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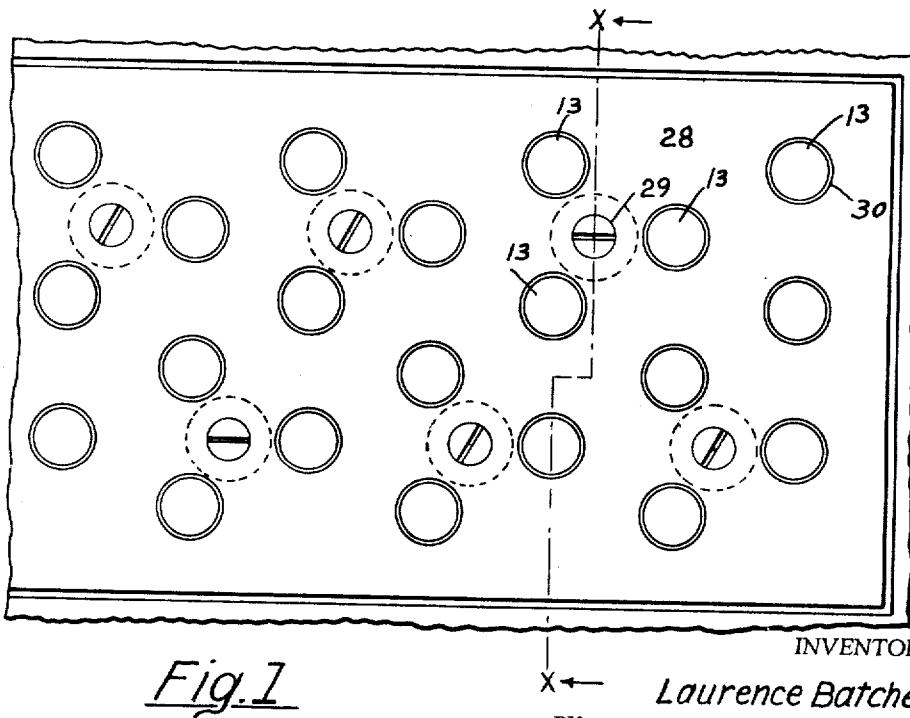
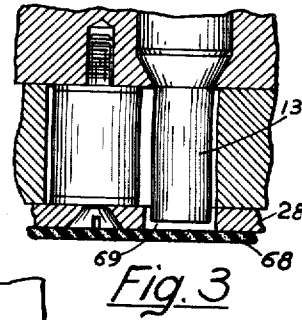
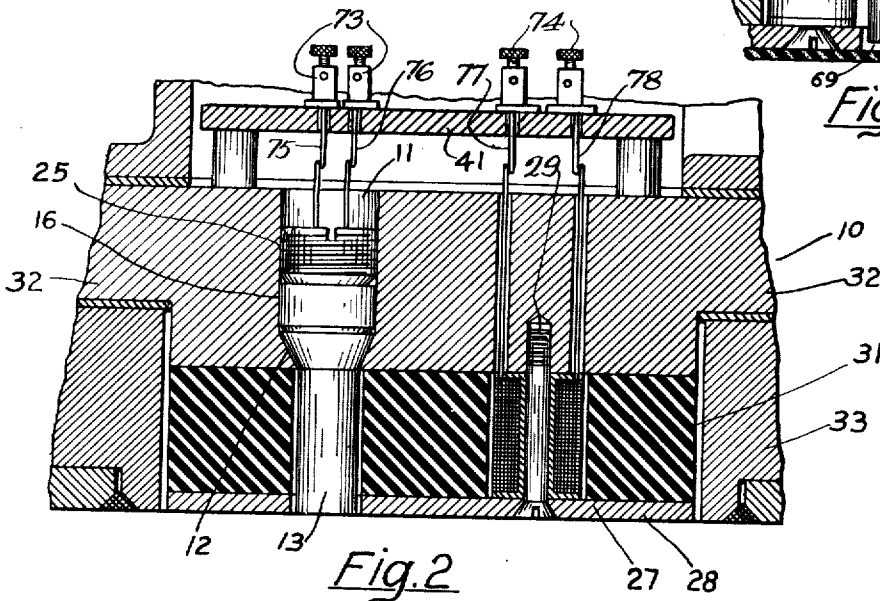
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2,380,931

