

Sept. 3, 1946.

H. C. HAYES

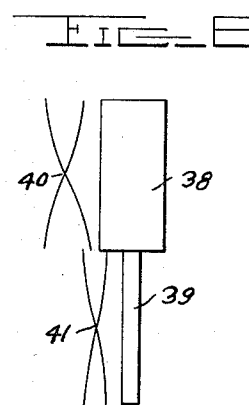
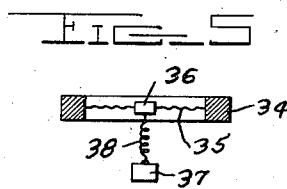
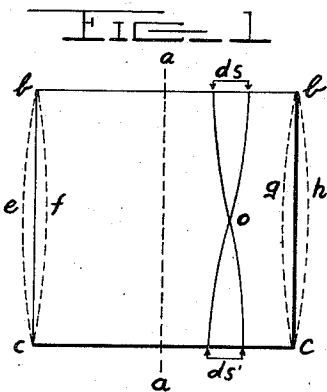
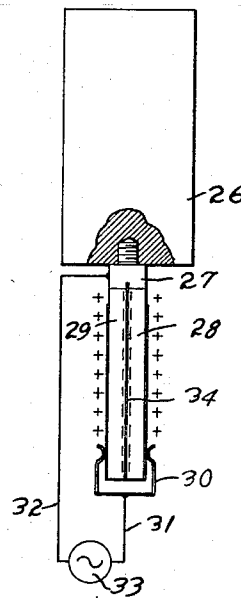
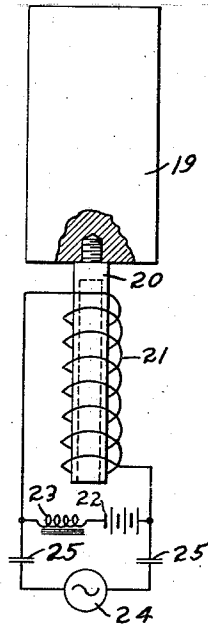
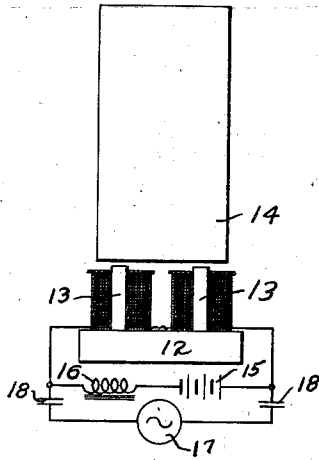
2,406,767

