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MAGNETOSTRICTIVE ELECTRO-ACOUSTICAL TRANSDUCER

Filed April 25, 1955

2 Sheets-Sheet 1

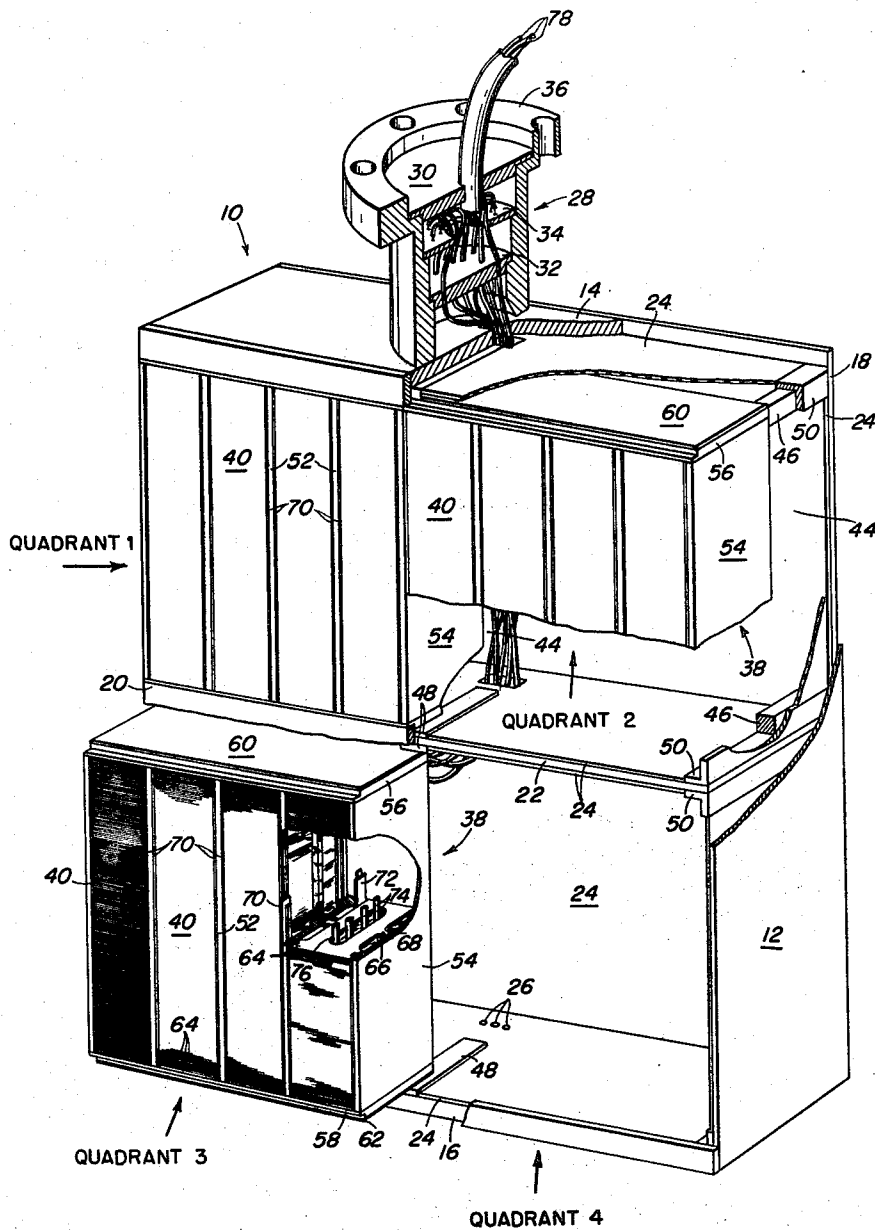


Fig. 1

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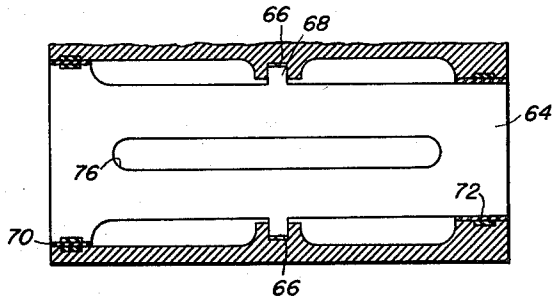


