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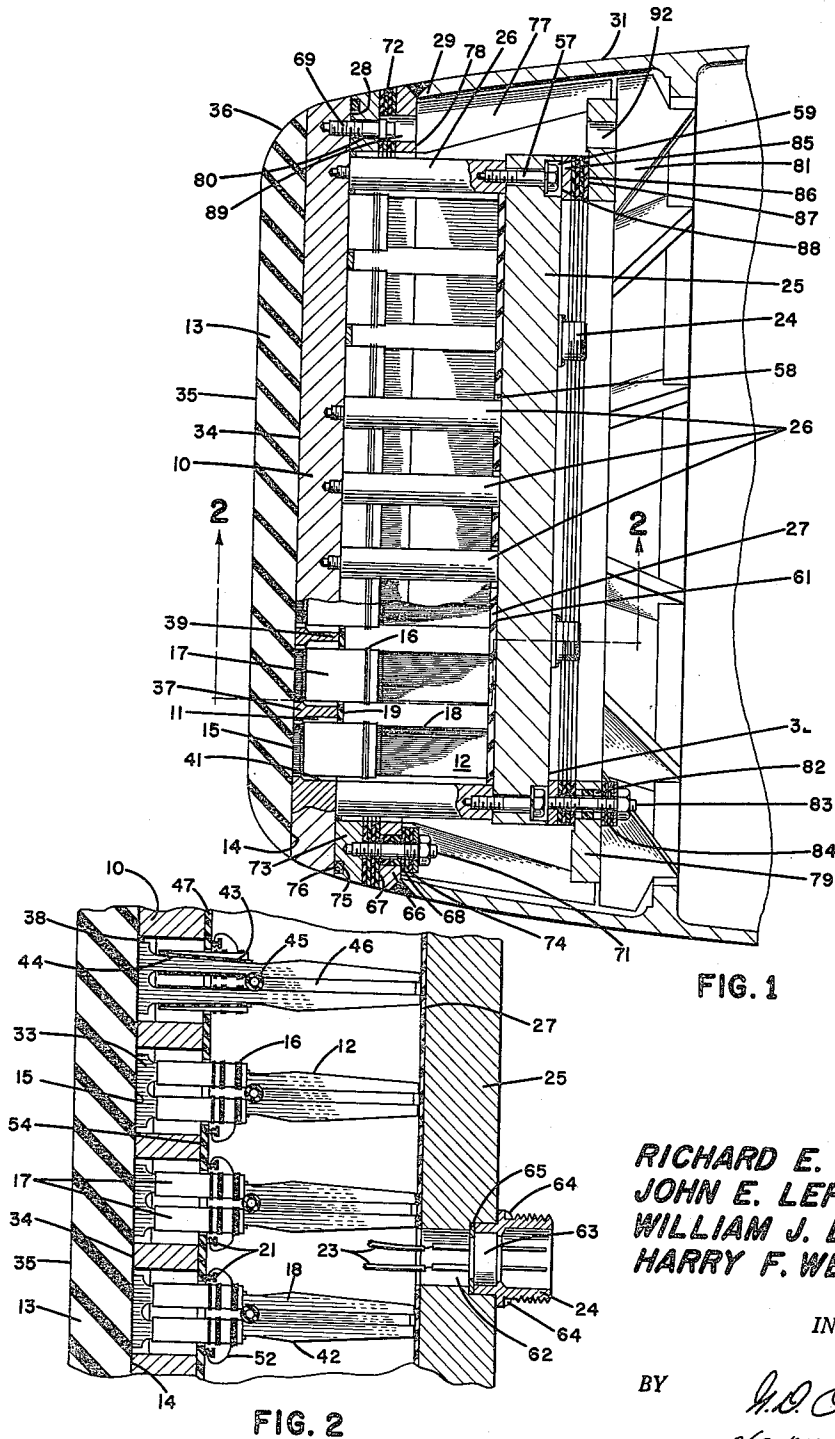
R. E. BLAND ETAL