COMPRESSIONAL WAVE TRANSMITTING AND RECEIVING APPARATUS

Filed May 19, 1933

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

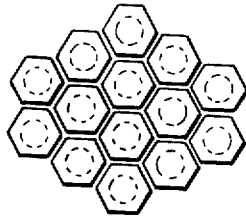


Fig. 8

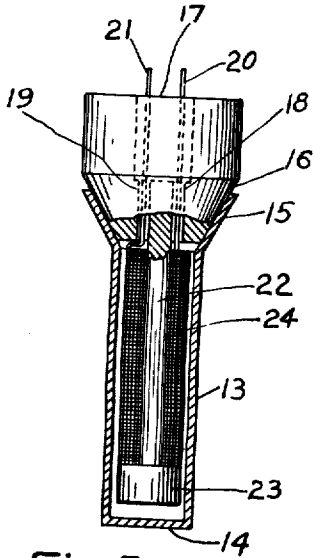


Fig. 5

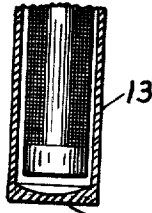


Fig. 6

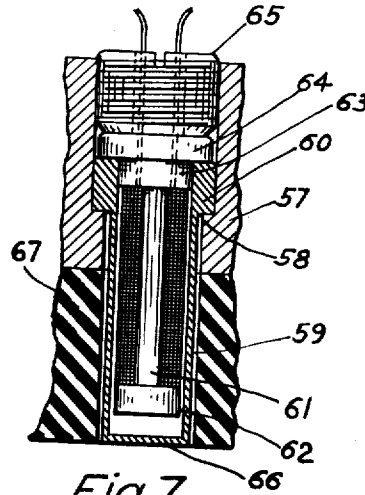


Fig. 7

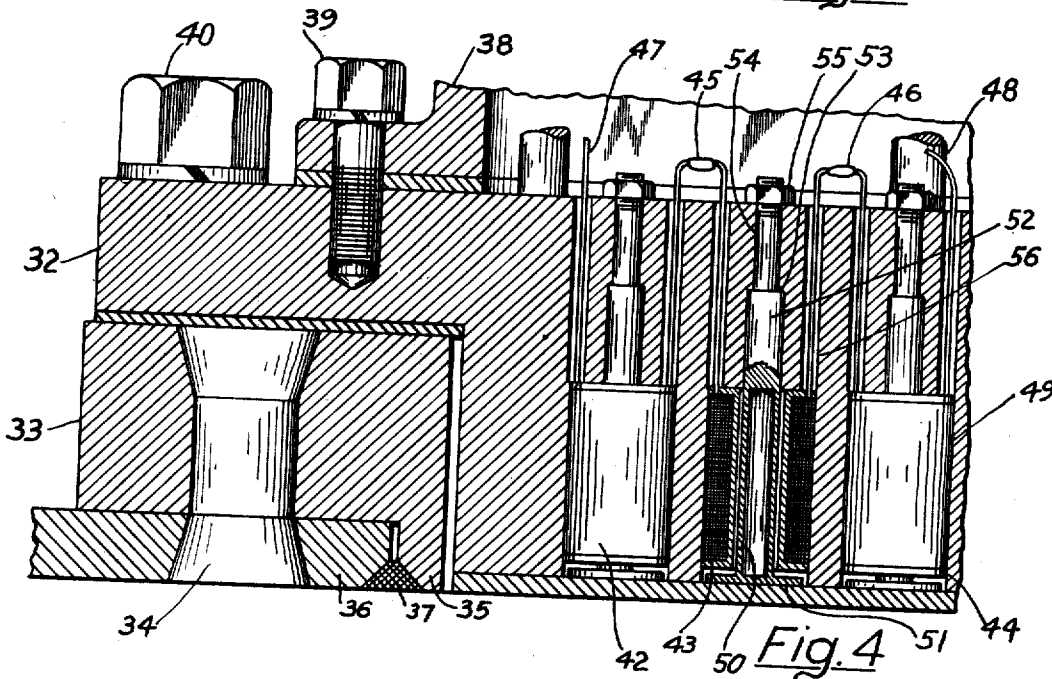


Fig. 4

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COMPRESSIONAL WAVE TRANSMITTING
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12 Claims. (Cl. 177—386)

The present invention relates to apparatus for producing compressional waves and is applicable for the production of such waves in air, water or in other media.

In the present invention the compressional waves produced are more particularly in the range of so-called supersonic frequencies, that is, frequencies which are beyond the audibility of the human ear, although to some extent the present invention is also applicable to the production of high-frequency compressional or sound waves which are situated in the upper part of the audibility range of the human ear and just beyond it.

Due to the fact that metals possess great elasticity and that the wave lengths of high frequency compressional waves are very short in metals, it is difficult to assume that the masses involved in compressional-wave apparatus of this type move as masses alone without partaking in the vibration of the vibrating elements.

In the prior art devices have been used in which a radiating surface or area was very large as compared with the wave length of the sound to be propagated in the propagating medium and the radiating surface was vibrated at a plurality of points in order to produce a plane wave or a directed beam of sound or compressional waves. Such devices have been usefully employed both in so-called piezo-electric oscillators and in oscillators of the magnetic type.

In supersonic oscillators of the piezo-electric type a mosaic of piezo-electric crystals are mounted between steel plates. The thickness of the plates together with that of the crystals are such as to establish a tuning in a direction perpendicular to the plate surface and each crystal, in fact, vibrates that part of the plate where it is attached. An examination of this type of oscillator indicates that the whole plate does not move with the same amplitude and that between the places where the crystals are applied the vibrational energy is sometimes quite small.

