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UNDERWATER SOUND TRANSDUCER

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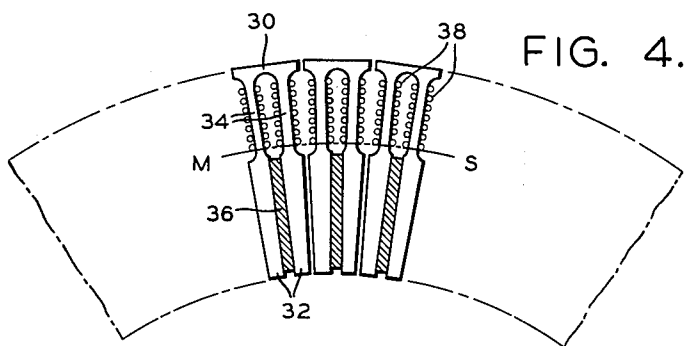


FIG. 4.

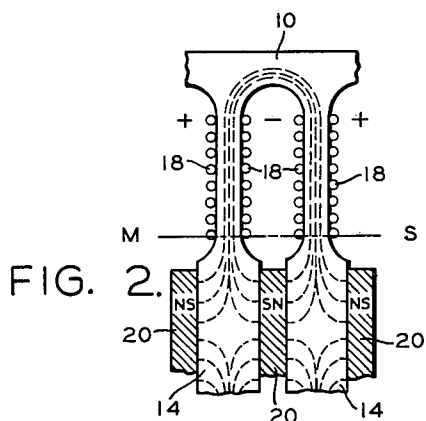


FIG. 2.

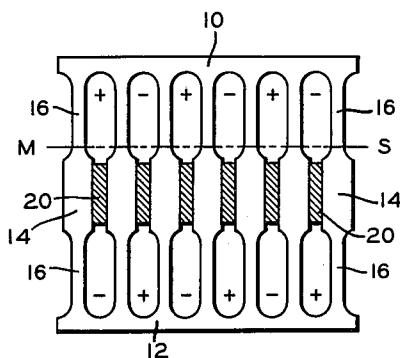


FIG. 1.

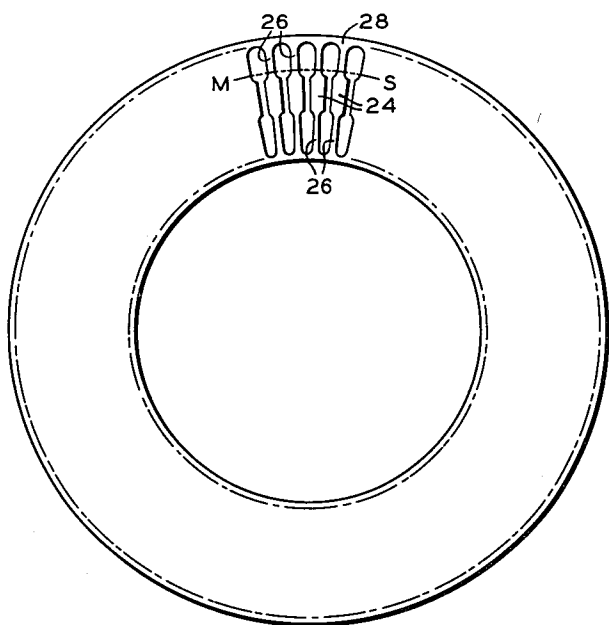


FIG. 3.

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UNDERWATER SOUND TRANSDUCER

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9 Claims. (Cl. 340—11)

This invention relates to underwater sound transducers and more particularly to transducers of the magnetostrictive type.

Transducers as constructed heretofore usually comprise an oscillator made of consolidated thin laminations and having slots of uniform width arranged perpendicular to the active vibrating face of the oscillator. The portions of the oscillator between the slots constitute magnetostrictive legs of uniform width which are energized by coils disposed in the slots. Permanent magnets between the legs and substantially filling the slots laterally thereof, provide a polarizing flux which enters the legs substantially perpendicular thereto at their centers. Since the point of maximum strain in a leg when it is vibrating is at the node, this point also, in a leg of uniform width is at the center of the leg. Consequently, the magnetostrictive effect of the flux is impaired because the direction of flow of the flux at the point of maximum strain departs from the effective direction of the magnetostrictive force and particle movement in the leg, which is lengthwise of the leg.