3,082,401

DIRECTIONAL UNDERWATER MAGNETOSTRICTION TRANSDUCER

Filed Nov. 21, 1956

2 Sheets-Sheet 1



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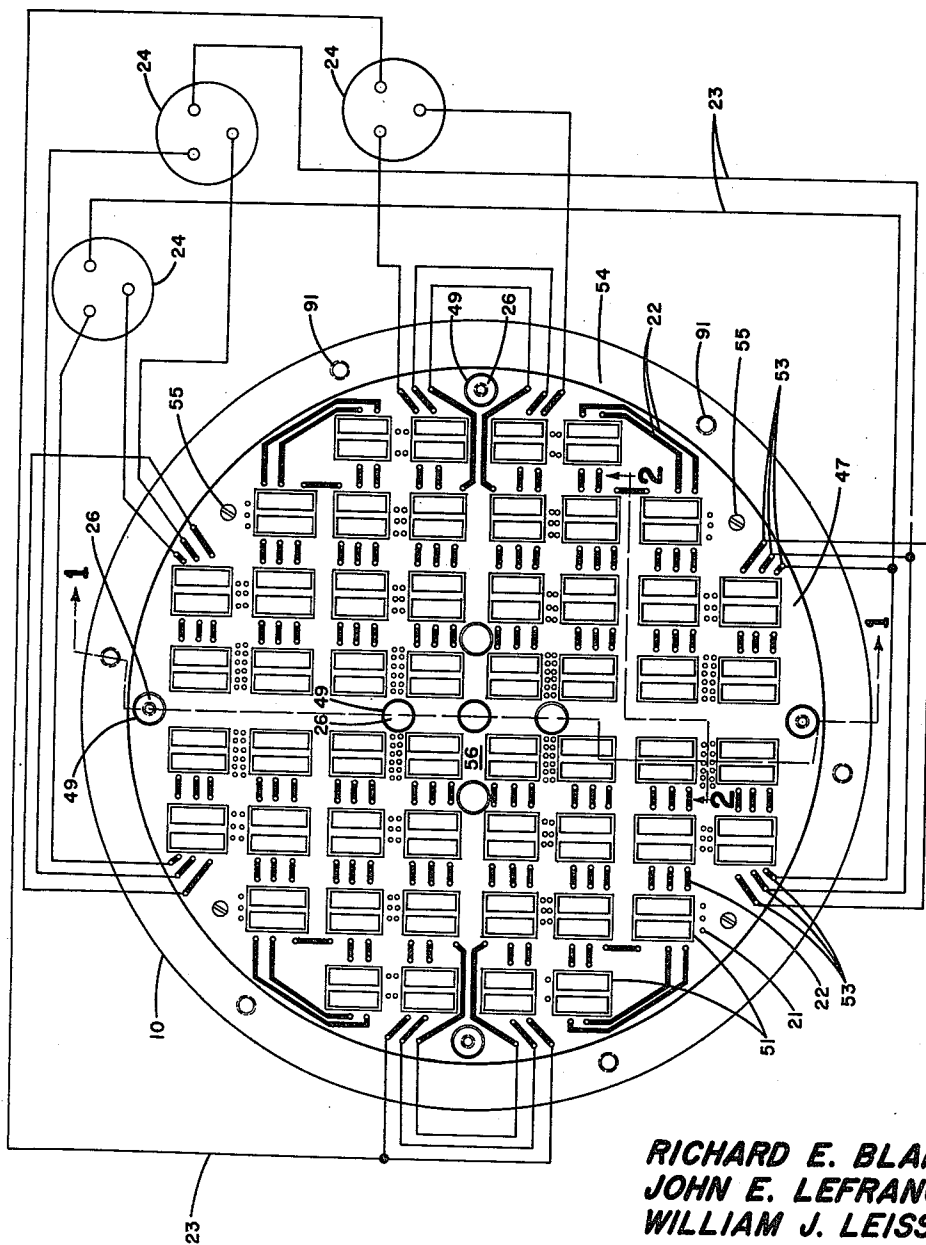


Fig. 3

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3,082,401

**DIRECTIONAL UNDERWATER MAGNETO-
STRICTION TRANSDUCER**

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This invention relates to underwater signalling apparatus, and more particularly to magnetostrictive type transducers having a planar array of individual units so disposed as to produce desired directional effects used especially in underwater signalling at substantial depths. In this connection "signalling" is intended to include both the generation and/or detection of frequencies within as well as above the audible range.

Electromechanical transducers for use in water at sonic and ultrasonic frequencies commonly employ laminated electroresponsive units having a generally U-shaped form with the active face located at the bight of the U. Excitation and improved directivity of transducers utilizing such electroresponsive or magnetostrictive units are commonly secured by providing series windings having greater or lesser number of turns on each leg of each unit whereby a desired pattern having certain directional characteristics may be secured.

Construction of transducers comprised of generally U-shaped magnetostrictive units referred to hereinabove having series windings of opposite polarity on the restricted portions of each unit has heretofore been difficult and time consuming due to the configuration of the U-shaped magnetostrictive units which does not lend itself to the winding of coils on each leg. Heretofore it has been the practice to wind each coil by hand or with special winding apparatus and to interconnect the coil wires on each unit prior to bonding each unit to an acoustic window. In addition to the time factor involved this procedure is particularly disadvantageous in that a high degree of skill is necessary to assemble such a transducer and if a coil is improperly wound, the proper polarity is not observed or an improper connection is made it is very difficult if not impossible, to correct such errors. As may now be obvious, such transducers are not amenable to repair or modification and an error in construction or a coil failure generally results in the loss of the entire transducer. As may now be also obvious, such transducers are not adaptable to mass production methods and require specially trained and highly skilled personnel for their construction thereby resulting in undue assembly time and construction costs. Thus, it is one of the objects of the present invention to provide a magnetostriction transducer that lends itself to mass production and that can be more easily and simply constructed.

Another object of the present invention is to provide a magnetostriction transducer employing an array of vibrator units having removable windings whereby such a transducer may be more easily constructed, modified, or repaired.

Another object of the present invention is to provide a winding harness for magnetostriction transducers employing an array of vibrator units that may be separately assembled more easily and quickly and that is easily removable in part or in combination.

Still another object of the present invention is to provide a removable winding harness for magnetostriction transducers employing an array of vibrator units that will allow substantially improved and more versatile utilization of multiple windings on each vibrator unit.

It is known in the underwater echo-ranging art that the

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absorption of so-called "acoustic" signals in water is dependent upon frequency and is inversely proportional to the square of the distance and that for a particular frequency an underwater transducer has an optimum size for maximum range. It is also well known that the directivity of an underwater transducer is increased by making the transmitting face large relative to the wave length in water and that the effect of a large face can be obtained by using a large number of small vibrator units positioned in a common surface. It is further well known that directional characteristics can be improved in some respects and for some purposes by shading, which is to say, by making the vibrator units progressively less sensitive from the middle to the outer edge, i.e., directivity and increased range may be secured by shading and by operating at a lower frequency but in order to maintain the same degree of directivity the size of the transmitting face must be increased.

Optimization of frequency and transducer size for maximum range is not difficult for ship mounted sonar, because the transducer is always relatively close to the surface and hydrostatic pressure on the transmitting surface of the transducer is small. Although submarines dive to substantial depths, the effects of hydrostatic pressure on the transmitting surface of submarine mounted sonar are negligible because the vibrator units are generally mounted on a spool-like frame. Since the hydrostatic pressure is transmitted through the vibrator units to the core of the spool, and since this force is equal in substantially all directions normal to the transmitting surface little or no deformation or misalignment of the vibrator units occur.

Still further, the selection of a transmitting face area and suitable reinforcement thereof is not limited since submarine borne sonar is to a substantial degree neither space nor weight limited.