In other types of oscillators the same characteristics are found and while it is possible to produce some vibration over an entire plate, it has been found a fact that the vibration is more particularly produced opposite the places where the vibrational energy is applied. This gives evidence of the fact that in high frequencies there is difficulty in making a plate act as a diaphragm and the tendency is for it simply to act as a transmitting medium.

In devices employing other than piezo-electric means, for instance, in oscillators of the magnetostrictive type, it is possible to use resonant tubes

or rods for driving a sound diaphragm over its surface in the same phase. The difficulty, however, of making the whole diaphragm or plate to which the rods are attached vibrate is also present here, and it is usually observed that the vibration occurs more particularly at the points where the rods or tubes, producing the compressional wave energy, are attached.

I have also observed that it is quite impossible to predict just how such plates or diaphragms will vibrate and just what load either radiating or mass load should be considered as belonging to each operating unit. In fact it appears that rods or tubes similarly attached which beforehand had the same resonant frequencies may well after attaching have other resonant frequencies. This fact alone makes it difficult to obtain a uniform resonance of all the operating units and seriously handicaps and limits the available power output, since some units are operating on resonance while other units are off the resonant point. This condition also distorts the sound beam since it is apt to destroy the uniform phase vibration of the entire vibrating surface.

In the present system which I have devised I have avoided many of these difficulties by constructing each unit as an independently operating unit and establishing the same resonance point for each so that they can all operate with the same amplitude in the same phase at the same frequency. In order to produce a fixed beam of compressional waves it is only necessary in the present system to have a sufficiently large number of independently operating units positioned or nested close together vibrating in the same phase in order to produce a plane wave whose width in the propagating medium will be many times the wave length of the sound or compressional wave produced.