DIRECTIVE TRANSCIVER FOR SOUND

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2 Sheets-Sheet 1

FIG. 2 FIG. 3 FIG. 4



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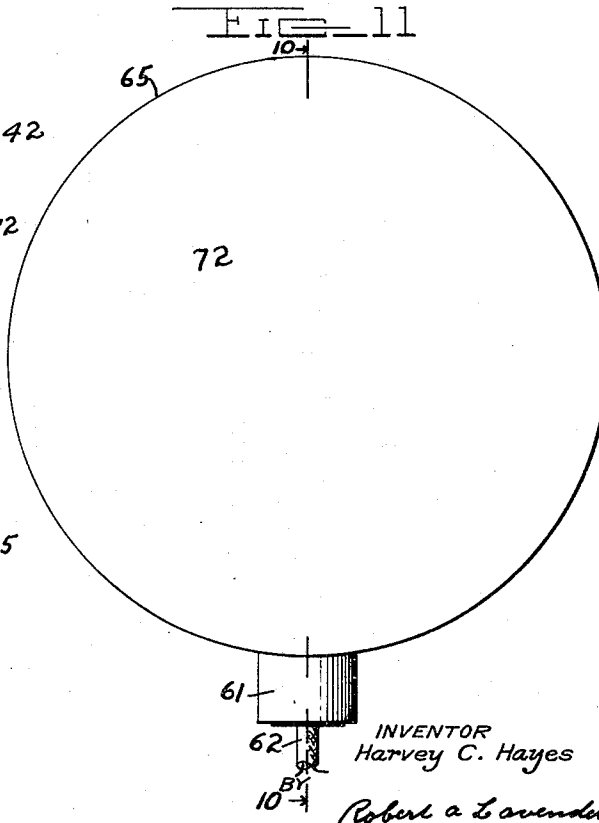
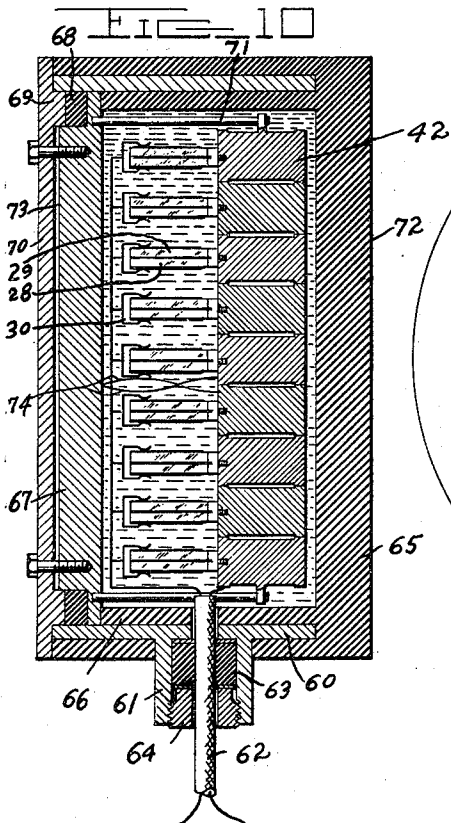
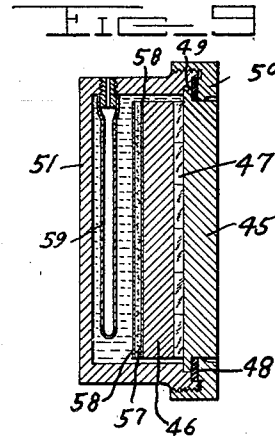
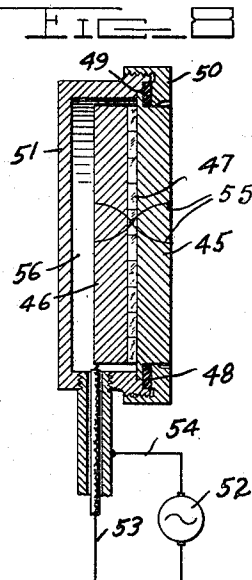
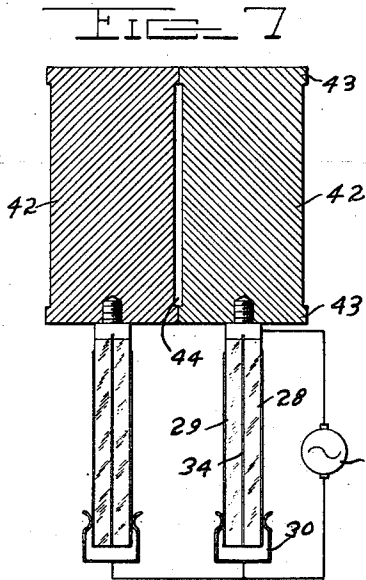
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DIRECTIVE TRANSCIEVER FOR SOUND

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2 Sheets-Sheet 2



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DIRECTIVE TRANSCIVER FOR SOUND

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Application October 22, 1932, Serial No. 639,129

10 Claims. (Cl. 177—386)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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This invention relates to means for producing directive beams of high frequency sound and has for one of its objects to provide a driving mechanism whereby all parts of the face of the transmitter shall be forced to vibrate in phase.

A further object is to increase the efficiency of the apparatus by preventing the radiation of sound energy from the back face of the oscillatory system.

With the above and other objects in view, the invention consists in the construction, combination and arrangement of parts as will be described more fully hereinafter.

In the drawings:

Fig. 1 shows diagrammatically the conditions existing in a member vibrating like a transmitter element that may be employed in my invention;

Figs. 2 and 3 show two devices vibrated by magneto-strictive forces;

Fig. 4 shows piezo-electric means for driving a vibrating element;

Fig. 5 shows a vibrating system having two resonant frequencies in which the masses are separated from the elastic elements;

Fig. 6 shows a vibrating system having two resonant frequencies with the masses and the elastic forces incorporated in the same body;

Fig. 7 is a detail view of a portion of the driving mechanism of my invention;

Fig. 8 is an axial sectional view of an assembled transmitter constructed to prevent radiation of sound energy from the back face of the vibrator;

Fig. 9 is a like view of an improved form of device such as that shown in Fig. 8;

Fig. 10 is an axial sectional view of the form of my invention that is at present preferred, on line 10—10 of Fig. 11;

Fig. 11 is an elevational view of the transmitting face of the device shown in Fig. 10.

