April 29, 1947. E. E. TURNER, JR 2,419,608

ELECTRICAL OSCILLATOR

Filed May 29, 1935 3 Sheets-Sheet 1

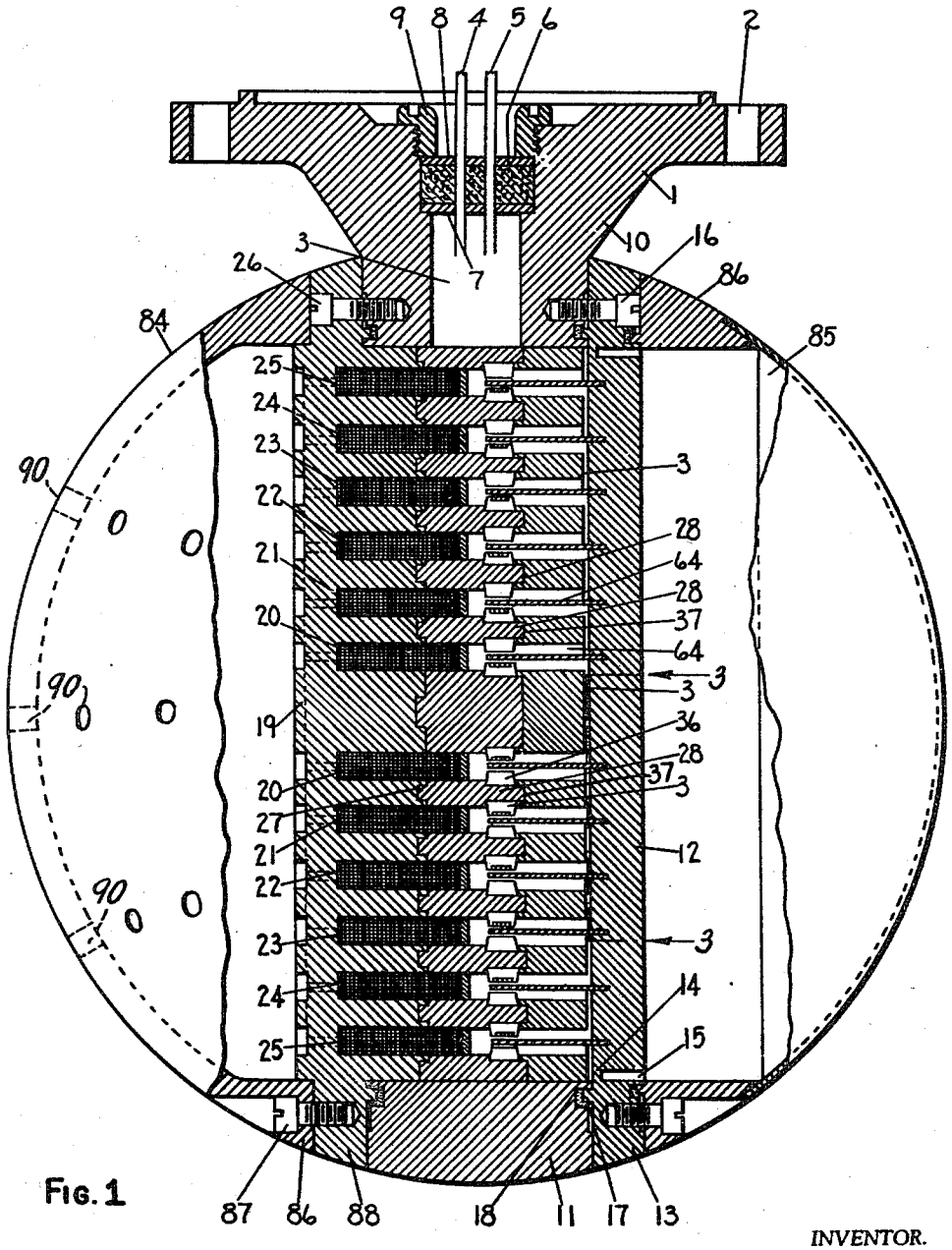


FIG. 1

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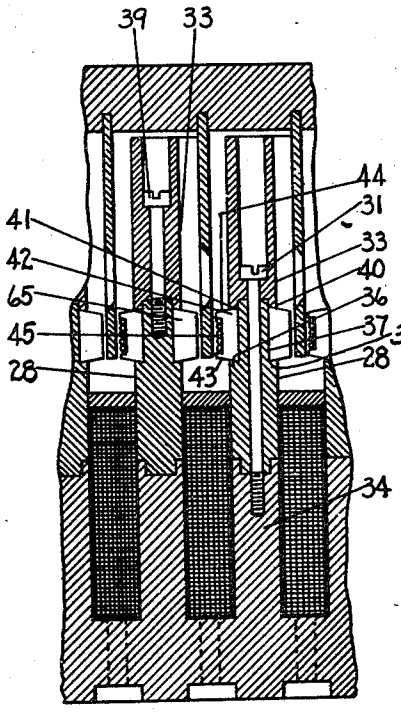