When it is desired to produce a directive beam of sound or compressional waves whose direction can be controlled or varied, this may be done by vibrating lines or groups of individually operating units with proper phase differences, it being preferable under such conditions to have the individually operating units relatively point sources so that each point in the medium may have the right vibrational phase.

Without further describing the features of the present invention, the invention will be described in connection with the drawings which show several embodiments of the invention. Fig. 1 shows a plan view of the compressional-wave producing means; Fig. 2 shows a section on the line X—X of Fig. 1; Fig. 3 shows a modification of the con-

struction shown in Fig. 2; Fig. 4 shows a further modification of the structure set forth in Fig. 2; Fig. 5 shows a modification of the details of construction of the vibrational tube; Figs. 6 and 7 show further modifications of the detail shown in Fig. 5; and Fig. 8 shows a face view of the nesting of the individual operating units in a modified form.

In Figs. 1 and 2 the construction of the oscillator shows a heavy plate 10 in which there may be made perforations or holes 11 having conical shoulders 12. The plate 10 has a great number of perforations in which are placed the oscillating tubes 13, 13, 13, etc. as indicated in Fig. 1.

The construction of the operating unit including the oscillating tube 13 is shown more in detail in Fig. 5. The oscillating tube 13 in Fig. 5 is provided with a cap 14 covering one end of the tube while the other end 15 of the tube is flared out conically to rest in the shoulder 12 of the plate 10. A clamping plug 16 rests within the flared-out end 15 of the tube. The plug 16, as indicated in Fig. 5, has a center hole 17 and two small conduits 18 and 19 through which the conductors 20 and 21 pass. Formed as a part of the clamping plug 16 is a rod 22 which has a cap 23 at the end of it. The core 22 is preferably of magnetizable material and may be permanently magnetized as well as the cap 23. In this construction it is sometimes preferable to make the center core of iron and the ends of cobalt or chrome steel grilling the holes 18 and 19 through the end portion of the core of iron. About the core 22 is wound a coil 24 to which the alternating current or the desired frequency is supplied for generating the compressional waves and a direct current excitation also if desired although two separate windings may be used. The coil 24 may in part be supplied with a magnetizing current in addition to, or in place of, permanently magnetizing the core 22. As indicated in Fig. 5, the core 22 extends downward within the tube 13 and the cap 23 is positioned near the end of the tube 13 near the cap 14, the size of the head or cap 23 being such that its edge comes very close to the inner wall of the tube 13.

As indicated in Fig. 3 the tube 13 and the clamping cap 16 are held clamped in place by means of the externally threaded nut 25 which is threaded into the plate 10. The tube 13 is made of magnetostrictive material such as nickel or some other suitable material, and compressional vibrations are produced by vibration of the tube 13 which vibrates the cap 14 at the end of the tube.

The varying flux necessary to operate the tube 13 is obtained through the coil 24 which in effect provides two poles, one in the clamping cap 16 and the other in the head 23 near the unclamped end of the tube 13. These two poles set up a magnetic flux which passes longitudinally through the tube 13 and the variation in this flux about a normal value produces compressional forces on the tube to generate the mechanical vibrations.

In Fig. 5 the cap 14 is of the same thickness as the tube 13 and it should be noted that the size and thickness of the cap 14 may be such as to produce a resonance which, coupled with the resonance of the tube 13, produces the resonance of the operating system. Two points of resonance may be noted, the one point at which the tube resonance predominates and the other point at which the plate or head resonance of the cap 14 predominates. In one case, in the case of the

tube resonance, the mechanical vibrations will be greater at the edge of the cap 14 than in the center, while in the case of diaphragm resonance, or resonance of the plate 14, the vibrational effect will be greater at the center of the diaphragm than at the edge where the head 14 is attached to the tube.