Numerous difficulties are encountered in an attempt to generate efficiently an intense, high pitched submarine sound beam. Theoretically this can be done by employing a radiating area of small dimensions placed at the focus of a parabolic reflector or of a condensing lens, but practically this is impossible for the reason that there is a definite limit to the amount of sound energy that can be radiated from a unit area due to the fact that cavitation occurs at the radiating surface when the amplitude of oscillation exceeds a definite value. This limiting amplitude is determined somewhat by the temperature and air content of the water, depth of submergence of the transmitter, etc. But under

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the most favorable operating conditions the maximum radiation from a square centimeter of area falls well within two watts. As a result it is impossible to generate enough sound energy over the largest area that can be employed at the focal point of a practical sized mirror or lens to give a powerful sound beam.

Since, in order to generate sufficient energy for an intense sound beam a radiating surface of considerable area is required, a solution must be found for the difficult problem of so actuating such an area that all parts thereof vibrate in phase. Unless all portions do oscillate in phase, the radiation from one part of the transmitter may completely annul that from another part. The intensity of the sound beam at any point is the vector sum of the radiation from all increments of radiating surface and such addition will not result in maximum efficiency unless the radiation from all portions of the area is accurately in phase.

An ordinary diaphragm driven at one or several points cannot serve for such a sound generating area for the reason that if it is made thick enough to resonate at such high frequencies it ceases to act as a diaphragm and becomes a medium for transmitting the sound generated at the several driving points as separate sources, and if it is made thin enough to function as a diaphragm, i. e., with a thickness less than a quarter wave length of the sound generated in the material of the diaphragm at the driving points, it will break up into nodes and loops over the surface and the condition for uniformity of phase cannot exist.

Further, all the radiated energy must be so directed as to form a beam. Theoretically and practically this can be accomplished if a plane radiating area of dimensions large with respect to a wave length of the sound generated in the transmitting medium can be provided. Directivity is then provided through the action of well known laws of interference of wave energy. Enough sound energy can be transmitted to give an intense sound beam from an area smaller than that required to give good directivity, so the difficulty of confining the sound to a beam is simply another aspect of the problem of oscillating a large surface with all its parts in phase.

Professor Langevin has overcome these difficulties in an ingenious way by directly generating a standing wave system in a sandwich-like arrangement consisting of two like metal disks cemented together with an intercalated layer of quartz crystals so cut that the X axis is perpendicular to the plane surfaces of the metal disks

and arranged in mosaic form. An alternating voltage applied across the crystals causes them to expand and contract along the X axis and when the frequency of the applied A. C. voltage is properly adjusted, the sandwich oscillates as a standing wave system, the fundamental of which is that frequency which gives a single node in the plane bisecting the quartz crystals, and a loop in each of the outside circular metal faces. It is obvious that the system can also be resonated at the harmonics of this frequency. In this way it has proved possible to oscillate, in phase, plane areas of dimensions adequate to give good directivity. However, due to its inefficiency, this scheme does not generate a sound beam of sufficient intensity to make it of practical value.

My invention centers about three studies: First, a study of the variation in the modes and amplitudes of vibration of rectangular, hexagonal and cylindrical prisms as the ratio between length and transverse dimensional area is varied; second, a study of various ways and means of setting up in these prisms standing wave systems along the direction of their length; and third, a study of means for causing a multiplicity of such prisms to oscillate in phase.

It was found that the end areas of such prisms, when energized at their fundamental frequency (a loop at each end surface and a node at the mid plane), will all oscillate substantially in phase if the ratio of length to diameter is as great as two, but that this condition begins noticeably to fail for ratios as low as one. The shape of the cross section appears to make little difference. It can be shown theoretically that the experimental results obtained should be expected. An important fact disclosed by this work and one which has much to do with the success of my invention, is that the amplitude of oscillation of the ends of the prisms under a given stimulus increases noticeably as the ratio of length to diameter is increased from values less than 1 to values as great as 2. It will, therefore, be seen that when the prisms are so dimensioned as to meet the requirement that the end areas shall oscillate in phase at the fundamental resonant frequency, the conditions are also favorable for a large amplitude of oscillation. These two conditions make for high acoustical efficiency both for generation and reception of sound energy.