FIG. 2

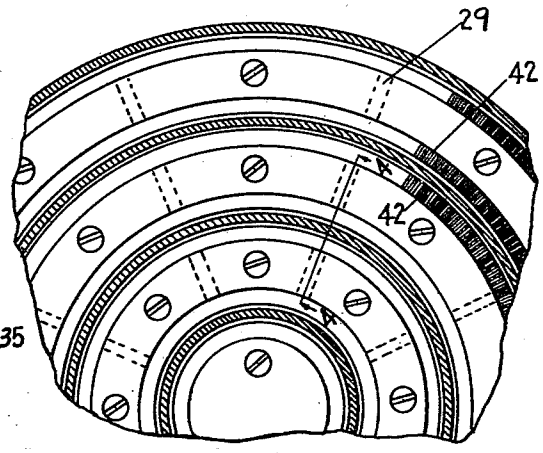


FIG. 3

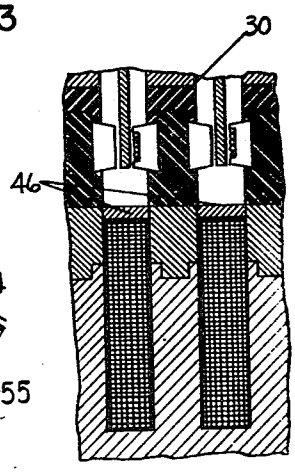


FIG. 4

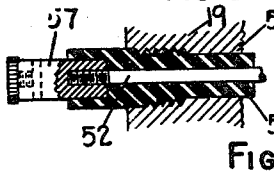


FIG. 9

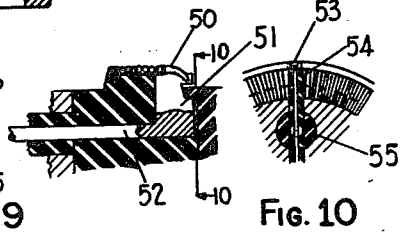


FIG. 10

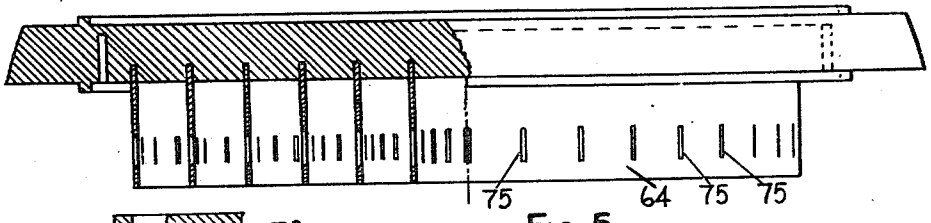


FIG. 5

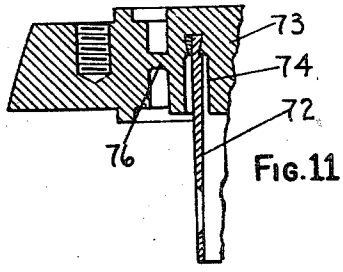


FIG. 11

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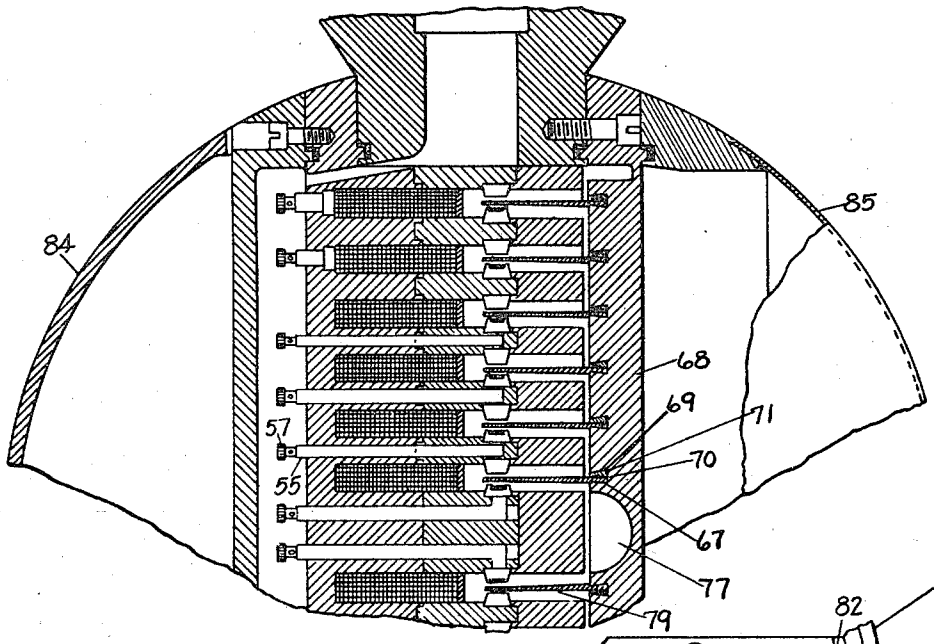