Fig. 2

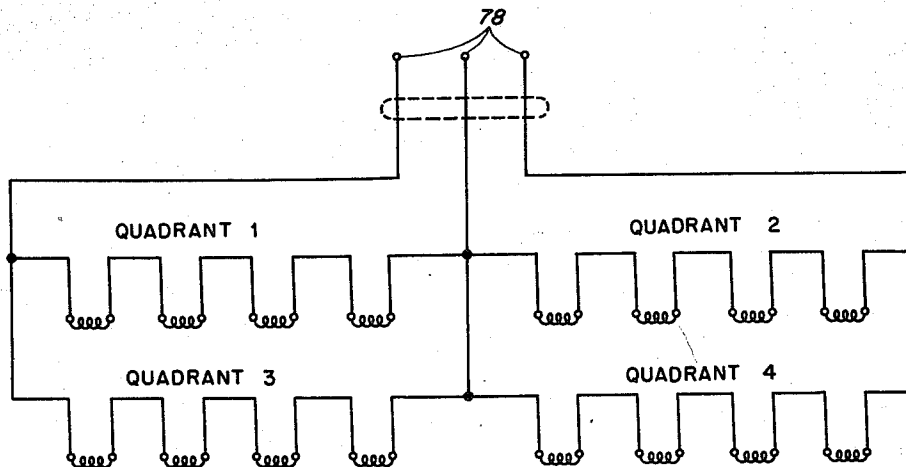


Fig. 3

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1

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(Granted under Title 35, U.S. Code (1952), sec. 266)

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 means for producing and receiving a beam of compressional energy in a liquid and more particularly to a high power laminated magnetostrictive electroacoustic transducer.

It has heretofore been proposed to make underwater transducers in the form of a single stack of laminations of magnetostrictive material. Since such apparatus is frequently used in electrically conductive sea water, it has been deemed necessary to completely enclose the entire assembly in a water tight casing thereby necessitating the incorporation of special non-conducting liquid coupling medium such as castor oil and the use of a vibratory plate or membrane as a "sound window" to couple vibrations of the liquid oil coupling medium with the surrounding water. This sealing of the transducer introduces problems of vibration impedance matching and heat dissipation which severely limit the power handling capacity of the transducer.

The present invention comprises an externally polarized transducer including a plurality of stacks of laminations of a specially prepared magnetostrictive material which are wound with a highly insulated wire and an apertured casing enclosing all but the radiating surface of the magnetostrictive stacks whereby the assembly is efficiently cooled by being free flooded with the wave propagating medium and the radiating faces of the magnetostrictive material are in direct contact with such medium.

It is an object of this invention to provide a transducer capable of producing high levels of compressional energy.

It is a further object of this invention to provide a transducer which will more efficiently convert electric power to vibratory energy.

Another object of this invention is the provision of a transducer capable of withstanding greater input powers without breakdown.

Still another object of this invention is the provision of a simple and efficient means for dissipating the heat generated by a high power transducer.

A further object of this invention is the provision of a transducer which requires no intermediate coupling between its primary vibrating elements and the medium through which the vibration is to be propagated.

Still another object of this invention is to provide a means for mounting a plurality of stacks of magnetostrictive laminations in a single assembly.

Another object of this invention is the provision of a magnetostrictive transducer of increased receiving sensitivity.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same be-

2

comes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a pictorial representation of the transducer of this invention partly assembled and with parts broken away;

Fig. 2 is a sectional view of a stack of laminations and its mounting; and

Fig. 3 is a schematic circuit diagram of the core windings.