Fig. 1 may serve to explain why the two desiderata (uniformity of phase over end areas and increased amplitude) are approached as the ratio of length to sectional diameter is increased. This figure shows a plane longitudinal section of a prism containing the axis $a-a$ with the two equal end diameters $b-b$, $c-c$ and the two equal side elements $b-c$, $b-c$. Assume push-pull forces applied over one end surface of the prism and directed parallel to the axis $a-a$, and that the frequency of these forces can be varied uniformly. As the frequency is slowly changed from, say lower to higher values, the character of oscillation of the top end, as indicated by sand patterns, will at some definite frequency show marked activity at the center but not much at the edges and at a slightly different frequency a vigorous oscillation at the edges but diminished movement at the center. The maximum displacement at any portion (ds) of the surface will occur when the sub-prism having end areas of (ds) and (ds') oscillates as a half wave length with a node at o , as shown in Fig. 1. The ve-

locity of sound along any of these sub-prisms is given by the expression:

$$V = \sqrt{\frac{E}{\rho}}$$

where E is the elasticity and ρ is the density of the medium. The effective value of E which measures the restoring forces brought into play as the prisms oscillate is less for portions near the sides because of lack of supporting inertia in a radial direction. As a result of such lack of inertia support, the cross section of the whole prism does not remain uniform when it oscillates, but varies somewhat in accordance with the exaggerated contour lines $b-e-c$ and $b-f-c$ or $b-g-c$ and $b-h-c$, assuming the convex form $b-e-c$ and $b-h-c$ when the cylinder is at its shortest length and the nodal plane through o is at the maximum pressure, and the concave form $b-f-c$ and $b-g-c$ when the cylinder is at its maximum length and the nodal plane is at a minimum pressure.

The lengthwise restoring forces brought into play are less near the boundaries e and h than they would be if the sectional area were infinite, because in the latter case there could be no radial motion of the medium and for the same reason the lengthwise restoring forces for sections near the boundaries e and h are less than for regions farther in toward the axis $a-a$; as a result the natural period of the sections near the boundaries is less than for sections near the axis because the velocity of sound by virtue of the relation

$$V = \sqrt{\frac{E}{\rho}}$$

is less for sections near the boundary than for sections near the axis. It is obvious, however, that the difference in resonant frequency between boundary and axial sections becomes less as the ratio of length to sectional diameter is increased. Tests have demonstrated that this difference becomes sufficiently small to permit the entire end areas to pull into phase when this ratio becomes greater than about two-to-one. Under these conditions the lateral pressure release at the boundary becomes effective even at the axis $a-a$ of the prism. It is for this reason that the end surfaces can then oscillate in phase. It is also obvious that when the diameter of the prism is sufficiently small with respect to the length to permit the radial pressure release to become effective to the center, that the prism can oscillate to greater amplitudes than is the case for a prism of infinite cross section where there can be no side displacement of the material of the prism or, in fact, in case of a prism having ratio of length to diameter sufficiently small to approach this condition.

Two types of devices have been found for setting the prisms into resonant oscillations, one of which introduces periodic forces suitable for setting up the desired mode of oscillation without attaching any inert mass to the prism, while the other class employs a second tuned mechanical oscillator that can be driven electrically and which in turn is coupled to one end of the prism. Fig. 2 represents the first class and Figs. 3 and 4 the second class.

In Fig. 2 the electromagnet 12 is disposed with its poles 13 adjacent one end of prism 14. A polarizing direct current is supplied to the magnet coils by battery 15 through choke coil 16. A source 17 of alternating current is connected to the magnet circuit through condensers 18 in ac-

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cordance with common practice. This type of drive requires that the material of the prism be magnetic and the vibrations of the prism are due to magneto-strictive forces.

The prism 19 in Fig. 3 is mechanically connected to a magnetic member 20 around which is a magnetizing coil 21 energized by battery 22 through choke coil 23. Alternating current from source 24 is supplied to the magnet circuit through condensers 25. In this form the magneto-strictive forces set up in element 20 cause the prism 19 to vibrate.

Fig. 4 shows a prism 26 to which is mechanically connected a base 27 whereon are mounted the piezo-electric crystal elements 28 and 29 with faces of like polarity disposed against electrode 34 that is grounded to base 27. Spring clip 30 contacts the two piezo-electric elements and the electric circuit is completed by means of wires 31 and 32 that connect a source 33 of alternating current to the clip 30 and the base 27. The crystals are so cut that they expand and contract longitudinally with the variations in voltage applied thereto, the movement thereof acting to vibrate the prism 26. This type of driving element is preferable to those shown in Figs. 2 and 3 in that there are no energy losses due to hysteresis or eddy currents.