In torpedo echo-ranging systems it has been found preferable to use a transducer comprised of a plurality of vibrator units positioned in a single plane and to utilize amplitude or phase comparison to determine azimuth and target angle. It has been found that for a phase comparison system the time required for a signal to first strike one vibrator unit and then the next vibrator unit is critical and hence that it is essential that the front surface of each vibrator unit remain in the same or a fixed plane at all times. As with ship borne sonar, misalignment of the vibrator units does not occur in a torpedo utilizing a transducer comprised of a planar array of vibrator units when the torpedo is fired at or near the surface.

However, hydrostatic pressure has heretofore seriously limited the effectiveness and range of anti-submarine torpedoes in that optimum operation of a transducer utilizing a planar array is particularly sensitive to hydrostatic pressure for the reason pointed out hereinabove, in addition to the fact that such a transducer is space and weight limited.

Heretofore it has been the general practice to utilize either four separate generally forward looking transducers each having a relatively small transmitting surface or a small single transducer having a planar array, such single transducers having a maximum diameter of about six inches. With regard to deep running torpedoes, heretofore the hydrostatic pressure present at such depths in combination with other operational requirements required the use of a relatively small transmitting surface which in turn placed limitations on the transmitting frequency and directivity. Although such practice permits torpedo echo-ranging or homing at substantial depths, this type of construction and operation required a relatively high transmitting frequency which seriously limited the range and effectiveness of the torpedo.

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It is, therefore, another object of this invention to provide an underwater magnetostriction transducer employing a planar array of vibrator units for use especially at great depths.

It is another object of this invention to provide a substantially improved construction of magnetostriction transducers employing a planar array of vibrator units for use in torpedoes or the like operable at great depths.

It is a further object of this invention to provide for use especially in a deep running torpedo a transducer that has improved directional and range characteristics not heretofore obtainable at such depths.

A still further object of this invention is the provision in a deep running torpedo of a transducer wherein the torpedo shell forms a part of the transducer and means for acoustically isolating the transducer from the torpedo shell is utilized in cooperation with other new and novel features to provide improved directional and range characteristics at depths as deep as 1000 feet.

These and other objects and features of the invention, together with their incident advantages, will be more readily understood and appreciated from the following detailed description of a preferred embodiment thereof selected for purposes of illustration and shown in the accompanying drawings, in which:

FIGURE 1 is a cross sectional view with reference to line 1—1 of FIGURE 3 of a fully assembled torpedo mounted transducer incorporating features of the present invention.

FIGURE 2 is a cross sectional view taken on line 2—2 of FIGURE 1 to illustrate more clearly the relationship of the vibrator units and associated parts.

FIGURE 3 is a rear view of a partially assembled transducer to illustrate more clearly constructional features of the present invention.

Referring first to FIGURE 1 and FIGURE 2, the transducer therein disclosed comprises a rigid circular grid 10 having openings 11 to freely receive a plurality of magnetostrictive vibrator units 12, and a circular rubber window 13 bonded to the front surface 14 of the grid 10 and to the working surface 15 of each magnetostrictive vibrator unit 12. The windings 16 for each vibrator unit are wound on coil forms 17 adapted to slip over the legs 18 of each vibrator unit and are interconnected in the desired manner by means of a printed circuit 19 having provided thereon the necessary terminals 21 and electrical circuits 22. The coil forms 17 with the windings 16 assembled thereon and connected to the printed circuit 19, terminal leads 23, and electrical connectors 24 (see FIGURE 3) are hereinafter referred to as the "winding harness." A rigid circular backup plate 25 is held in fixed spaced relationship with the grid 10 by means of standoff bolts 26 or the like and acoustically isolated from the vibrator units 12 by means of a pressure release material 27, such as for example, "Fairprene," a fabric coated with a synthetic elastic composition, or the like. The outer rear periphery 28 of the grid is supported by and held in a normally fixed position by, although acoustically isolated from, the forward periphery 29 of the torpedo shell 31. In a like manner, the outer rear periphery 32 of the backup plate 25 is supported by and held in a normally fixed position by acoustic isolation means fixed to or carried by a portion of the torpedo shell rearward of the most forward periphery 29 of the torpedo shell.

As best shown in FIGURE 2, each vibrator unit 12 comprises a laminated core of general U-shape. The shape of the vibrator units 12 shown in the drawings is in substantial accordance with that shown and described in Patents Numbers 2,550,771, issued May 1, 1951, and 2,530,224, issued November 14, 1950, to which reference is made. It is to be understood, however, that the present invention is not limited to utilization of magnetostriction cores of the particular shape shown or referred to and may utilize other various known types of magnetostrictive cores.

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As shown in FIGURE 2, the solid end 33 of the vibrator units are utilized to form a working face 15 which is bonded to the inner surface 34 of the rubber window 13. As used herein, the working face of each vibrator unit means the face in direct sound transmitting and receiving relation to the fluid medium through which the sound is to be transmitted or received. The rubber window 13 is preferably comprised of "Rho C" rubber or the like which is known to have substantially the same acoustic impedance as water and to propagate sound waves in the same manner. It is to be noted that the present invention is not applicable to transducers having heavy metal diaphragms and is applicable only to the type disclosed herein, in which the front surfaces of the individual vibrator units themselves constitute the working face. The rubber window 13 preferably has a substantially flat circular front surface 35 and it has been found that a thickness of about one inch is satisfactory. It has been found that a radius of curvature of the outer periphery 36 of the rubber window of about two inches is satisfactory although the degree of curvature is not critical. It is to be noted, however, that some curvature is necessary to prevent an undue amount of cavitation at the periphery 36 of the rubber window for a torpedo installation.