FIG. 6

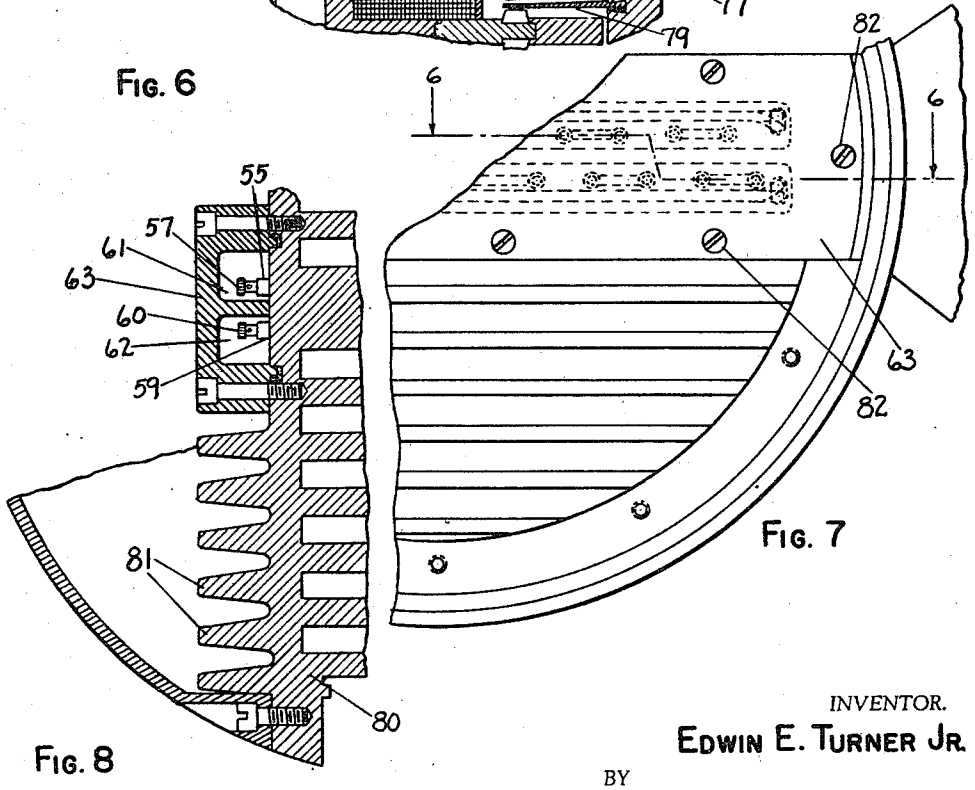


FIG. 7

FIG. 8

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UNITED STATES PATENT OFFICE

2,419,608

ELECTRICAL OSCILLATOR

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Application May 29, 1935, Serial No. 24,078

12 Claims. (Cl. 177—386)

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The present invention relates to means for producing compressional vibrations and particularly compressional vibrations of a range of frequencies above those audible to the human ear, although the same principles employed in the present invention may be extended below the superaudible range into the audible frequencies.

The present invention is applicable to the generation and reception of compressional waves in water or in some other medium in a directive beam, or the apparatus may be used to produce compressional and vibrational energy for such operations as the de-aeration of liquids, in making emulsions and the like where compressional waves, particularly of higher frequencies and considerable power, have proved to be desirable and useful.

The present invention is particularly adapted for producing comparatively high power vibrational energy at the higher frequencies and also is chiefly adapted to transmit compressional wave energy into a liquid or viscous medium as, for instance, water, oils or other liquids or substances, either liquids or semi-solids where large forces and small amplitudes are essential to the production of such energy.