In Fig. 6 a means is shown whereby the resonance of the cap 26 may be placed above that of the tube 13 without increasing materially the mass of the cap. This may be accomplished, as indicated in Fig. 6, by cupping the inside of the cap 26 so that the parts of the cap near the tube 13 are stronger than the center of the cap. The combination shown in Fig. 6 produces a piston action of the cap 26 and provides, because of its uniformly large amplitude of the whole plate 26, a larger radiating area to the propagating medium.

In Fig. 2 means are provided in addition to the means indicated in Fig. 5 for providing magnetization of the tube 13. In Fig. 2 it will be noted that a coil 27 is provided which is clamped between a magnetizable plate 28 and the plate 10 by means of a bolt 29. The magnetizable plate 28 may extend over the whole surface of the oscillator and is provided, as indicated in Fig. 1, with holes 30 concentric with the tubes 13. The flux generated in the coil 27 is impressed upon the tubes 13 between the holes 30 formed in the plate 28 and the clamping plates at the shoulders 12 of the plate 10. The flux in the tubes 27 is such as to aid the flux due to the permanent magnetization of the core 22 or the direct current excitation in the coil 24.

All parts of the plate 28 are substantially at the same magnetic potential and equal flux will flow through each tube 13 increasing the normal flux carried by the magnetostrictive tubes. In this connection it may be remarked that the generation of mechanical vibrations in magnetostriction action is produced by a variation in flux density occurring in the magnetostrictive element and that the most favorable and effective results are produced when the normal magnetization of the magnetostrictive material is at a desired fixed flux density. This density is obtained by polarizing the magnetostrictive element either with a permanent magnet or an electromagnet as described above.

Between the heavy plate 10 and the plate 28, as indicated in Fig. 2, there is a plate or cover 31 which is preferably of hard rubber or some such material and serves not only to fill the space between the plate 10 and the external plate 28, but also to furnish a baffle for the cap 14 of the tube. The plate 31 is provided with a flange 32 and this rests upon the heavy inertia seat 33 which may be riveted to the ship, as indicated in Fig. 4, through the rivets 34. As indicated in the figure the seat 33 has an outwardly extending flange 35 lining the opening in the vessel, and the skin of the vessel 36 is joined to the flange 35 through the weld 37 or in some other well-known manner.

A cover 38 may be provided, as indicated in Fig. 4, and this may enclose the back end of the oscillator, it being attached to the plate 10 in the flange 32 by means of the bolts 39. The whole oscillator is attached to the heavy seat 33 through the bolts 40 spaced around the oscillator and passing through the flange 32. In Fig. 2 there is also indicated a plate 41 having terminals 73 and 74 which provides a means for making the electrical connections with the leads

75, 76, 77 and 78 coming from the individual coils.

As indicated in the modification shown in Fig. 4 the three coils 42, 43 and 44, which preferably are positioned in a vertical straight line as indicated in Fig. 1, are connected in series through the connecting wires 45 and 46, there being therefore only two leads 47 and 48 which are brought out to the terminal or connecting board 41. In the modification shown in Fig. 4 the heavy plate 49, corresponding to the plate 10 in Fig. 2, extends outwardly towards the skin of the vessel and no rubber plate, as shown in Fig. 2, is provided. The oscillating unit as indicated in this figure comprises a magnetostrictive tube element 50 having a cap 51 at the sound radiating end which is larger than the tube itself. The sound radiating end 51 may be extended beyond the plate 49 and made hexagonal as shown in Fig. 8, so that the entire group of radiating elements may be nested together as indicated in that figure. The radiating element 51 is indicated as a flat plate, but, as indicated in Fig. 6, this may be strengthened in the vicinity of the junction of the tube so as to make the plate 51 vibrate as a unit or in the piston fashion.