Shown in Fig. 1 is a transducer assembly constructed in accordance with a preferred embodiment of this invention. A casing 10 comprising sides 12, top 14, bottom 16, back plates 18, horizontal retaining strips 20 and cross member 22 is lined with pads 24 of a radiation absorbing material such as air cell rubber or the like which is cemented or otherwise suitably secured to the casing elements to provide a radiation insulated enclosure having an open front face. If desired, strips 20 may be interconnected by vertical strips at their ends to provide an integral skeletal retaining frame. The casing elements are securely fastened by screws or the like but no effort is made to effect liquid tight joints. On the contrary, the casing is apertured as at 26 to provide liquid conduit means for freely admitting to the interior of the casing and its contents, the liquid in which the assembly is immersed during operation. While the purpose of these apertures has been found to be satisfactorily served by the location thereof solely in the bottom of the casing, as illustrated, it is to be understood that additional liquid passage apertures may be located in other casing elements as desired. A sealed liquid tight terminal housing 28 is rigidly secured to casing 10 as by welding or the like and includes upper and lower packing plates 30, 32, a terminal plate 34 and an apertured flange 36 by which the assembly is mounted.

Mounted within the casing 10 are two pairs of identical magnetostrictive assemblies 38 which having coplanar radiating surfaces 40 substantially flush with and filling the open face of the casing while the opposing sides of the assemblies are spaced from the casing to provide a chamber 44, the spacing being maintained by abutment of the assemblies with front frame member 20 and spacing blocks 46 which are fixed to the casing. The assemblies 38 rest on and between supports 48, 50 which complete the detachable securing of the assemblies within the casing.

Each assembly subframe comprises a plurality of parallel mutually spaced separator plates 52, a pair of end plates 54, top and bottom clamping frames 56, 58 secured to the respective ends of the separator and end plates and cover plates 60, 62 secured to respective clamping frames. Between each pair of adjacent separator and end plates is mounted a stack or stave comprising a great many extremely thin laminations of nickel of at least 99.9 percent purity. Each lamination 64 has a thickness on the order of .004 inch and is shaped as shown in Fig. 2 to a length determined by the desired frequency with supporting lugs 68 located at $\frac{1}{4}$ wave length points, the mid points of the lamination length. After shaping of the laminations, as by punching or the like, the burrs are removed and they are annealed in hydrogen at a temperature of at least 700 and preferably 1000 degrees centigrade. The desired number of laminations for one stave are then loosely stacked and clamped in a suitable jig with coplanar alignment of the lamination ends being carefully maintained. The stacks are then placed in a tank above a quantity of insulating varnish and the tank is evacuated and heated to a temperature such as 80° C. for three hours. The varnish impregnated stacks are removed from the tank and compressed while still hot

to the desired height. Following a plurality of successive baking periods such as eighteen hours at 60° C. and 120°, the excess varnish is removed and the jigs are replaced with the subframes 52—58. While the varnish insulation described above is preferred, it may be satisfactory to utilize other types of non-magnetic insulation which will effectively reduce the eddy current losses. For example, one may separate the laminations before stacking in the jig by layers of insulating paper or mica dust and thus dispense with the varnish impregnating procedure.