It will be seen that the auxiliary oscillators of Figs. 3 and 4 each have a definite mechanical resonant frequency to which they will respond vigorously when the frequency of the A. C. supply is adjusted thereto. Moreover, the prism also has a definite resonant frequency to which it will respond when energized at that frequency. As shown in Figs. 3 and 4, two tuned members each having a definite frequency peculiar to itself may be combined into a unit that will oscillate vigorously at two different frequencies whose relations to the uncoupled frequencies when expressed in terms of the respective wave lengths in the transmitting medium are as follows:

$$(a) \quad f' = \sqrt{\frac{1}{2}(f_1^2 + f_2^2) + \frac{1}{2}\sqrt{(f_1^2 - f_2^2)^2 + 4\tau^2 f_1^2 f_2^2}}$$

$$(b) \quad f'' = \sqrt{\frac{1}{2}(f_1^2 + f_2^2) - \frac{1}{2}\sqrt{(f_1^2 - f_2^2)^2 + 4\tau^2 f_1^2 f_2^2}}$$

where f_1 and f_2 refer respectively to the individual resonant frequency of each member when uncoupled and f' and f'' to the two resulting frequencies when they are coupled. The coefficient of coupling τ , which must have some value between zero and unity is dependent on the relative masses and the distribution of the mass in the two separate oscillators and cannot be definitely evaluated mathematically except for certain ideal combinations. However, experimental determinations have shown that τ can be varied over a considerable range without running the design to impractical dimensions and that in this way a single sound generator can be made to operate efficiently at two different frequencies. This proves to be a valuable feature under some conditions, but whether or not both resonant frequencies are desired, numerous tests have shown that the coupled system indicated in Figs. 3 and 4 is to be preferred for energizing the prism. It is recognized that the theory of coupled oscillators is old and has been applied by others to two resonant mechanical systems wherein the masses are concentrated and oscillate as a whole, but it is believed to be novel to apply this theory to two oscillators where the frequencies involved are so high that masses and restoring forces (elastic

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members) cannot be separated, but wherein resonance must be obtained by such a distribution of mass and restoring elasticity as to give a standing wave system in the material forming the oscillating members.

This point can perhaps be clarified by Figs. 5 and 6. Fig. 5 represents schematically a sound generator for relatively low pitched signals wherein the numeral 34 designates a somewhat massive ring within which a relatively thin diaphragm 35 is mounted and carries at its center a mass 36. Mass 37 is coupled to mass 36 by a relatively light elastic member 38. The combined mass of ring 34 and mass 36 with their elastic coupling 35 has a definite resonant frequency and masses 36 and 37 alone with their elastic coupling 38 also form a system having a definite natural frequency. When the two systems are coupled as shown, the combination has two resonant frequencies as described. The point to note is that the masses and the restoring members are separated. Fig. 6, which simulates the oscillating system of my invention, is made up of two oscillators 38 and 39 each of which resonates at its particular resonant frequency as shown by the half wave forms 40 and 41 when the two are not coupled. Here the elastic deformation takes place in the mass itself and the masses cannot be separated from the restoring or elastic members. The natural frequency of each member in Fig. 6 is determined by the velocity of sound in the material, while for Fig. 5 the velocity of sound does not determine the resonant frequency of the two separate systems when uncoupled. When a system like that of Fig. 6 is used, the length of the prism 38 should be at least equal to $2\frac{1}{2}$ times its cross sectional diameter.

To energize a large transmitting surface it is necessary to operate a multiplicity of such prisms arranged side by side with their respective ends substantially in the same plane and the spacing between prisms not greater than a quarter wave length of the sound waves generated in the medium to produce a directive sound beam. It was found possible to obtain good results when the prisms were placed in close mosaic and surrounded by a viscous oil such as castor oil. In this case the shearing forces introduced along the side surfaces due to slippage when adjacent prisms were out of phase gave sufficient mechanical coupling to help pull them into phase. A preferable construction is shown in Fig. 7 which is a cross section of two adjacent prisms 42 on a plane through their axes. Each prism has a narrow flange 43 formed at each end which flanges may be joined together by welding or brazing to form a mechanical unit of all the prisms and yet leave spaces 44 between the bodies of the prisms to allow for the deformation thereof during vibration. Instead of a large number of prism units joined together, the vibrating body may be a single casting cored to leave spaces such as 44 therein to permit lateral expansion and contraction of the columns between the spaces in their nodal regions. This mechanical coupling of the prisms to each other causes the several sections to pull into phase with each other even when the natural periods of the sections are considerably different.

The end surface of such a mosaic can be given any desired area, can be oscillated in phase and can be driven to exceptionally large amplitudes because the intervening air spaces permit each section freely to expand and contract its sectional area throughout the nodal region. While I prefer that the several prismatic sections shall have

the same cross sectional form and area, their cross sections may vary considerably among themselves in form so long as the sectional area remains substantially the same for all. While the mosaic operates well when the sections are coupled at but one end, I prefer that they be coupled at both ends as this gives added assurance that the several sections will pull into phase, and for the further reason that it greatly stiffens the assembly so that it will not readily damage under rough handling. Though almost any homogeneous, highly elastic material may serve for the prism elements, I prefer a metal having small temperature coefficient of elasticity and low internal losses attendant upon mechanical oscillation with relatively large amplitude. Invar, phosphor bronze and aluminum have proved to be the best of the several metals tested.