The grid 10 hereinabove referred to is, for the embodiment disclosed in FIGURE 1 and FIGURE 2, a circular metal plate composed of aluminum, steel, or the like, having a diameter substantially equal to the diameter of the forward periphery 29 of the torpedo body 31 and having a plurality (in this case 52) of transverse openings 11 positioned in accordance with the required position of the vibrator units 12 to secure the desired pattern or directivity and which are adapted to freely receive the vibrator units 12 with their respective coil forms 17 and windings 16. In order to provide maximum rigidity of the grid and minimum extrusion of rubber between the grid openings 11 and their respective vibrator units, it is desirable that the forward portion 37 between each grid opening 11 be as large as possible, there being a small clearance space 38 at all points between the vibrator units 12 and the grid 10. Due to the more or less T-shape cross section of each vibrator unit in the horizontal plane and its rectangular cross section in the vertical plane as shown respectively in FIGURE 2 and FIGURE 1, it has been found preferable to undercut the rear portion 39 of the horizontal portions of the grid between each grid opening 11 and also the outer surface 41 of each outer grid opening for the case of vertically disposed coil forms to provide clearance for the coil forms 17 and the windings 16 thereon while maintaining minimum clearance between the front portion 37 between grid openings and the working surface 15 of each vibrator unit.

The thickness of the grid is not critical and may vary within certain limits depending on structural requirements, the length of the vibrator units and the number of windings on each vibrator unit. For operation at depths at least as deep as 1000 feet an aluminum grid having a thickness of about one inch has been found satisfactory when reinforced in the manner described hereinafter. It is also believed that the undercutting of grid portions 39 provides in effect a dual layer grid which tends to damp the grid thus also tending to break up the nodes of vibration of the grid and the existence of a resonant frequency for the grid.

As best shown in FIGURE 1 and FIGURE 2, the coil forms 17 are comprised of a suitable dielectric material having sufficient rigidity and of such internal depth and width that they will just pass over the largest upper portion 42 of each vibrator unit leg 18. The length of the coil forms 17 may vary and will depend upon the size of the vibrator units that are used, the number of coils it is desired to wind on each coil form and the method and means used to prevent movement or vibration of the coil forms on the legs of the vibrator units.

It has heretofore been the practice to wind each vi-

brator unit winding directly on both legs of each vibrator unit to reduce leakage reactance as much as possible. Further, it has also been the practice and considered necessary that one half of each vibrator unit winding be wound in opposite directions on each leg of the vibrator unit.

It has been found that the provision of windings as and for the purposes described herein, even though the air gap is materially increased, does not materially affect the operation of the transducer and that if it is desired to provide a plurality of windings on each vibrator unit an entire winding may be wound on one portion of a single coil form whereby at least six separate windings may be easily and simply provided on a single vibrator unit which has heretofore not been thought feasible.

The windings 16 for each vibrator unit may be wound on the coil forms 17 in any conventional manner either all on one coil form or divided equally between the two coil forms for each vibrator unit. A compressive material 43 such as rubber or the like may be affixed to the outer lower portion 44 of each vibrator unit to acoustically isolate the lower portion of each coil from the vibrator unit and a compressible material 45 substantially cylindrical in form such as for example rubber hose, may be inserted above the coil forms to hold the upper end of the coil forms in place and also support the end portion of magnets 46. Magnets 46 are held in place by friction between legs 13 of vibrator units 12 and retained by a fibrous adhesive tape in a manner well known in the art. The compressible material 43 and 45 in contact respectively with the lower and upper portions of each coil form 17 allows any necessary movement of the coil forms but holds the coil forms in a substantially fixed position thereby resulting in substantially reproducible vibrator unit electrical characteristics and also provides a substantial measure of acoustic isolation thereby preventing the generation of noise and the like in the transducer as a result of vibrations of the coil forms 17 due to external sources.

Interconnection of the vibrator unit windings is provided by a printed circuit 19 wherein the desired circuitry 22 and assembly information is printed in any conventional manner on a suitable dielectric base 47 such as ethoxylene glass fabric or the like. In addition to the printed electric circuitry 22 and terminal pins 21, the base 47 is provided with holes 49 to receive the mounting means for the backup plate (in this case 9 standoff bolts) and holes 51 (in this case 52) formed and positioned in accordance with the grid holes and adapted to freely receive the vibrator units 12 and their assembled coil forms 17.

After the windings 16 for each individual vibrator unit have been wound on the coil forms 17, the coil forms may be placed in the holes 51 in the printed circuit base 47 corresponding to their respective vibrator unit and the leads 52 from each winding may then be easily and quickly soldered to its respective terminal 21 on the base 47. The pattern array terminals 53 for each pattern array may be placed on the periphery of the base 47 and wires 23 soldered to these terminals to form a cable for connection to an electrical connector 24. As shown in FIGURE 3, electrical circuitry and connections for three separate pattern arrays are shown, but it is to be understood that a greater or lesser number of pattern arrays comprised of a greater or lesser number of individual windings may be used and the output and/or input wires for each pattern array may be combined and terminate in one or more electric connectors. As mentioned hereinabove, the connector wires 23 of each pattern array may be combined into a single cable and electric connector but it has been found preferable and desirable that the connector wires for certain arrays be separated and disposed away from the connector wires of certain other arrays to reduce crosstalk and simplify construction and repair or testing.

When assembled the winding harness comprising the coil forms, printed circuit, connector wires and electric connectors may be mounted on the vibrator unit assembly by sliding the coil forms 17 down over their respective legs 13 of the vibrator units 12 and affixing the printed circuit 19 to the inner surface 54 of the grid by means of screws 55 or the like.

It is the general practice in the design of underwater phase comparison transducers to space the vibrator units less than one wavelength apart, the usual spacing being of the order of one-half wavelength. Although it should be understood that the features of construction of the present invention are applicable to high resonant frequency transducers as well as those having a low resonant frequency, a point may be reached at the higher frequencies where there is insufficient space between the vibrator units for all the desired connections to be made on one printed circuit, or alternately, it may be desired to employ such a number of windings on each vibrator unit, such as for example, six windings, that the interconnections for such windings cannot be printed on one base. These disadvantages may be simply and easily overcome by using two or more printed circuits and stacking them in fixed spaced relationship one above the other. For example, the windings on the right leg of the vibrator units may be connected to one printed circuit and the windings on the left leg connected to a second printed circuit or all the windings of a portion of the vibrator units may be connected to a first printed circuit, all the windings of another portion of the vibrator units may be connected to a second printed circuit, another portion to another printed circuit, etc., and if necessary, the various printed circuits can then be interconnected as desired by wires or the like.