Within the subframes longitudinal movement of the laminations as a unit is prevented by insertion of lugs 68 in mating grooves 66 of the plates 52, 54 while longitudinal expansion and contraction of the lamination ends is permitted. These ends are insulated from plates 52, 54 by resilient vibration insulation strips 70, 72 which may be built up of cemented strips of neoprene or the like suitably secured to the plates. The stacks are wound about the sides thereof and through slots 76 with a few turns of wire 74 which has a heavy insulation of a material such as a deproteinized rubber capable of withstanding high voltage, on the order of 25,000 volts R.M.S., while immersed in sea water. Each stave has its own winding both ends of which are brought out through grooves (not shown) in the back of clamping frame 56 and extend through chamber 44, apertures in the casing elements 22 and 14 and sealed apertures in packing plate 32 to electrical connection with terminal plates 34 so that with the sixteen staves shown there are provided thirty two terminals on plate 34. As shown in Fig. 3, the windings of the staves of each quadrant are connected in series while the windings of the two quadrants on one side are connected in parallel by jumpers (not shown) on the terminal plate whereby one side of the transducer, quadrants 1 and 3 may be connected in a first circuit of a bearing deviation indicator and quadrants 2 and 4 may be connected in a second circuit of the indicator and the ground connection of the two circuits may be a common lead. Thus there are three leads 78 from the sealed terminal housing extending to the various transmitting, receiving and display apparatus with which the transducer is used. The bearing deviation indicator is thus supplied with two separate signals corresponding respectively to the echoes received and converted by the two halves of the transducer and provides a display which is a measure of the phase difference of the two signals. This phase difference in turn is a measure of the angle between the axis of projection of the transducer and a line between the transducer and the echo source.

In operation the transducer is externally polarized by a steady D.-C. current from a suitable source which must be highly filtered to prevent unwanted hum from getting into the receiver input. The polarizing current is of a magnitude to ensure operation on the correct portion of the B-H magnetization curve and effects a more linear relation between the A.-C. field and the expansion and contraction of the core. The external polarization increases the efficiency of the transducer and results in an unexpectedly increased sensitivity of the device as a receiver of compressional waves as compared with a magnetostrictive transducer which embodies a permanently magnetized core or a non-polarized core. The permanently magnetized type has the disadvantage of being depolarized if overdriven which would require removal and replacement.

As one example of the dimensions of a transducer according to this invention which will be resonant at 15 kc. the laminations may be about two inches wide and six inches long with 2900 laminations in each twelve inch high stack. The casing then may be about 22 inches wide by 29 inches high by 9 inches deep. A transducer of these approximate dimensions when provided with a 30 ampere polarizing current has been found to be capable of handling 137 kw. of pulse power input to pro-

duce a source level of 137 db above one dyne per square centimeter at one meter using a pulse length of three milliseconds or less without electrical or physical breakdown. Since it is known that an increase of 3 db in source level requires doubling of the input power it might be assumed that any desired increase in source level could be achieved by simply providing a suitably increased input power. Such an assumption, however, fails to take into account several power limiting factors such as cavitation and electrical breakdown. It has been found that the cavitation threshold of water is higher than that of conventional coupling fluids such as castor oil or gasoline so that the elimination in the present invention of such coupling medium by direct contact of the radiating face with the sea water enables the use of higher powers. Furthermore, with the movement of the transducer through the water air bubbles at the radiation face are swept away thus decreasing coupling losses and cavitation effects. Increased resistance to electrical breakdown is provided by more effective cooling of the windings in the free flooding casing while efficiency as both transmitter and receiver is increased by the external polarization. It will be seen that great power levels of the disclosed apparatus are not merely the result of a larger power source but are achieved by means of a construction which effectively avoids those factors which limit the capacity of a transducer to operate without breakdown.

In operation the transducer is immersed in the liquid medium through which acoustic energy compressional waves are to be propagated and the medium becomes an efficient cooling agent filling the chamber 44 through apertures 26 and passing through the spaces between the several staves and the mountings to free flood the windings and the staves. Upon the steady polarizing current in the windings is superimposed a varying amplitude signal at the resonant frequency of the transducer which causes the expansion and contraction of the magnetostrictive laminations to thereby set up a planar source of acoustic vibrations at radiating surface 40. This surface is in direct contact with the propagating medium and thus the usual liquid coupling medium and vibratory sealing diaphragm or plate is eliminated. While the varying amplitude current in the windings which causes the transducer to project or vibrate is cut off during the time in which the transducer is acting as a receiver to convert compressional waves which impinge upon surface 40 to electrical signals, the steady D.-C. polarizing current remains unchanged through both projecting and receiving operation and thus provides increased receiving sensitivity.