Maximum efficiency is secured when the sound energy is radiated only from the surface designed for that purpose, i. e., from the surface opposite to the coupling point. However, the surface to which the driving elements are attached oscillates strongly and forms a potential radiating area about equal to that of the transmitter face and this surface will propagate sound energy into any medium with which it makes contact. Energy so radiated from the back faces reduces the intensity of the sound beam by approximately the amount of such energy and therefore the effectively transmitted sound is equal to only about one-half of the input energy. It is therefore desirable to reduce as much as possible the sound emitted from the back faces. This may be done by exposing the back surfaces to a light medium, preferably a gas, in which, because of its low elasticity and density, comparatively little sound energy will be developed by the relatively small amplitude through which the prisms oscillate. This is not new, but it is believed that my method of applying it is new.

That the distinction between my invention and prior devices of like nature may be made more clear, there is shown in Fig. 8 one way in which this idea has been employed by Langevin. The sound generating part consists of circular steel disks 45 and 46 both cemented to an intercalated mosaic 47 of quartz crystals. A water-tight enclosure for the mosaic is provided by gasket 48 compressed against flange 49 on disk 45 by means of a ring 50 screwed onto casing 51 within which the mosaic is disposed. Alternating current from source 52 is conducted to disk 46 by wire 53, while disk 45 is grounded to casing 51 which is connected to source 52 by wire 54. When an alternating voltage of the proper frequency is applied to disks 45 and 46, the crystals of mosaic 47 expand and contract and throw the assembly of disks and crystals into half wave resonant oscillation with a loop in the free face of each disk and a node in the median plane of the mosaic as indicated by lines 55. Space 56 between the free face of disk 46 and casing 51 is filled with gas and hence this face radiates very little sound energy. This design is objectionable in that the pressure of the water, which may be great when the instrument is used on a submarine, acts upon one side only of the vibrating disk and crystal assembly thereby producing in that assembly strains which tend to loosen the cement between the several parts thereof and also tend to prevent the whole area of the radiating face from oscillating in phase. Further, while the air backing as shown in Fig. 8 prevents the radiation of any considerable quantity of sound energy from

the back surface, unless the volume and relative dimensions of air space 56 are correct, the reflection of sound at the metal surfaces bounding that space will result in reverberations that build up to a point where the reaction of the nodes and loops of the air waves on the back plate will prevent the oscillating assembly from vibrating in phase due to the fact that the air waves are not uniform either as to amplitude or phase. That is, unless the backing-up air chamber is properly dimensioned, its reaction on the back surface of the oscillating system will tend to destroy the uniformity of phase throughout this system which, as already shown, must be maintained if the device is to generate a powerful directive sound beam.

In Fig. 9 is shown a very effective construction for preventing radiation loss from the back surface without being open to the objections pointed out in connection with the device shown in Fig. 8. This device has the same arrangement of plates, crystals and casing as in Fig. 8, the like parts being given corresponding numerals. However, instead of having the space back of disk 46 filled with air, there is placed against the free face of that disk a piece 57 of porous felt sealed between two thin sheets 58 of metal, rubber or any other light and flexible material. Instead of felt enclosed in sheets of other material, I may use a thin sheet of pressed cork such as is used for gaskets, or a thin disk of sponge rubber sealed air-tight around the edge. Since the amplitude of oscillation of the surface of disk 46 is only a fraction of one-thousandth of an inch, a thin backing serves as well as a thick one. The remainder of the space within the casing 51 is filled with a liquid that is a good electrical insulator such as oil, castor oil being preferred if rubber is used in the backing, as this oil does not react with most grades of rubber. An expansion chamber is maintained inside casing 51 by a flexible bag-like member 59, preferably round in outline, hung therein and having communication with the exterior of the casing. This expansion chamber permits the pressure of the medium outside of casing 51 to be applied to the free face of disk 46 and hence no strains are set up in the mechanism by that pressure against the outer face of disk 45 since the pressures on the opposite faces of the vibrating mechanism will be equal and oppositely directed.