It may now be obvious that utilization of coil forms and a printed circuit in the manner described herein greatly simplifies construction and the interconnection of the vibrator unit windings 16 and provides a unitary removable winding harness that may be simply and quickly assembled or removed. Further, a single coil form or a plurality of coil forms may also be easily and quickly removed and/or replaced or repaired as is not possible or feasible in prior art transducers. Still further, utilization of a printed circuit allows the printing of assembly information and directions which greatly facilitate construction and repair with a proportionate reduction in possible assembly errors since the position of the magnet in each vibrator unit and the direction of winding the coils for each vibrator unit must have a fixed pre-determined relation.

For operation at depths as deep as 1000 feet where the hydrostatic pressure is of the order of 500 pounds per square inch, it may be obvious that the relatively thin grid will not withstand such forces or even maintain the working faces 15 of the vibrator units in a common plane. As mentioned previously herein, it is essential in a transducer comprising a part of a phase comparison detection system that the working faces of the vibrator units remain at all times substantially in the same plane. Experience has shown that a misalignment of the working face of vibrator units of about $\frac{1}{32}$ of an inch or more with the working surface of other vibrator units materially reduce the effectiveness and accuracy of the transducer.

In order to help overcome the above mentioned undesirable condition, there is provided in combination with the grid 10 a relatively thick backup plate 25 comprised of aluminum, steel, or the like held in fixed spaced relationship with the rear surface 34 of the grid by standoff bolts 26 or the like.

As shown in FIGURE 1 and FIGURE 3, nine standoff bolts or spacers 26 are utilized to hold the backup plate 25 in fixed spaced relationship with the rear surface 34 of the grid, four being located for abutting relationship with the periphery of the backup plate and spaced 90

degrees apart and five being located in the center portion 56 of the grid for abutting relationship with the center portion of the backup plate.

The number, position and length of the standoff bolts or spacers are not believed critical so long as at maximum operating depth, the grid is kept substantially coplanar with the backup plate within the limits specified hereinabove. The standoff bolts 26 which are positioned for and in abutting relationship with the outer periphery of the backup plate, have a threaded forward portion adapted for threaded engagement with the grid, a cylindrical middle portion and an internally threaded rear portion adapted to receive the backup plate bolts 57. The centrally located standoff bolts 26 are similar to the peripherally located standoff bolts except that their rear portions are not internally threaded. The front surface and rear surface of the standoff bolts should preferably be coplanar with respectively the grid and the backup plate.

A pressure release material 27 such as for example "Fairprene," a fabric coated with a synthetic elastic composition, or the like, having holes 58 provided to receive the rear portion of the standoff bolts, is disposed between the rear surface of the vibrator units and the front surface of the backup plate to acoustically isolate and insulate the vibrator units from the backup plate and to prevent crosstalk between vibrator units. The backup plate is additionally provided with four counter bored holes 59 in axial alignment with the peripherally located standoff bolts 26 to freely receive the backup plate bolts 57 which are adapted for threaded engagement with the internally threaded rear portion of the aforementioned standoff bolts 26.

As mentioned previously hereinabove, the length of the standoff bolts 26 is not critical in terms of over-all length, but it is important that the standoff bolt be so formed and of such a length and that the front surface 61 of the backup plate is held substantially coplanar with the front surface of the grid such that when the backup plate bolts 57 are tightened, the pressure release material 27 interposed between the vibrator units and the backup plate will exert a small amount of pressure on the rear surfaces of the vibrator units without disturbing the aforementioned coplanar relationship of the vibrator unit working surfaces 15. It has been found that if the front and rear surfaces of the grid are coplanar with the front surface of the backup plate and the length of the standoff bolts are held to a tolerance of $\pm .002$ inch, the vibrator units will be properly positioned.

As best shown in FIGURE 2, the backup plate is additionally provided with at least one (in the present invention there are 3) counterbored transverse passages 62 adapted to receive the output leads 23 and electrical connectors 24 of the pattern arrays. To facilitate assembly and dis-assembly of the transducer, it is desirable that the connector wires 23 of the pattern arrays be fixedly connected as by soldering to electrical connectors 24 that are separable from the backup plate 25 such that the backup plate may be removed and separated from the winding harness without disturbing the soldered connections of the electrical connectors 24.

Separability of the backup plate and the electrical connectors may be achieved by using conventional connectors such as for example AN 3 102 connectors. By providing sufficiently long connector wires 23, after assembly the center portions 63 of each electrical connector 24 may be passed forwardly through the passages 62 by first removing screws 64, pulling the connector 24 rearwardly sufficient to allow removal of the retaining ring 65 and then passing the center portion 63 forwardly through passage 62. For assembly the above procedure is simply reversed.

In addition to the grid and backup plate there is provided acoustic isolation and reinforcing means in which the forward portion of the torpedo shell 31 forms an in-

tegral part, which means form an important part of the present invention and which cooperate with the grid and backup plate to insure maintenance of proper vibrator unit location at substantial depths. The forward portion of the acoustic isolation and reinforcing means is comprised of an inwardly protruding pressure ring 66 having a front surface 67 substantially transverse to the longitudinal axis of the torpedo and attached to the extreme forward periphery 29 of the torpedo shell as by welding or the like and having a plurality of transverse holes 68 on a common bolt diameter to freely receive the mounting bolts 69 and the acoustic isolation bolts 71. A plurality of layers of acoustic isolation material 72 such as for example, "Fairprene," a fabric coated with a synthetic elastic composition, or the like, having poor sound transmitting properties and of the same general configuration as the pressure ring 66 are provided between the pressure ring 66 and a mounting ring 73 which are all held in watertight relation by the acoustic isolation bolts 71 which are acoustically isolated from the torpedo shell by isolation washers 74. The mounting ring 73 is adapted for threaded engagement with the acoustic isolation bolts 71 and has provided in its front surface an annular groove 75 adapted to receive an O-ring 76 to provide a watertight seal between the mounting ring 73 and the grid 10.