Thus, a transducer of this type has a low effective electro-mechanical coupling coefficient, and hence, a low efficiency.

Under conditions conducive to high echo strength, a transducer of this type may be satisfactory; but one of greater efficiency is required for applications in which the echo strength may be expected to be low and a correspondingly high transmitting power is necessary.

In view of the foregoing, it is a primary object of the invention to provide an improved magnetostrictive transducer of higher efficiency than has been attained in this type of equipment heretofore.

To this end, and in accordance with one feature of the invention, the magnetostrictive legs of the illustrated oscillator are so shaped and arranged as to cause the flux therein resulting from a polarizing field to flow, at the point of maximum strain, in the direction of the magnetostrictive force and particle movement in the legs, whereby a maximum magnetostriction is caused by any given amount of flux.

In the illustrated oscillator, the polarizing field is provided by permanent magnets disposed between its magnetostrictive legs. Furthermore, the portions of the legs which are coextensive with the magnets have lobes which make them relatively stiff and massive as compared with the remaining length of the legs which is relatively elastic. This construction, in which invention is to be recognized, gives rise to two conditions which mutually effect the maximum magnetostriction in the legs in response to any given energizing power.

First, in making the central portion of the legs relatively massive, and hence relatively rigid, the point of maximum strain is moved away from the nodal point beyond the magnets toward the active vibrating face of the oscillator. Secondly, because of the entry of flux from the magnets into the relatively massive portion of the legs, the flux flow is such that the flux density is increased

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at the point of maximum strain and becomes parallel to the direction of strain at that area. Hence, except for unavoidable losses arising from eddy currents, heat, and the like, the transfer of energy between its electrical and mechanical or acoustic phases, in the operation of the illustrated transducer, is as complete as possible.

With the above and other objects and features in view, the invention will now be described with reference to the accompanying drawings, which illustrate preferred embodiments of the invention, and will be pointed out in the claims.

In the drawings:

Fig. 1 is a diagrammatical view of an illustrative magnetostrictive oscillator for a transducer embodying the invention;

Fig. 2 is a diagrammatical view illustrating certain electrical features which result from the oscillator construction provided by the invention;

Fig. 3 is a plan view of a lamination for an oscillator like that of Fig. 1 but cylindrical in form; and,

Fig. 4 is a diagrammatical plan view of a modification of the oscillator of Fig. 3 in which is employed a circular arrangement of segmental magnetostrictive units.

The oscillator shown in Fig. 1 comprises a stack of nickel laminations of any suitable height, as for example 2" to 3" the laminations being aligned, and consolidated by an adhesive and insulating substance. Each lamination has a series of perforations of unequal width which result in the formation of opposed flanges 10 and 12, and integral therewith a series of legs each of which has a relatively massive lobed portion 14 intermediate between relatively narrow elastic portions 16.

In the larger parts of the slots between the elastic leg-portions are placed coils 18 (Fig. 2) by which the transducer is energized. In the interest of clarity the coils have been omitted from Fig. 1, but their orientation has been indicated by positive and negative signs. Each coil comprises about twenty-five turns of wire and is generally rectangular in form.

Inside each coil and between the lobed leg-portions 14 are disposed one or two polarizing magnets 20 which are substantially coextensive with the leg-portions 14. Successive magnets are arranged with their like poles facing each other across the intervening leg.

In the usual type of prior transducer having legs of uniform width, the point of maximum strain, which is at the node of the vibratory member, is at the center of each leg. Furthermore, with magnets and coils disposed as above described with respect to a leg of uniform width, it is apparent that since the flux from the magnets enter the central portion of the legs substantially at right angles thereto, the direction of the flux flow at the point of maximum strain is perpendicular, or nearly so, to the direction of the magnetostrictive stress. Accordingly, a transducer so constructed has a low effective electro-mechanical coupling coefficient and hence a low efficiency. For example, in a typical transducer having legs of uniform width, the coupling coefficient has a theoretical value of 0.082 and a measured value of 0.0304, for a lamination material having a maximum coupling coefficient of 0.223. The reason for the discrepancy and the low actual coupling is essentially in the relatively ineffectual direction of the flux path provided by the legs of uniform width at the point of maximum strain.