The tube 50 at its upper end, as indicated in Fig. 4, is solid in the center, thus forming a rod 52 which is provided with a shoulder 53 and a thinner end cylindrical portion 54 threaded to receive the nut 55. As is evident from the drawings, the tube 50 is held in place by being clamped to the plate 49 between the shoulder 53 and the nut 55, the solid portion of the element 52 being driven into the plate 49 in a forced fit so that the cylinder 52 and the plate 49 really form a single unitary mass. Conduits 56 may be provided in the plate 49 to receive the conductors for the coils 43, etc. It will be noted in Fig. 4 that the plate 49 surrounds each coil 43, etc. and provides a return path for the magnetic flux established in the coils 43, etc. The magnetic flux path is through the tube 50, through the plate 51, through the mass 49 and returning in the solid cylinder 52. In this manner a very efficient magnetic path is provided for the magnetostrictive tube and the magnetic flux is concentrated chiefly in the space that the tube occupies.

A further modification of the operating unit is indicated in Fig. 7. Here the plate 57 which is of the same general structure as that shown in Fig. 2 is provided in the perforations corresponding to the perforations 11 in Fig. 2 with rectangular shoulders 58 on which the magnetostrictive tube 59 rests. The magnetostrictive tube 59 is provided at its upper end with a square shoulder 60 which corresponds and fits snugly on the shoulder 58 of the plate 57. The internal electrical element in this case comprises a core 61 having at opposite ends caps 62 and 63. The cap 63, however, has an outwardly extending flange 64 of such size that it is adapted to rest upon the shoulder 60 of the magnetostrictive unit. The threaded clamping plug 65, similar to that shown in Fig. 2 and threading into the plate 57, is used to clamp the unit firmly in place. The magnetostrictive tube 57 may be capped with a cap 66 of the same type as indicated in Fig. 5 or it may have a piston type cap as indicated by 26 in Fig. 6. A hard rubber plate 67, corresponding to the plate 31 in Fig. 2, may be provided to serve the same purpose as the plate 31

in Fig. 2 and form a continuous surface with the skin of the vessel.

It will be noted, in fact, in Figs. 1, 2 and 4 that the oscillator is formed as a continuous surface and may be made, as indicated in Fig. 4, continuous with the skin of the vessel 38. This is extremely important in preventing points of pressure release behind the operating unit and providing a continuous rigid surface at the points of generation of the plane wave in order to insure that no distortion of the plane wave may exist through irregularities surrounding the vibrating surfaces.

As has been pointed out above, the radiating elements indicated in Fig. 4 may be hexagonal in shape and they also may take other shapes which are suitable to be nested together to form a continuously vibrating surface.

In the drawings shown in Fig. 8 the total dimensions of the vibrating system should be many times the wave length of the sound or compressional waves in the propagating medium and preferably the nesting, when it is desired to produce a fixed directive beam, should be such as to produce vibrational energy over the entire vibrating surface. When it is desired to produce a beam whose direction may be controlled, the individual units should be substantially a point source and for this reason it is preferable to have the effective dimension of the radiating sources small compared with a wave length. It is also preferable in such cases in order to prevent the secondary maxima from being objectionable and to have a beam which may be uniformly shifted, to have successive lines of units spaced at distances no greater than one-half wave length apart. It should be noted that for operating the system both as a fixed source and as an adjustable source the entire surface may be efficiently used if the units are nested together in such a fashion that their dimensions are approximately one-half wave length and they are practically touching one another. From the discussion above, however, it should be noted that the units should be independent and be independently operated in order that the phase, tuning and frequency might be accurately controlled.

In the modification shown in Fig. 3 which corresponds for the most part to the modification shown in Fig. 2 it should be noted that the magnetizable plate 28 extends beyond the cap of the tube 13 providing a space around the end of the cap 13. This space may be covered with a cover 68 which preferably may be a soft rubber cover or similar material. The space 69 between the cover and the end of the tube 13 may be filled with some liquid, either water or castor oil, providing a transmitting medium between the radiating end of the tube and the propagating medium beyond the cover 68. Otherwise the construction shown in Fig. 3 is similar to that indicated in Fig. 2.