The mounting ring 73 and the acoustic isolation material 72 are further provided respectively with a plurality of transverse holes 80 and 89 (in this case 6) to freely receive the mounting bolts 69 which are adapted for threaded engagement with the outer periphery of the grid as at points 91 and which provide the sole means for securing the vibrator unit assembly to the acoustic isolation and reinforcing means more thoroughly described and discussed hereinbelow.

Radially spaced ribs 77 parallel to the longitudinal axis of the torpedo in abutting relation with the rear surface 78 of the pressure ring 66 and affixed to the torpedo shell 31 as by welding and the like provide reinforcement of the pressure ring 66. Although a welded construction has been described it is to be noted that the pressure ring 66 and the reinforcing means thereof such as for example, radial ribs 77 or the like, may be formed as an integral part of the torpedo shell.

As will be more fully explained later, it is considered important that the mounting ring 73 be acoustically isolated from the torpedo shell 31 and it is considered essential that it be attached thereto in such a manner that as pressure is applied to the front surface of the rubber window 13, the grid may move rearwardly as a unit a certain distance depending upon the compressibility of the acoustic isolation material 72.

The rear portion of the aforementioned acoustic isolation and reinforcing means is comprised of a second annular ring-like pressure ring 79 carried by a plurality of gussets or longitudinal ribs 81 and has an inside diameter less than the diameter of the backup plate. The gussets or longitudinal ribs 81 may be attached to the inner surface of the torpedo shell 31 as by welding or the like or, alternately, may be formed as an integral part of the torpedo shell as may the second pressure ring 79.

The second pressure ring 79 is provided with a plurality of transverse holes 82 on a common bolt diameter adapted to freely receive a like number of acoustic isolation bolts 83, the rear portions of which are acoustically isolated from the pressure ring as by isolation washers 84. An annular ringlike spacer ring 85 adapted for threaded engagement with the isolation bolts 83 and a plurality of layers of acoustic isolation material 86 having a configuration similar to the spacer ring 85 and having substantially the same thickness and properties and characteristics as the acoustic isolation material 72 in the forward portion is carried on the forward inner surface 87 of the second pressure ring 79 by reason of the isolation bolts

83. For convenience in mounting and removing the vibrator unit assembly access holes 92 may be provided in the second pressure ring 79 in axial alignment with and having the same diameter as holes 89 in the forward pressure ring 66.

It is believed essential for optimum operation of the transducer at substantial depths that the front surface 88 of the spacer ring 85 and the peripheral rear surface 32 of the backup plate in contact with the spacer ring be in a plane substantially transverse to the longitudinal axis of the torpedo, or, to say it another way, substantially coplanar with the grid surfaces, and that they be a predetermined distance rearwardly of the front surface of the mounting ring, such distance being such that when the vibrator unit assembly is mounted in the torpedo proportional forces will be exerted on the forward and rearward acoustic isolation material 72 and 86. It has been found preferable that this distance be within a tolerance of $\pm .002$ inch.

This distance and the coplanar relationship of the various surfaces as indicated hereinabove may be held within the desired tolerance if prior to mounting the vibrator unit assembly in the torpedo the forward isolation bolts 71 and the rearward isolation bolts 83 are tightened with substantially the same amount of tension, thereby subjecting the forward acoustic isolation material 72 and the rearward acoustic isolation material 86 to the same amount of compressive force, and then securing the proper distance between the front surface of the mounting ring and the front surface of the spacer ring by forming these surfaces on a lathe after assembly in the torpedo.

As may now be apparent, the present invention as disclosed and described herein incorporates, for a torpedo installation, the forward portion of the torpedo as an integral part of the transducer to provide an improved transducer having a larger diameter and occupying a minimum amount of space and having improved range and directional characteristics for use especially at substantial depths. Additionally, the acoustic isolation means for the vibrator unit assembly is utilized in cooperation with the torpedo shell reinforcing means in a new and novel manner to insure the proper alignment of the vibrator units at substantial depths.

It may now also be obvious that to insure the proper alignment of the vibrator units it is necessary that as the hydrostatic pressure on the face of the transducer increases, the outer periphery of the grid and the outer periphery of the backup plate remain in a fixed relation one with the other as well as their center portions. An acoustically isolated but unyielding connection at one peripheral point but not at the other results, at substantial depths, in distortion of the vibrator unit assembly and hence, misalignment of the vibrator units. An unyielding connection at both points, while satisfactory from a structural point of view, is unsatisfactory because of the high sound transmitting properties of such a connection thereby resulting in detection by the vibrator units of torpedo machinery noise and the like and hence, an undesirably high background level.

The optimum in acoustic isolation and structural requirements is substantially attained by the construction shown and described herein where in addition to an integrated grid and backup plate, this combination is acoustically isolated at the structural reinforcement points and wherein the acoustic isolation is so constructed and designed as to be compressible in the direction of the compressing force whereby the entire vibrator unit assembly is allowed to move rearwardly, albeit a very small distance, the compressive force thereby being substantially equally distributed at the points of reinforcement from maximum hydrostatic pressure to minimum hydrostatic pressure thereby also allowing an accurate determination of and a proportionate reduction in the structural strength of the points of reinforcement.

