrode 14 to which cable lead 15 is attached and the conical inner surface 17 of which is coated with a thin metal electrode 18 and to which cable lead 19 is attached. In order to sensitize hollow cone 12, a high voltage is applied between these electrodes 14, 18 to produce volume electrical polarization of the material. After such polarization, the application of pressure to the exterior of the cone 12 will cause radial expansion of the cone thus causing a potential difference to appear across the electrode. The cone 12 is supported on a metal ring 21 affixed to a suitable base 22. The metal ring support is provided with slots 24 parallel to its axis to provide radial flexibility of the support. The interior of the cone 12 is further provided with a coating 25 on the inside surface of electrode 18. Coating 25 is an air-filled material such as air cell rubber. Because of coating 25, motion of the cone will not cause appreciable movement of any filling material or fluid which may be introduced inside the cone for the purposes of hydraulic support and insulation. Air-filled material 26 is also applied to the back side of the base 22 to isolate it from sound impinging on the back side of the transducer 11.

The transducer 11 can be included in a directional array assembly having many such transducer units mounted in a predetermined pattern relative to a flat surface and all having their electrodes 14, 18 electrically connected. The mechanical impedance of the transducer 11 can be designed to match the impedance of sound medium by a suitable adjustment of the geometry of element 12 through a proper choice of the radius at the base, the cone angle, and the wall thickness.

In Fig. 2 there is shown an omnidirectional unit comprising two cone elements 12 arranged base to base. The inner electrodes 18 of cone elements 12 are connected together at 27. Fig. 2 provides simple and compact means for constructing an omnidirectional transducer, by using two cones and insulating coatings and cabling provisions to produce a transducer. If the polarizations of the two cones are suitably chosen, the connections as shown are in series and the output voltage (also the electrical impedance will be twice that of a single unit. When the device is very small as compared to a wavelength, a cone provides a support of desirable mechanical properties for

a similar cone. The same connections are assumed for Figs. 5 and 7.

In Fig. 3 transducer 11 is shown in outline with broken parallel lines 31 to represent imaginary dividing planes for dividing the cone element 12 into rings 32 parallel to the base 22. The ring 32 of largest diameter, which is adjacent the base 22, possesses a particular radial vibration resonant frequency. The ring 33 next above possesses a resonant frequency slightly higher than that of ring 32. Likewise the other rings have correspondingly higher resonant frequencies up until the vertex 34 is reached where resonance of maximum frequency can be excited. This maximum resonant frequency can coincide with a resonant vibration involving the whole cone in a mode of motion which varies the wall thickness. Thus the transducer will possess a broadband based resonance which is distributed between two well defined frequency limits.

Fig. 4 shows a conical transducer element such as 12 in Fig. 1 in which the imaginary separations 31 of the zones as illustrated in Fig. 3 is made real by incorporating circumferential grooves 35 to partially decouple the portions of the separate zones. The conical construction is characterized by useful sensitivity at frequencies that are lower than its lowest resonant frequency which is the resonant frequency of the ring section adjacent the base. We have separate rings, each having its own natural resonant frequency in radial oscillation. If all the incremental ring transducers are effectively in parallel, and each is highly efficient at its resonant frequency, a band of relatively high efficiency results, in principle, for the transducer as a whole.

In Fig. 5 is shown an omnidirectional air transducer similar to that of Fig. 2 but having a cushioning support 38 and a housing 39. Omnidirectional air transducers can also be constructed using the sensitive cone principle in other types of constructions than shown in Fig. 5. In any case they do not include air-filled material such as 25 in Fig. 1.

Figs. 6 and 7 illustrate two further modifications of the transducer for use as underwater omnidirectional transducers. In Fig. 6 shielding 44 is included to shield against vibration from above; also the lower conical transducer is included in a plastic housing 47. Both conical transducers of Fig. 7 are included in plastic housing 47.

The modification shown in Fig. 8 illustrates the construction of an underwater transducer embodying the features of Fig. 1 together with the addition of a metal weight 45 affixed in the vertex of the cone 12 for the purpose of lowering and narrowing the resonant frequency band and further increasing efficiency. The use of such loading is advantageous for sonic applications. The weighted vertex, Fig. 8, alters the vibratory mechanics of the device, lowering the resonant frequency of the simple mode in which the vertex moves axially and the base moves radially. This can be advantageous when narrow band (resonant) operation is desired, under which conditions improved efficiency results. The important feature and property of the device of Fig. 8 is the weighted cone version as a low frequency receiver. The weighted vertex type possesses acceleration sensitivity, and may be useful in this sense. If the radially com-

pliant support for the cone of Fig. 8 were mounted on the rigid inner wall of a hollow closed container, such as a sphere or a cylinder with spherical ends, the device would be sensitive to underwater sound, as an acceleration or displacement sensing device, inertia actuated. It would thus be directional, even when small compared to a wavelength (in contrast to pressure devices which must be large in wavelengths to achieve directionality). Hydrophones which are directional at low frequencies, though small, are in demand.

The transducer of this invention is useful for directional and nondirectional broadband hydrophones and underwater projectors; with mass loading it is useful for semi-broadband directional hydrophones and projectors. It is generally useful in both air and water in a number of forms for listening, signaling, detection, vibration, pick-up, two-way communication and the like.

In operation, the application of pressure to the exterior of the cone will cause radial expansion of the cone. Because of the volume electrical polarization of the material, a potential difference between the thin metal electrodes coating the conical inner and outer surfaces of the cone element will appear. Due to the element's conical shape, it acts as a series of adjacent rings each of which has a different resonant frequency thereby yielding a broadband frequency response. By attaching a weight at the apex the band may be narrowed and the efficiency further increased.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. In a transducer, a sensitive element in the form of a hollow cone, said sensitive element being formed of electrostrictive material, a pair of electrodes one on the inner and one on the outer face of said cone, a layer of air-filled rubber covering the inside of said cone, and a ring upon which said sensitive element rests for supporting said sensitive element, said ring being formed of metal, said ring being provided with slots parallel to its axis to provide radial flexibility.

2. In a transducer, a sensitive element in the form of a hollow cone, said sensitive element being formed of electrostrictive material, a pair of electrodes one on the inner and one on the outer face of said cone, a layer of air-filled rubber covering the inside of said cone, a ring upon which said sensitive element rests for supporting said sensitive element, said ring being formed of metal and provided with slots parallel to its axis to provide radial flexibility, a base supporting said ring, and air-filled rubber material on the side of said base opposite said cone.

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