Having now described my invention, I claim:

1. Means for producing a beam of compressional waves comprising a heavy plate, a plurality of magnetostrictive tubes having radiating caps at one end thereof, a magnetic core positioned within each of said tubes, said core having a winding thereon, means clamping the tubes in said plate and the cores in the tubes, a rubber diaphragm covering said tubes and solid means substantially filling the space between the tubes.
2. Means for producing a beam of compressional waves in water comprising a plurality of

spaced, independently operating magnetostrictive units having the same characteristics, liquid tight casing means holding said units in a unitary structure, each unit operating as an independent element therein, a watertight rubber diaphragm covering the radiating ends of said units exposed to the propagating medium, and liquid means carried within said casing surrounding said units.

3. Means for producing a beam of compressional waves in water comprising a plurality of spaced magnetostrictive units having similar characteristics, means surrounding said units to polarize the same, said units having radiating elements, means holding said units in a unitary structure having only one side exposed to the propagating medium and a watertight rubber diaphragm covering the radiating ends of said units positioned at said open side, each unit operating as an independent element therein.

4. Means for producing a beam of compressional waves in water comprising a plate having perforations therein, a plurality of spaced radiating units having magnetostrictive means independently operating the same and mounted in and projecting from the perforations in said plate, means surrounding said units for polarizing the same, said means extending beyond said units forming a cavity over the units, a watertight covering extending over the means surrounding the units and forming with the plate a liquid tight casing and a liquid filling the space between the cover and the units.

5. In a means for producing a beam of compressional waves, a radiating unit adapted to vibrate at longitudinal resonance comprising a magnetostrictive tube having a cap thereon having the rim thicker than the center and means energizing the tube, positioned within it.

6. In a means for producing a beam of compressional waves, a radiating unit adapted to vibrate at longitudinal resonance, comprising a magnetostrictive tube having a cap thereon at one end and a shoulder at the other end, a plate in which said shoulder fits and means clamping said tube in said plate at said shoulder.

7. Means for producing a beam of compressional waves comprising a plate, a plurality of magnetostrictive tubes, means mounting and individually supporting said tubes in said plate close to one another and projecting to the surface of the plate to form substantially a continuous radiating plane surface, and electrical means for

individually energizing each of said tubes in desired phase relation.

8. Means for producing a beam of compressional waves comprising a heavy plate having recessed portions therein positioned perpendicular to the surface of the plate, magnetostrictive tubes placed in said recessed portions, each having a cap thereon substantially filling the recessed opening in the plate, means clamping the tubes in said plate and a coil surrounding each tube positioned just below the cap on said tube.

9. In a means for producing compressional wave energy by the vibration of a plurality of similar units, a hollow magnetostrictive tube having a cap closing one end thereof, a core positioned within said tube, said core comprising a stem portion and an end portion projecting towards the inner surface of the magnetostrictive tube near the cap end, a coil positioned about said stem portion for energizing said tube and means provided at the other end of the tube for holding said core and tube rigidly together.

10. In a means for producing a beam of compressional wave energy, a plurality of hollow magnetostrictive tubes each having one end closed by a cap element, a core positioned within each of said tubes, said core having a stem portion and an enlarged end portion projecting towards the side walls of the tube near the cap end, said core being provided at the other end with a flanged portion extending over the end of the tube and means for clamping said tube and core rigidly in place.

11. In a vibratory mechanism, a plurality of magnetostrictive tubes each of which is closed at one end by a radiating cap, a heavy plate having recesses shaped to fit and surround said radiating caps, means mounting said tubes in said plate with the radiating cap flush therewith, and means associated with said tubes for imparting vibratory energy thereto or receiving vibratory energy therefrom.

12. In a vibratory mechanism, a plurality of magnetostrictive tubes each of which is closed at one end thereof by a radiating cap, said radiating cap having the shape of a regular polygon, a plate member having recesses adapted to receive said tubes, and means mounting said tubes in said recesses in said plate with the radiating cap flush therewith and means associated with said tubes for imparting vibratory energy thereto or receiving vibratory energy therefrom.

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