It may now be seen that there has been shown and described a transducer construction having improved range and directivity characteristics for use especially at substantial depths in combination with a torpedo. It is to be noted and understood, however, that the construction and components as shown and described herein are subject to modification as is the use and installation of the transducer since it may be used with underwater bodies other than a torpedo and in underwater installations without departing from the spirit and scope of the invention.

The construction shown and described herein is in many respects inexpensive to fabricate and is versatile as to construction, modification, repair, and use. It also lends itself readily to mass production methods thereby resulting in less expensive transducers and transducers having more predictable and more uniform characteristics. Still further, it allows the use in a torpedo of an improved directional transducer having a working face that approaches the diameter of the torpedo, that occupies a minimum amount of space, and that has improved directional characteristics at maximum operating depth substantially the same as its directional characteristics at minimum operating depth.

While the present invention has been described in its preferred embodiment, it is realized that modifications may be made, and it is desired that it be understood that no limitations upon the invention are intended other than may be imposed by the scope of the appended claims.

Having now disclosed our invention, what we claim as new and desire to secure by Letters Patent of the United States is:

1. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly, said vibrator unit assembly comprising a rearwardly movable first rigid plate, said plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to said acoustic window, one each being positioned in each of said openings, windings associated with said vibrator units, a rearwardly movable second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and reinforcing means carried by said shell and in abutting relationship with said first and second plate whereby said first and second plates are maintained in substantially coplanar relationship as hydrostatic pressure on the front surface of said acoustic window increases.

2. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly, said vibrator unit assembly comprising a rearwardly movable first rigid plate, said plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to said acoustic window, one each being positioned in each of said openings, windings associated with said vibrator units, a rearwardly movable second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and means to reinforce said vibrator unit assembly carried by said shell in peripherally abutting relationship with said first and second plate whereby said first and second plates are maintained in mutual coplanar relationship as hydrostatic pressure on the front surface of said acoustic window increases.

3. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly, said

vibrator unit assembly comprising a rearwardly movable first rigid plate, said plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to said acoustic window, one each being positioned in each of said openings, windings associated with said vibrator units, a rearwardly movable second rigid plate in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and means to reinforce said vibrator unit assembly disposed between said shell and said first and second plate whereby said vibrator unit assembly may move rearwardly as hydrostatic pressure on the front surface of said acoustic window increases.

4. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly disposed within said shell and closing said open end, said vibrator unit assembly comprising a rearwardly movable first rigid plate, said plate having a plurality of openings in predetermined different positions, said openings having a front portion and a rear portion, said front portion having an area less than said rear portion, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual longitudinal magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to the rear surface of said acoustic window, each of said working faces having an area less than the area of the front portion of each of said openings, one vibrator being centered in each of said openings, windings associated with said vibrator units, a rearwardly movable second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and reinforcing means carried by said shell and in abutting relationship with said first and second plate whereby said first and second plates are maintained in substantially coplanar relationship as hydrostatic pressure on the front surface of said acoustic window increases.

5. A transducer according to claim 4 in which the thickness of the first plate is substantially less than the length of said vibrator units.

6. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly disposed within said shell and closing said open end, said vibrator unit assembly comprising a rearwardly movable first rigid plate, said plate having a plurality of openings in predetermined different positions, said openings having a front portion and a rear portion, said front portion having an area less than said rear portion, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual longitudinal magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to the rear surface of said acoustic window, each of said working faces having an area less than the area of the front portion of each of said openings, one vibrator being centered in each of said openings, windings associated with said vibrator units, a rearwardly movable second rigid plate in fixed spaced relationship with said first plate, plate, spacing means interposed between and connecting said first and said second plate whereby said first and said second plate may be held in substantially coplanar relationship, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and means to reinforce said vibrator unit assembly disposed between said shell and said first and second plate whereby said vibrator unit assembly may move

rearwardly as hydrostatic pressure on the front surface of said acoustic window increases.

7. A transducer according to claim 6 in which the spacing means comprises a plurality of longitudinal elements disposed at the periphery and center of said first and second plates.

8. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly, said vibrator unit assembly comprising a first rigid plate, said plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual longitudinal magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to said acoustic window, one vibrator being positioned in each of said openings, windings associated with said vibrator units, a printed circuit having a plurality of individual openings adapted to freely receive said vibrator units, said printed circuit providing electrical circuitry for interconnecting at least a part of the windings, a plurality of coil forms removably carried by said vibrator units, said windings being wound on and supported by said coil forms and connected to said printed circuit in a predetermined manner, a second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and reinforcing means carried by said shell in abutting relationship with said first and second plate whereby said first and second plates are maintained in substantially coplanar relationship as hydrostatic pressure on the front surface of said acoustic window increases.

9. A transducer according to claim 8 in which the openings in said first plate have a front portion and a rear portion, said rear portion having an area greater than said front portion and adapted to freely receive said coil forms; and said printed circuit is carried by said first plate.

10. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly, said vibrator unit assembly comprising a first rigid plate, said plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual U-shaped magnetostrictive vibrator units, one each being centered in each of said openings, each of said vibrator units being comprised of a front portion and two rearwardly extending leg portions, said front portion having a working face of substantial area affixed to said acoustic window and said leg portions having individual rear surfaces, coil forms removably carried by said leg portions, windings carried by said coil forms, a printed circuit having a plurality of individual openings positioned and adapted to freely receive said vibrator units and said coil forms, said printed circuit providing fixed electrical circuitry for interconnecting said windings, a second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and reinforcing means carried by said shell in abutting relationship with said first and second plate whereby said first and second plates are maintained in substantially coplanar relationship as hydrostatic pressure on the front surface of said acoustic window increases.

11. A transducer according to claim 10 in which one coil form is mounted on at least one leg portion of each vibrator unit and said printed circuit is carried by said first plate.

12. A transducer according to claim 10 in which a plurality of printed circuits are provided in stacked spaced relationship and a portion of said windings are interconnected by each printed circuit.