The above mentioned condition is avoided in the illustrated oscillator by the provision of the massive lobed leg-portions 14, as will now be explained with reference to Fig. 2. Such thickening of the legs adjacent to the magnets renders those portions of the legs relatively stiff, with the result that the point of maximum strain (stress per unit area) occurs in the narrow relatively elastic

leg-portions 16 near their junctions with the stiff leg-portions 14. This point is indicated by the dot and dash line M—S. It will further be observed from Fig. 2, in which the direction of the flux flow is indicated in dotted lines, that all the flux at the point of maximum strain flows lengthwise of the legs and in the direction of the magneto-strictive force and mechanical strain.

The lobed leg portions 14 further provide a path for the flux which has its junction between the polarizing magnet and the leg at a location where the leg is relatively stiff and therefore of relatively little use for magneto-striction.

Thus, the point of maximum strain and the path of the flux flow have been brought into the optimum relation from the standpoint of obtaining the maximum magneto-strictive effect from a given amount of flux. The efficiency of a transducer constructed in accordance with the invention as compared with one having legs of uniform width is approximately quadrupled, the effective coupling coefficient being about 0.164.

This increased efficiency of the illustrated transducer is also derived partly from an improvement in the flow of flux between the magnets and the lobed leg-portions. To the extent that the lobed portions of the legs are widened, the distance between them, and hence the reluctance of the path of A. C. flux from the windings is reduced. Similarly, since the magnets necessarily have a high resistivity, the narrower their lateral dimension, the lower will be the reluctance of the path of the A. C. flux in the magnets. For best results, the width of the magnets should be between $\frac{1}{10}$ and $\frac{1}{15}$ of the length of the flux path along two adjacent legs and the flange connecting them.

In a transducer of the type shown in Fig. 1, both flanges 10 and 12 are oscillating members capable of initiating sound in directions perpendicular to their faces. However, if only one flange, such as 10 for example, is desired to be utilized as a sound propagating flange, the transducer may be mounted with its back flange 12 against a pressure release material with low acoustic resistance (such as air cell neoprene or corprene) to prevent radiation from it.

Where sound radiation is to be effected throughout an angular area, with the above described advantages provided by the invention, an oscillator of the cylindrical form illustrated in Fig. 3 may be employed. This figure represents a type of lamination which is perforated to provide legs having stiff lobed portions 24, and elastic portions 26, and also a sound propagating flange 28. A section including such legs and the flange may be of any desired size, depending upon the angular area to be covered. Only a small sector has been shown in Fig. 3 for ease of illustration.

In the modification shown in Fig. 4, the oscillator comprises a series of segmental units arranged, as a whole, in an annular formation. The laminations of each unit have a sound propagating flange 30 from which extend two legs each having a terminal, relatively stiff, lobed portion 32 and a relatively narrow and elastic portion 34. Magnets 36 are disposed between the lobed leg-portion 32 of the units and coils 38 are associated with the elastic leg-portion 34.

It is noted that the relation between the point of maximum strain, which is along the line M—S, and the flux flow is the same in the transducers represented by Figs. 3 and 4 as in the type of transducer shown in Figs. 1 and 2.

It will be apparent that other forms of laminations may be used within the scope of the present invention as defined in the claims.

What is claimed is:

1. An underwater sound transducer comprising a laminated oscillator of magneto-strictive material having a sound propagating flange, spaced legs integral with and extending from said flange, polarizing magnets disposed

between said legs and spaced from said flange, and energizing coils positioned about the portion of said legs between said magnets and flange, said legs having lobes substantially coextensive with said magnets providing relatively massive leg-portions adjacent to said magnets whereby the points of maximum strain in said legs are established at areas where the flux in said legs flows in the effective direction of the magneto-strictive force.