The apparatus of the present invention is designed to produce a uniform compressional wave amplitude over a large surface in contact with the medium, the dimensions of the surface being large compared to the wavelength of sound in the medium at the frequency chosen. Under such conditions the surface must vibrate with uniform amplitude and in the present invention this is accomplished by producing a true so-called piston-diaphragm action in which all points of the diaphragm move with equal amplitude and in phase.

The piston diaphragms used in the prior art may be confined to two groups, one in which the diameter of the diaphragm was comparable to a fractional part of the wavelength of the energy produced, and the other in which the diaphragm was used to produce a beam of sound. In the first case, no beam of sound was produced since the diaphragm was not many times the wave length and, therefore, certain problems which the applicant finds arises in the use of the diaphragm large in comparison with the wavelength did not present objectionable or difficult features for the use of a piston diaphragm that was comparable with the wavelength. In the case of a piston diaphragm producing a beam of compressional wave energy where the force is applied at a great many points on the diaphragm consideration will show that if each point of force is looked upon as a

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point source, the compressional waves propagated or radiated therefrom will travel over the diaphragm in all directions.

Therefore, in the piston diaphragms of the prior art there is present along with the motion normal to the surface of the diaphragm a wave motion along the surface and this wave motion along the surface may in some cases have a considerable magnitude and distort the effect of a true piston diaphragm as well as reduce the total available energy that is transferred to the propagating or absorbing medium. In these cases, the force is applied at the rear of the diaphragm and therefore not only moves the diaphragm back and forth, but tends to compress it in accordance with the difference in pressure set up between the back of the diaphragm and the resistance at the front, which forces are always different since motion is to result therefrom.

In the present invention a longitudinal motion of the diaphragm due to this effect is practically eliminated and the radiating surface has substantially a uniform amplitude directed entirely normal to the surface of the radiating element.

The above-described feature in the present invention is accomplished in connection with means whereby the greatest allowable amplitude of motion is presented to the propagating medium. The applicant has found that mechanical motion can be generated more efficiently with elements moving in larger amplitudes than that efficiently useful for transfer of the energy to the compressional wave propagating medium. The applicant has also found that such energy transfer is most efficiently accomplished by obtaining the greatest possible conversion of motion consistent with the internal losses in the metals employed and inversely by use of the greatest possible mass ratio between the elements which generate the mechanical force and which apply it to the sound propagating medium.

In the present invention the applicant has employed a set of parallel concentric rings in which the electrical current is induced towards free ends thereof and which are so designed that at the frequency at which the mechanism is to operate—and in the present invention it should be stated that the mechanism is to be operated only at one frequency—a resonance occurs in the concentric rings near to its point of contact with the rear of the radiating surface. Under these circumstances the rear of the radiating surface presents practically a point of node, and since the thickness of the plate is less than one-eighth wave length and the rings are spaced the same

distance apart, any wave propagation that might occur transverse of the diaphragm will have substantially the same vector phase at the radiating side of the diaphragm as that due to movement of the diaphragm as a whole, and, therefore, produce a uniform motion normal to the surface of the plate or diaphragm. However, in addition to the facts above set forth, it should be noted that the portion of the plate directly associated with each ring is such as to furnish practically a dead mass at the end of the ring itself and therefore the plate acts more as a dead mass set in motion synchronously in the same phase in all of its portions, each portion associated with the particular ring that drives it. There will, therefore, be furnished to the plate by the major movement of the rings a direct amplitude that is inversely proportional to the mass ratio, one mass of this ratio being the effective mass of the ring itself and the other the mass of that portion of the plate associated with the ring.

It will further be noted in the present invention that the concentric rings are themselves substantially uniform throughout and free at one end while the plate itself comprises a solid mass into which the rings are placed and rigidly held. By employing a construction of the type described it is possible to apply the electrical forces at points where the mechanical elements will produce the greatest velocities and motional amplitudes and to step down these velocities and motional amplitudes to smaller amplitudes and larger available forces. In apparatus as in the present type, which is designed particularly for higher frequencies, difficulties arise in obtaining sufficient space and sufficiently large elements for the application and transformation of the mechanical forces.

In the present invention, as in my earlier application Serial No. 677,179, filed June 23, 1933, the present system allows, even at high frequencies, elements of substantial size. As in my prior application the system as a whole is at least a one-half wavelength system formed with the plate and the concentric rings. Since the amplitude node is established in the rings near the plate, the ring itself is longer than a corresponding quarter wavelength free element and this allows a reasonable length of ring and reasonable opportunities for the application of the dynamic generating system. This is a decided advantage over systems where the diaphragm itself forms a load on the driving vibrating element and reduces the effective available length of the driving element in order that a proper tuning may be established. In most of such constructions the free end of the rod is loaded and the attempt is made to obtain a maximum amplitude at the plate end.