In the form of my invention disclosed in Fig. 10, no attempt is made to prevent radiation from the rear surface but rather such radiation is facilitated by completely filling the housing with oil or other liquid having good electrical insulating qualities and then returning this energy to the oscillating system by reflecting it back in proper phase relation to augment the oscillations of the prisms. In this modification is a cylindrical metal member 60 having a neck 61 surrounding the aperture through which the lead cable 62 passes into the mechanism, the water-tight integrity of the device being maintained by a suitable packing 63 compressed by a gland nut 64 screwed into neck 61. The metal member 60 is enclosed in a one-piece molded member 65 of rubber compound or the like and which has a cylindrical portion 66 lying within the member 60 almost the full length of that member. A metal disk 67 is disposed within the member 60 against the free edge of cylindrical portion 66; the edge of disk 67 is rabbeted to form a seat for a gasket 68 which is compressed by a rib 69 on metal closure member 70 that is secured to disk

67. The compression of gasket 68 causes it to expand against the wall of member 60 and thereby forms a water-tight joint. The oscillating prisms 42, secured together as before described, are carried by rods 71 having one end of each fixed in disk 67 and the other end attached to the assembly of prisms 42. The prisms are made to oscillate by the piezo-electric crystals 28 and 29 as described in connection with Fig. 4. All space around the operating mechanism within the housing is filled with oil. The inner face of disk 67 is placed at such distance from the back faces of the prisms 42 that sound energy is reflected from the disk 67 and returned to reach the back faces of the prisms in phase with the oscillation of the back faces whereby those oscillations are reinforced by the reflected energy. The face 72 of the member 65 serves to transmit the high frequency sound vibrations to the surrounding medium in a directional beam. Since the oil is interposed between member 65 and the prisms 42, the inward deflection of member 65 due to the pressure of the water on that member will transmit the pressure through the oil to all surfaces of the vibrating assembly and hence there will be no tendency to distort the prism assembly nor to interfere with the vibrating of all parts of the surface in phase. The oil is practically incompressible and will efficiently transmit the vibratory energy from the outer face of the prism assembly to member 65 by which it will be imparted to the surrounding medium. Air space 73 between members 67 and 70 will prevent the propagation of sound energy from the back of the device to the vibratory mechanism, which would interfere with its functioning as a directive receiver.

In one construction that has been found to be very efficient the thickness of the plate 67 is made equal to one-fourth wave length, in the material of the plate, of sound of the frequency to which the vibratory mechanism resonates and the distance between the inner face of disk 67 and the back faces of prisms 42 is an odd number of quarter wave lengths in the liquid. Under these conditions a standing wave system is set up with a node in the inner face of disk 67 and a loop at the back face of the prism assembly. When the distance between those faces is three-fourths wave-length, the wave will stand as indicated by lines 74, Fig. 10. If the inner face of disk 67 be covered by an inelastic member such as 57, 58 in Fig. 9, it will reflect back the waves equally well but instead of a node at that surface, a loop will be formed there and the spacing between that face and the back faces of prisms 42 will have to be an even number of quarter wave lengths. The solid reflector is preferred to the last mentioned construction in that less movement of the member 65 is required to equalize pressure changes than if a compressible member is so placed in the casing as to be subjected to the pressure variations.

It is to be noted that this apparatus serves equally well as a receiver or transmitter of sound, to which type of device I have heretofore applied the name of transceiver. When sound waves impinge upon member 65, their vibrational energy is transmitted through the liquid in the casing to prisms 42 and thence to the piezo-electric driving units where the mechanical energy is converted into a fluctuating electric potential that may be amplified and utilized by any one of many devices for that purpose well known to the art.

It will be understood that the above description and accompanying drawings comprehend only the general and preferred embodiment of my invention, and that various changes in construction, proportion and arrangement of parts may be made within the scope of the appended claims without sacrificing any of the advantages of this invention.

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.

I claim:

1. A high frequency sound device, comprising a rubber compound casing member having a disk portion and two spaced concentric cylindrical portions extending laterally therefrom, the disk portion being adapted to radiate or receive sound energy and the inner of said cylindrical portions being shorter than the outer one, a cylindrical metal member disposed between said cylindrical portions and extending to the edge of the outer cylindrical portion, a metal disk seated on the edge of the inner of said cylindrical portions, said disk having a rabbet in its edge on its outer face, a flexible rubber ring seated in said rabbet, a second metal disk seated against the edges of said outer cylindrical portion and said metal member and having an annular rib seated on said rubber ring to compress said ring, said second disk being connected to the first mentioned disk and spaced therefrom, supporting members extending from the first mentioned disk, means to impart vibration to said disk portion carried by said supporting members, and an electrically insulating fluid filling all otherwise unoccupied space in said casing member.