2. An underwater sound transducer comprising a laminated oscillator of magneto-strictive material having a sound propagating flange, spaced legs extending from said flange, portions of said legs remote from said flange having lobes providing stiff leg-portions which are connected to said flange by relatively elastic leg-portions whereby the point of maximum strain is established within said relatively elastic portion near the junction of said elastic and stiff leg portions, polarizing magnets disposed between the lobes of said legs, and energizing coils positioned about the relatively elastic portion of said legs.

3. An underwater sound transducer comprising a laminated oscillator of magneto-strictive material having a sound propagating flange, spaced legs having relatively elastic portions extending from said flange, energizing coils positioned about said elastic leg-portions, polarizing magnets disposed between said legs, the portion of said legs adjacent to said magnets being stiff compared to said elastic portions whereby the points of maximum strain are spaced from said magnets in said elastic leg-portions where substantially all the flux from said magnets flows in the direction of particle movement.

4. An underwater sound transducer comprising a laminated oscillator of magneto-strictive material having a sound propagating flange, spaced legs integral with and extending from said flange, each of said legs having a lobed, relatively stiff intermediate portion between recessed, relatively elastic portions, polarizing magnets disposed between the lobed portions of successive legs, and energizing coils disposed in the slots between the recessed elastic portions of successive legs.

5. An underwater sound transducer comprising a laminated oscillator of magneto-strictive material having a sound propagating flange, spaced legs extending from said flange, each of said legs having a relatively elastic portion integral with said flange and a lobed relatively stiff terminal portion integral with said elastic portion, energizing coils associated with said elastic leg-portions, and means for impressing a polarizing flux on said stiff leg-portions whereby substantially all of said flux flows in said elastic portion in the direction of particle movement therein.

6. A sound transducer comprising, a plurality of flat annular laminations of magneto-strictive material packed together to form a core having a plurality of spaced radial slots cut therein to form a plurality of spaced legs extending substantially across said annular laminations, each of said legs having a lobed portion intermediate relatively elastic portions, polarizing magnets disposed between the lobes of successive legs, and energizing coils positioned about the elastic portions of said legs.

7. A sound transducer comprising, a laminated core of magneto-strictive material having a sound propagating flange, spaced legs integral with and extending from said flange, each of said legs having a lobed intermediate portion between relatively elastic portions, polarizing magnets disposed between the lobed portions of successive legs, and energizing coils positioned about the elastic portions of said legs.

8. A transducer comprising, a stack of laminations formed of magneto-strictive material having a series of perforations of nonuniform width therethrough forming a pair of opposed flanges having a series of legs integral therewith and extending therebetween, each of said legs having a massive lobed portion intermediate narrow relatively more elastic portions, a plurality of polarizing magnets disposed between the lobed intermediate portions

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of successive legs with like poles facing each other across the intervening leg, a plurality of current carrying coils disposed between the narrow portions of said legs and surrounding said magnets, said lobed portions together with said arrangement of magnets and coils providing a flow of flux in said narrow portions of said legs which is parallel to the effective magnetic force in said narrow portions at the point of maximum strain in said narrow portions.

9. A transducer comprising a stack of laminations of magneto-strictive material having a series of spaced perforations therethrough forming a flange having a series of legs integral therewith, each of said legs being of non-uniform width along its length having a narrow portion adjacent said flange and a wider lobed portion remote from said flange, a plurality of polarizing permanent magnets disposed between the lobed portions of successive legs, a like plurality of current conducting coils positioned in the perforations between the narrow portions

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of successive legs, the shape of said legs causing the point of maximum strain in said legs to exist in the narrow portion of said legs and the arrangement of said magnets and coils providing a concentration of flux density at said point of maximum strain, the direction of the flow of flux at said point of maximum strain being parallel to the direction of strain at said point.

References Cited in the file of this patent

UNITED STATES PATENTS

1,882,401	Pierce	Oct. 11, 1932
1,966,446	Hayes	July 17, 1934
2,088,324	John	July 27, 1937
2,190,666	Kallmeyer	Feb. 20, 1940
2,279,322	John	Apr. 14, 1942
2,411,911	Turner	Dec. 3, 1946
2,452,085	Turner	Oct. 26, 1948