In the design of the present invention this ratio is the same for all ring portions so that the amplitude of motion of the plate is exactly the same over its entire surface. The rings are vibrated electrodynamically by induced currents from a primary exciting coil. The rings themselves, while carrying electric current, are not insulated from each other and therefore the most efficient driving system possible is presented to the radiating plate which also is metallic. In avoiding the use of all insulating material the necessary attenuation of compressional wave energy is avoided and in this acoustic system, therefore, the transfer of energy is efficiently effected. The necessity of electric insulation is avoided because of the fact that the potentials in the rings are such that they will not interfere one with the other and, in fact, between any two points that might be chosen it can be shown that no difference of potential exists and that, therefore, there is no current flow through the plate.

Current is induced in the end of the ring or cylinder which may be made of copper, but in the present case has preferably been made of aluminum, by a primary winding adjacent thereto, both the winding and the end of the cylinders being situated in a magnetic field that is initially polarized by direct current. The arrangement of the circuit is such that the direct current and alternating current fluxes are substantially separated, and that the alternating current flux confines its induced current in the tubes in its lower portion that is in the magnetic field.

Besides the features enumerated above, there are many other features in the design and construction of the present invention which give it a marked superiority and utility over devices of the prior art.

These improvements and advantages will be more fully understood from the description of the embodiment described below when considered in connection with the drawings in which Fig. 1 shows a view of the invention with a fragmentary section taken on the center line of the apparatus; Fig. 2 shows an enlarged detail of the parts sectioned in Fig. 1 indicating the method of support of various elements in the interior of the device; Fig. 3 shows a fragmentary sectional view taken on the line 3—3 of Fig. 1; Fig. 4 indicates a large detail taken on the line 4—4 of Fig. 3; Fig. 5 shows a view partly in section of the plate element and rings shown in Fig. 1; Fig. 6 shows a fragmentary modification of the view shown in Fig. 1; Fig. 7 shows a rear fragmentary view of the modification shown in Fig. 6; Fig. 8 shows an end sectional view of the view shown in Fig. 7; Fig. 9 shows a detail of the method of connecting alternating current coils with the lead-in wires; Fig. 10 shows a section taken on the line 10—10 of Fig. 9; and Fig. 11 shows a further modification of the method and position of the ring in the vibrating plate.

In the structure shown in Fig. 1 there is provided a base element 1 which at the upper end is flanged outward and provided with bolt holes 2 whereby the unit as a whole may be properly supported and suspended from a shaft or tube. The base may also be provided with an interior opening 3 through which the cables 4 and 5 may be led to the operating mechanism within. A proper watertight stuffing box may be provided, and, as shown in the figure, this comprises a yielding disc element 6 held on both the inner and outer sides by metallic plates 7 and 8, the plate resting on a shoulder in the base and the plate 8 being forced inward by means of the clamping member 9 which threads into the base itself. The base 1 is tapered into a neck portion 10 to which is formed as an integral part a ring 11 in which the entire compressional-wave producing mechanism is mounted. It should also be noted that while primarily the present invention is designed to produce compressional waves, it may also be used as a receiver for compressional waves and, therefore, it may be usefully employed as a single rotatable element for determining the direction of a distinct reflecting source by periodically transmitting beams of compressional wave and picking up the reflected beam. The position of the mechanism, when the reflected beam is received, indicates the direction of the source, the beam being sent in a direction perpendicular to the radiating surface. For this

purpose the base 1 may be mounted upon a rotatable shaft and the whole mechanism made spherical in shape by proper covers as indicated in Fig. 1 and as will be further described later.

The ring 11 is provided on the right-hand side, as indicated in Fig. 1, with a heavy radiating plate 12 which is held fast to the ring 11 in the flange 13 of substantially the same thickness as the plate 12 but attached to it through the narrow ring portion 14 which may be made by cutting a slot 15 at the edge of the plate 12. In this fashion the plate 12 and the ring 13 as well as the narrow ring 14 may be made of one piece of material. The narrow ring 14 is preferably as thin as possible, consistent with the materials to be used to withstand the proper water or liquid pressure that the plate may be subjected to and also to withstand the stresses from the bending due to the movement of the plate as a whole.

The clamping flange or ring 13 is held to the frame 11 by means of the clamping bolts 16 which are suitably spaced around the periphery of the clamping ring. A suitable tongue 17 may be provided upon the flange 13 and a groove 18 on the ring 11 in which groove a proper stuffing material may be used to make a watertight joint. On the left side of the ring there is mounted a heavy back plate 19 which forms the support for the concentric circular coils 20, 21, 22, 23, 24 and 25 which are used to produce the direct current magnetization as will be presently explained. For this purpose the back plate 19 is provided with circular grooves into which the windings, just mentioned above, are placed. The whole plate may be held to the ring 11 by means of the bolts 26 passing through the flange and into the ring.