2. In a high frequency sound device, a substantially cup-shaped casing member, an elastic disk seated in the open end thereof in fluid-tight relation thereto, a mosaic of piezo-electric slabs disposed on the back face of said disk, a second disk contacting said mosaic, a thin vibration-absorptive member disposed on the free face of said second disk, a substantially disk-shaped hollow member with flexible walls suspended in said casing and having its interior in communication with the outside of said casing and electrically insulating fluid filling the otherwise unoccupied space in said casing.

3. In a device of the class described, a fluid-tight casing having a face portion adapted to transmit sound energy and a back portion, a body in said casing having a front face and a back face each of which is adapted to vibrate as a whole and having regularly arranged passages that divide the interior of said body up into columns of substantially uniform cross sectional area and shape, a base mechanically connected to said back face substantially on the longitudinal axis of each of said columns, an electro-mechanical vibratory unit mounted on each of said bases, means to reflect to said body vibratory energy emitted by said back face in such manner that such reflected energy shall be in phase with said back face, and means to apply an electric potential to said vibratory units.

4. In a device of the class described, a fluid-tight casing having a face portion adapted to transmit sound energy and a back portion, a body in said casing having a front face and a back face each of which is adapted to vibrate as a whole and having regularly arranged passages that divide the interior of said body into columns

of substantially uniform cross sectional area and shape, means to apply vibratory energy to each of said columns substantially along the longitudinal axis of each of said columns, and means to reflect to said body vibratory energy emitted from said back face in such manner that such reflected energy shall be in phase with said back face.

5. In a device of the class described, a fluid-tight casing having a face portion adapted to transmit mechanical vibratory energy and a back portion, a body in said casing having a front face and a back face each of which is adapted to vibrate as a whole and having regularly arranged passages that divide the interior of said body up into columns of substantially uniform cross sectional area and shape, means to impart vibratory energy to said body substantially along the longitudinal axis of each of said prisms, an elastic member in said casing adjacent said back portion but spaced therefrom, the thickness of said member being substantially one-fourth wave length of the vibration to which said body responds and the inner face of said member being spaced an odd number of fourths of said wave length from the back face of said body, and a fluid filling all otherwise unoccupied space in said casing forwardly of the said member.

6. In a device of the class described, a fluid-tight casing having a face portion adapted to transmit mechanical vibratory energy and a back portion, a body in said casing having a front face and a back face each of which is adapted to vibrate as a whole and having regularly arranged passages that divide the interior of said body into columns of substantially uniform cross sectional area and shape, means to impart vibratory energy to said body substantially along the longitudinal axis of each of said prisms, an elastic member in said casing adjacent said back portion but spaced therefrom, the thickness of said member and the distance of the inner face thereof from the said back face being such that vibrational energy emitted from the latter is reflected from the former to said back face in phase with said back face, and means in said casing to equalize the pressures on said back face and said front face.

7. In a device of the class described, a fluid-

tight casing having a face portion adapted to transmit mechanical vibratory energy and a back portion, a body in said casing having a front face and a back face each of which is adapted to vibrate as a whole and having regularly arranged passages that divide the interior of said body into columns of substantially uniform cross sectional area and shape, means to impart vibratory energy to said body substantially along the longitudinal axis of each of said prisms, and an elastic member in said casing adjacent said back portion but spaced therefrom, the thickness of said member and the distance of the inner face thereof from said back face being such that vibrational energy emitted from said back face is reflected to said back face in phase with said back face.

8. In a device of the class described, a fluid-tight casing having a face portion adapted to transmit vibrational energy, a body therein having a front face and a back face, means to cause every part of said front face and said back face to vibrate in phase with all other parts of such face, and means whereby energy emitted by said back face is reflected to said back face in phase with said back face.

9. In a device of the class described, a casing comprising a disk portion and two spaced concentric cylindrical portions extending laterally therefrom, the inner of said portions being shorter than the outer one, a backing member within said outer cylindrical portion seated against the edge of said inner cylindrical portion, a cylindrical metal member disposed between said cylindrical portions extending to the edge of said outer cylindrical portion, means forming a water-tight closure for said casing, and means in said casing to impart vibratory energy to said disk portion.

10. In a device of the class described, a cup-shaped casing, a disk seated in the mouth of said casing, means forming a water-tight junction between said disk and said casing, a piezo-electric mosaic on the inner face of said disk, a second disk contacting said mosaic, a vibration damping body on the inner face of said second disk, and means to equalize the pressure on the free face of said damping body with that on the outer face of said first mentioned disk.

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