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.

What is claimed is:

1. Means for generating an acoustic energy beam in a liquid medium comprising a casing having side and back elements and an open front, a plurality of pairs of magnetostrictive assemblies, each assembly comprising a magnetostrictive core and an insulated electrical conduit wound thereabout, means for mounting said assemblies within said casing with one surface thereof substantially filling said open front and an opposing surface of said assemblies spaced from said back element to provide a chamber, means for connecting the conduits of one assembly of each pair in a first circuit, means for connecting the conduits of the other assembly of each pair in a second circuit, and means for admitting said medium to said chamber through said casing elements.

2. Means for generating an acoustic energy beam in a liquid medium comprising a casing having side and back elements and an open front, a plurality of pairs of magnetostrictive assemblies, each assembly comprising a plu-

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rality of adjacent staves, each stave comprising a stack of magnetostrictive laminations and an insulated electrical conduit wound thereabout, means for mounting said assemblies within said casing with one surface thereof substantially filling said open front and an opposing surface of said assemblies spaced from said back element to provide a chamber, the conduits of the staves of one assembly being in series, the conduits of the staves of the other assemblies being similarly connected in series, means for connecting the conduits of one assembly of each pair in parallel in a first circuit, means for connecting the conduits of the other assembly of each pair in parallel in a second circuit, means for supplying a steady polarizing current to said conduits, and means for admitting said medium to said chamber through said casing elements.

3. Means for generating an acoustic energy beam in a liquid medium comprising a casing having side and back elements and an open front, a plurality of pairs of magnetostrictive assemblies, each assembly comprising a plurality of adjacent staves, each stave comprising a stack of magnetostrictive laminations and an insulated electrical conduit wound thereabout, means for mounting said assemblies within said casing with one surface thereof substantially filling said open front and an opposing surface of said assemblies spaced from said back element to provide a chamber, acoustic insulating means between adjacent assemblies and the staves thereof, a sealed terminal housing mounted on said casing, said insulated electrical conduits extending through said chamber into said housing, means for connecting the conduits of one assembly of each pair in a first circuit, means for connecting the conduits of the other assembly of each pair in a second circuit, and means for admitting said medium to said chamber through said casing elements.

4. A transducer comprising a plurality of pairs of subframes, each subframe comprising a plurality of parallel mutually spaced separator plates, a pair of end plates and top and bottom clamping frames secured to respective ends of said plates, a stack of thin elongated magnetostrictive laminations mounted between said clamping frames and between each pair of adjacent plates, vibration insulating means between each stack and its adjacent plates, an insulated winding extending through and around each stack, a casing having top, bottom, side and back elements and an open front, said side elements being of a width less than the length of said laminations, means mounting said subframes within said casing with

one end of each lamination spaced from said back element, sealed connecting means secured to said casing, end portions of said windings extending between said back element and laminations and into said connecting means, and a plurality of apertures in said casing, whereby said windings and laminations may be free flooded with a liquid in which the transducer may be immersed.

5. A transducer comprising two pairs of subframes, each subframe comprising a plurality of parallel mutually spaced separator plates, a pair of end plates and top and bottom clamping frames secured to respective ends of said plates, a stack of thin elongated magnetostrictive laminations mounted between said clamping frames and between each pair of adjacent plates, vibration insulating means between each stack and its adjacent plates, an insulated winding extending through and around each stack, a casing having top, bottom, side and back elements and an open front, said side elements being of a width less than the length of said laminations, means mounting said subframes within said casing with one end of each lamination spaced from said back element, sealed connecting means secured to said casing, and portions of said windings extending between said back element and laminations and into said connecting means, said connecting means including means connecting the windings of one subframe of each pair in one circuit and means for connecting the windings of the other subframe of each pair in another circuit, means for supplying a steady polarizing current to said windings, and a plurality of apertures in said casing, whereby said windings and laminations may be free flooded with a liquid in which the transducer may be immersed.

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