The connection may also be made watertight by a similar tongue groove and packing material as described in connection with the flange 13 of the plate 12. Between each groove in which the direct current windings are placed is a small groove or recessed portion 27 which is cut to fit the tongue at the base of the cylindrical elements 28 which rest upon the extended sides of the groove at the sides of the direct current coils. These cylinders or rings 28 are slotted partway down from the top, as indicated by the dotted slots 29 in Fig. 3, the slotted portion as indicated in Fig. 4 being filled with a Bakelite piece 30 or a piece of other similar insulating material of the same shape as the end of the cylinder 28. In this way the circulatory or eddy currents that might be induced in the cylinders through action of stray fields are kept down or reduced. The cylinders 28 fit tightly over the walls in the plate 19. They are further held in place, however, by means of the bolts 31, shown in Fig. 2, which set in the ends of the upper rings 33 and pass through the whole length of the cylinders 28 into the walls of the lower plate 19.

The cylinders 28 are formed with shoulders 35 and 36 on both inner and outer sides of the cylindrical surface, forming thereby end-projecting rings or cylinders 37 centrally located with respect to the cylinders 28. Resting upon the central elements 37 of the cylinders 28 are the cylinders 33 which are formed with a groove shaped to fit over the ends of the cylinders 37. The top rings or cylinders 33 are held to the lower cylinders 28 by means of the bolts 39 spaced about the rings.

The bolts 39 thread into the top cylindrical portion 37 of the cylinders 38 and serve not only to hold the two cylinders together, but also serve as a clamping means for the laminated pole elements about to be described. The cylinders 33 are extended upwards almost to the position of the end radiating plate 12 so as to limit the motion of this plate in event of some extraordinary external pressure as might be due to explosions or the like when the device is submerged in water on a naval vessel. The shoulders 36 and 37 are tapered, as more clearly indicated in Fig. 2, and similarly the projecting flanges 40 and 41 at the lower ends of the cylinder 33 are also tapered so that the inner dimension of the section formed between the two cylinders when clamped in position is wider than the outer dimension at the edge surface of the cylinders which are preferably shaped to be aligned in a continuous surface but for the laminations placed in between. The laminations 42 are of a trapezoidal shape with tapered side edges 43 and 44 and parallel front and back edges, the back edges resting against the surface of the cylindrical portion 37. The laminations on the external side of the cylinder carry a recessed slot in which is wound the coil 45. The laminations on the inside of the cylinder have a plane face. Both sets of laminations, as indicated in Fig. 3, extend all the way around a ring except for the portions, as indicated in Fig. 10, where the electrical connections are made to the coils as, for instance, the coil 45.

As indicated in Fig. 2, the laminations are set in the metallic envelope formed by the two cylinders 33 and 28 all the way around the cylinders except for the slots 29 in which are placed the Bakelite piece 30. These slots in the cylinder 28 run down from the top to a point just above the polarizing poles where the copper rings 46 are placed and in the piece 33 from the lower end up to a point beyond the position of the laminations. These slots are filled with interlocking Bakelite pieces carrying out a shape similar to that of the top of the cylinder 28 and the bottom of the cylinder 33. The coils 45, as has been stated, are wound on the external side of the cylinders, and terminate as indicated in Figures 9 and 10 in the connections there shown. These terminations are shown more clearly in Figures 6 and 7 and, as are indicated, are positioned just off the line of center of the apparatus. The coils 45 are single layer and the end connection of the coil 50 is connected to a copper plate member 51 which, in turn, is held or wedged into a similar copper rod 52. The copper plate 51 is insulated on both sides by Bakelite or other similar insulating elements 53 and 54. These Bakelite elements may be shaped similar to the laminations themselves but somewhat thicker. The copper plate 51 sets in the center of the rod 52 and is held fast therein. The rod 52, as indicated, is surrounded by an insulating bushing 55 which is passed upward through a hole 56 cut through the heavy plate element 19. The bushing 55 is preferably threaded into the plate 19 and is provided at the lower end with a terminal connection 57 which threads into the end of the rod 52.