13. A transducer comprising: an array of individual U-shaped magnetostrictive vibrator units, each vibrator unit comprising a front portion of substantial area and two individual rearwardly extending leg portions, each said front portion having a working face positioned in a common plane; a magnet disposed between the leg portions of each vibrator unit; a coil removably carried by at least one leg of each vibrator unit; a winding carried by each coil form; means removably disposed between said magnets and said coil forms to support said magnets and hold said coil forms in a normally fixed position with regard to its respective leg portion; and a printed circuit having a plurality of individual openings positioned and adapted to freely receive said vibrator units and said coil forms, said printed circuit providing electrical circuitry for interconnecting said windings in a predetermined manner.

14. An underwater transducer comprising: an outer shell open at one end; a vibrator unit assembly disposed within said shell and closing said open end, said vibrator unit assembly comprising a rearwardly movable first rigid plate, said plate having a plurality of openings in predetermined different positions, said openings having a front portion and a rear portion, said front portion having an area less than said rear portion, an acoustic window bonded to said first plate, said acoustic window having a front surface exposed to the water and a flat rear surface, an array of individual longitudinal magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to the rear surface of said acoustic window, each of said working faces having an area less than the area of the front portion of said openings, one vibrator being centered in each of said openings, windings associated with said vibrator units, a rearwardly movable second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and means carried by said outer shell in abutting relationship with said first and second plates whereby the outer periphery of said first and second plates are peripherally reinforced and isolated from the shell, said means allowing said first and second plates to move rearwardly a substantially equal distance as the hydrostatic pressure on the front surface of said acoustic window increases.

15. An underwater transducer comprising: an outer shell open at one end and having a front portion and a rear portion; a vibrator unit assembly disposed within said shell and closing said open end, said vibrator unit assembly comprising a first rigid plate, said plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate, an array of individual longitudinal magnetostrictive vibrator units having individual rear surfaces and having individual working faces affixed to the rear surface of said acoustic window, one vibrator being centered in each of said openings, windings associated with said vibrator units, a second rigid plate held in fixed spaced relationship with said first plate, and acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; first isolating means disposed in watertight relationship between the outer periphery of said first plate and said shell front portion whereby said first plate is acoustically isolated from said shell and may move rearwardly; and second isolating means carried by said shell rear portion in abutting relationship with said second plate whereby said second plate is acoustically isolated from said shell and may move in a rearwardly direction substantially the same distance said first plate moves rearwardly upon application of pressure on the front surface of said acoustic window, said first and second isolating means additionally providing reinforcement at the outer periphery of said first and second plates.

16. A transducer according to claim 15 in which said

first isolating means comprises an inwardly extending first pressure member adapted to peripherally reinforce said first plate and longitudinally compressible acoustic isolation material disposed between said first pressure member and said first plate; and said second isolating means comprises an inwardly extending second pressure member adapted to peripherally reinforce said second plate and longitudinally compressible acoustic isolation material disposed between said second pressure member and said second plate whereby the pressure on said isolation material in said first and second isolating means remains substantially equal.

17. In a directional transducer for use in torpedoes and adapted for use especially at substantial depths the combination comprising: an outer shell substantially open at one end and forming the most forward portion of the torpedo body; a rearwardly movable first rigid plate transverse to said open end, said first plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate and substantially closing said open end, said acoustic window having a front surface exposed to the water and a flat rear surface; an array of individual magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to said acoustic window rear surface, one vibrator being positioned in each of said openings; windings associated with said vibrator units; a rearwardly movable second rigid plate held in fixed spaced relationship with said first plate; acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and reinforcing means carried by said shell in abutting relationship with said first and second plate whereby said first and second plates are maintained in substantially coplanar relationship as hydrostatic pressure on the front surface of said acoustic window increases.

18. In a directional transducer for use in torpedoes and adapted for use especially at substantial depths the combination comprising: an outer shell substantially open at one end and forming the most forward portion of the torpedo body; a rearwardly movable first rigid plate transverse to said open end, said first plate having a plurality of openings in predetermined different positions, an acoustic window bonded to said first plate and substantially closing said open end, said acoustic window having a front surface exposed to the water and a flat rear surface; an array of individual magnetostrictive vibrator units having individual rear surfaces and having individual working faces of substantial area affixed to said acoustic window rear surface, one vibrator being positioned in each of said openings; windings associated with said vibrator units; a rearwardly movable second rigid plate held in fixed spaced relationship with said first plate; acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and means to reinforce and isolate said first and second plates disposed between said shell and said first and second plate whereby said first and second plates may move rearwardly a substantially equal distance as hydrostatic pressure on the front surface of said acoustic window increases.

19. In a directional transducer for use in torpedoes and adapted for use especially at substantial depths the combination comprising: an outer shell substantially open at one end and forming the most forward portion of the torpedo body; a first rigid plate transverse to said open end having a front surface and a rear surface, said first plate having a plurality of openings in predetermined different positions, said openings having a front portion and a rear portion, said front portion having an area less than said rear portion, an acoustic window bonded to the front surface of said first plate and substantially closing said open end, said acoustic window having a front surface exposed to the water and a flat rear surface; an array of individual magnetostrictive vibrator units having individual rear surfaces and having individual working faces of sub-

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stantial area affixed to said acoustic window rear surface, each of said working faces having an area slightly less than the area of the front portion of each of said openings, one vibrator being centered in each of said openings; windings associated with said vibrator units; a second rigid plate disposed a fixed distance rearwardly of said first plate and substantially parallel therewith; spacing means interposed between said first and second plates whereby said first plate may be held in substantially fixed coplanar relationship with said second plate; acoustic isolation means interposed between said vibrator unit rear surfaces and said second plate; and means to reinforce and isolate said first and second plates disposed between said shell and said first and second plates whereby said first and second plates may move rearwardly a sub-

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stantially equal distance as hydrostatic pressure on the front surface of said acoustic window increases.

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