As indicated in Fig. 9, the terminal 57 may set into a recessed portion at the end of the insulating fitting and a terminal connection of the type desired may be used. The insulating bushing and the terminals are indicated quite clearly in Fig. 6 and the ends are also indicated in Fig. 8. In the present design one terminal of the winding is brought out through one set of bushings, as illustrated by 55 in Fig. 8, and the other terminals

through another set of bushings, as illustrated by 59 in the same figure. These terminals 57 and 60 are brought out in separate terminal compartments 61 and 62 in a common terminal box covered with the casing 63.

In the arrangement shown in Fig. 1 the aluminum or copper rings 64 extend down from the plate 12 to the air gap formed between the laminations 42 and the opposing laminations 65. The upper end of the aluminum or copper rings may be held into the plate 12 by being forced therein or, as shown in Fig. 6, the copper ring may have a straight surface on the external side and a tapered surface 67 on the internal side fitting into a corresponding taper in the plate 68. The open part of the groove in the plate 68 between the straight side of the ring and the wall 69 of the groove 70 may be filled with some appropriate metal 71, such as type metal, or the like, to hold the rings firmly in place.

The rings are placed in the plate at a uniform spacing and preferably at such a spacing that the thickness of the plate is equal to the space between the rings. The plate itself must be one-quarter of a wavelength in thickness or less on the basis of the speed of sound in the material of which the plate is made, and preferably the thickness of the plate should be one-eighth of a wavelength or less. Under these conditions there is very little wave motion or wave propagation in the plate itself and the plate substantially moves as a unit mass. The plate should not be much less in thickness than one-eighth of a wavelength as it is highly desirable to obtain as great a mass ratio as possible between the mass of the plate and that of the aluminum rings. By having the aluminum rings free at their ends and making them thin and using a plate in which with each ring there is associated a mass having dimensions substantially one-eighth of a wave length thick, a large mass ratio can be built up. This mass ratio may be increased by the means indicated in Fig. 11 in which the aluminum ring 72 is not supported at the end of the plate 73 corresponding to the plate 12 but is supported at a point along the center line of the mass or preferably, as indicated, just towards the outer half of the mass so that the node of the ring 72 and the mass 73 comes just at the center line of the mass 73. In this case it will be noted that the mass or plate 73 is supported in a center flange 76 or preferably located along the line of nodes of the aluminum or copper ring 72.

In order to place the aluminum ring in the position indicated in Fig. 11 the plate or mass 73 must be recessed with a circular recess 74 extending all the way around the plate. In the illustration shown in Fig. 11 a mass ratio of 70 may be obtained, that is the force at the point of application of the copper or aluminum ring to the plate is 70 times that generated at the end of the aluminum or copper ring. The amplitude is, of course, correspondingly reduced. As indicated in Figs. 5 and 11, each aluminum or copper ring 64 or 72 is slotted with slots 75, 75, all the way around the ring commencing at a point slightly above the place where the magnetic flux crosses the ring and extending somewhat above it, as indicated in Fig. 2. These slots run vertically arranged in the rings. These slots confine the current induced from the primary winding at the ends of the rings and within the magnetic field flowing across from the laminations 42 to 65.

As shown in Fig. 1 the rings have a uniform spacing between each other commencing with the first ring whose diameter is somewhat larger than the distance between successive rings. In order to provide approximately the same mass for each ring, as indicated in Fig. 6, a center portion 77 is removed from the plate, making the mass associated with the first ring 79 equal to the mass associated with each successive ring.

In Figs. 7 and 8 the rear face view and section of the apparatus is shown. It will be noted that in these modifications the rear plate 80 is provided with a plurality of fins 81, 81, etc., the function of which is to allow radiation of the heat that may be generated within the plate due to the current passing through the coils and the vibration of the apparatus. At the central portion of the back there is provided the casing 63 which is held to the rear plate by means of the bolts 82, 82, etc. The whole apparatus is preferably entirely enclosed by means of spherical cap plates 84 and 85 indicated in Figs. 1 and 6. The cap plate 84 may be heavier than the plate 85. These cap plates are held by means of peripheral rings 86 forming a part of the cap plates through which the bolts 87 are passed, fastening in to the flange 88 of the back plate 19. Free circulation of water is permitted between the spherical back plate 84 and back plate 19 by suitable holes 90 in spherical back plate 84. On the other hand, the space between the diaphragm 12 and front plate 85 is sealed and filled with suitable liquid under pressure.

Having now described my invention, I claim:

1. Means for projecting a beam of supersonic compressional waves comprising a plate of homogeneous material having a substantial thickness and surface dimensions of many times the supersonic wave length to be propagated in the medium, a plurality of concentric rings mounted on one side of said plate at right angles thereto, and means for vibrating the rings simultaneously in the same phase said plate and rings forming a supersonic wave-transferring means having a node in the rings near the plate.

2. Means for projecting a beam of supersonic compressional waves comprising a plate of homogeneous material having a substantial thickness and surface dimensions of many times the supersonic wave length to be propagated in the medium, means for mounting said plate with the edge thereof substantially free and a plurality of concentric rings mounted on one side of said plate at right angles thereto for vibrating the entire plate simultaneously in the same phase said plate and rings forming a supersonic wave-transferring means having a node in the rings near the plate.

3. Means for producing a supersonic beam of compressional waves comprising a plate of homogeneous material having a substantial thickness and surface dimensions of many times the supersonic wave length to be propagated in the medium, means for mounting said plate to allow substantially a free movement normal to the surface thereof, a plurality of concentric rings mounted on one side of said plate with their axes normal to the surface of the plate and electrodynamic means applied at the end of the rings away from the plate for vibrating the rings substantially in the same phase said plate and rings forming a supersonic wave-transferring means having a node in the rings near the plate.

4. Means for producing a beam of compressional waves at high frequencies comprising a plate of homogeneous material having substantial thickness and surface dimensions of many times

the supersonic wave length to be propagated in the medium, means mounting said plate with the edges thereof substantially free, a plurality of concentric rings mounted on one side of the plate at right angles thereto, said rings being spaced an equal distance apart one from the other and said plate and rings forming a supersonic wave-transferring means having a node in the rings near the plate.

5. Means for producing a beam of compressional waves at high frequencies comprising a plate of homogeneous material having substantial thickness and surface dimensions of many times the supersonic wave length to be propagated in the medium, means mounting said plate with the edges thereof substantially free, a plurality of concentric rings mounted on one side of the plate at right angles thereto, said rings being spaced an equal distance apart one from the other, the thickness of said plate being substantially equal to the spacing between successive concentric rings.

6. Means for producing a beam of compressional waves at high frequencies comprising a plate of homogeneous material having substantial thickness and surface dimensions of many times the supersonic wave length to be propagated in the medium, means mounting said plate with the edges thereof substantially free, a plurality of concentric rings mounted on one side of the plate at right angles thereto, said rings being spaced an equal distance apart one from the other, said rings being spaced apart at a distance not more than one-quarter of the wave length of the wave in the material of the plate at the frequency it is desired to produce in the propagating medium.

7. Means for producing a beam of high frequency compressional waves comprising a plate of homogeneous material having a substantial thickness and surface dimensions of many times the supersonic wave length to be propagated in the medium, means mounting said plate to have a substantially free edge, a plurality of concentric rings mounted normally to said plate on one side thereof and spaced an equal distance apart one from the other, the outer ring being spaced away from the free edge one-half of the distance between the rings and said plate and rings forming a supersonic wave-transferring means having a node in the rings near the plate.

8. Means for producing a beam of high frequency compressional waves comprising a heavy radiating plate of substantial and uniform thickness, means mounting said plate with the edge thereof substantially free, a plurality of concentric rings mounted on one side of said plate at right angles thereto, said rings having slots spaced substantially around their whole circumference and extending to the lower part thereof, means providing a magnetic field between the position of said slots and the lower end of said rings and means positioned within said magnetic field for vibrating said rings.

9. In a means for producing a beam of compressional waves of high frequency, a magnetic field, means providing concentric cylindrical elements forming a part of said magnetic field, said concentric cylindrical elements comprising two parts, a lower part and an upper part, and means for holding said two parts together, said cylindrical parts being provided with engaging recessed portions, a laminated core positioned in said recessed portions, said core being clamped by the means holding said cylindrical parts together.

10. Means for producing a beam of compressional waves of high frequency comprising a plate of substantial thickness, said plate having cylindrical recessed slots extending substantially half way into said plates, a plurality of concentric rings mounted at the inner ends of said slots and means supporting said plate at the edges in a plane substantially coinciding with the ends of said slots.

11. In a means for projecting a beam of supersonic compressional waves, a plate having a large radiating surface, said plate being provided with concentric slots having a cross section wedge shape, a ring positioned in said slot and having one surface thereof conforming to one side wall of the slot and an expansive metal molded into the other side of the slot to retain the ring firmly in the slot.

12. Means for projecting a beam of supersonic compressional waves comprising a plate having a substantial thickness, a plurality of concentric rings mounted on said plate, said rings having a substantially uniformly distributed mass and being free at the end not mounted in the plate and said rings and plate forming one-half wavelength system with the amplitude node near the plate and means for vibrating the rings comprising electrodynamic means positioned to apply the mechanical vibrations at the free end of the rings.

EDWIN E. TURNER, JR.

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