May 30, 1939. E. E. TURNER, JR 2,160,007

MAGNETOSTRICTIVE VIBRATOR

Filed May 27, 1936

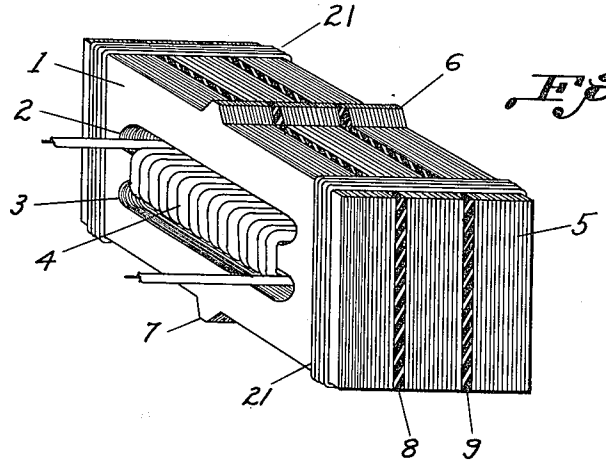


Fig. 1.

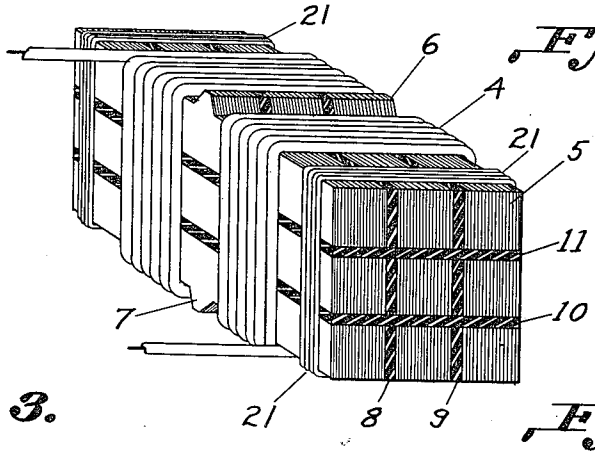


Fig. 2.

Fig. 3.

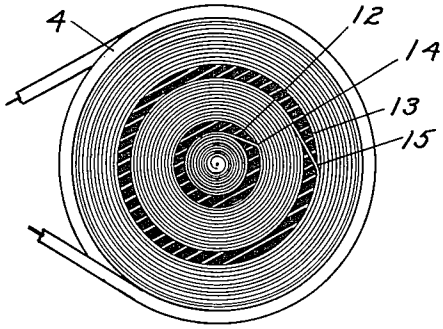
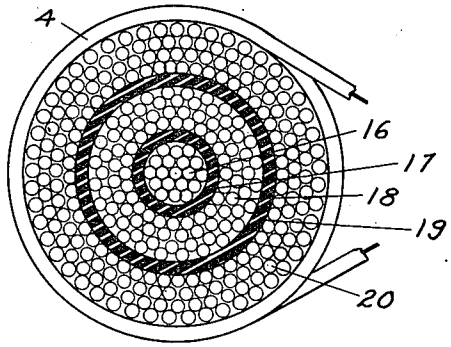


Fig. 4.



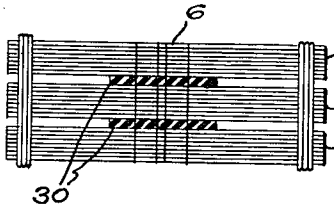


Fig. 5.

INVENTOR.
Edwin E. Turner Jr.
BY
Ezekiel Wolf
ATTORNEY.

Patented May 30, 1939 2,160,007

UNITED STATES PATENT OFFICE

2,160,007

MAGNETOSTRICTIVE VIBRATOR

Edwin E. Turner, Jr., West Roxbury, Mass., assignor to Submarine Signal Company, Boston, Mass., a corporation of Maine

Application May 27, 1936, Serial No. 82,038

11 Claims. (Cl. 177—386)

The present invention relates to a magnetostrictive vibrator. More particularly the present invention relates to a magnetostrictive vibrator for the production of compressional waves in a desired medium.

It is well known that if a block of magnetostrictive material, such as nickel, be subjected to an alternating electro-magnetic flux, the nickel will alternately expand and contract. The maximum effect is obtained when the dimensions of the nickel block are such that its natural frequency corresponds to the frequency of the exciting flux. A convenient form of such a magnetostrictive vibrating element is that of a rod, preferably a half wave length long, which is supported at a vibrational node.

Now, it is well known that when a magnetostrictive rod is energized to vibrate longitudinally, it will also vibrate transversely. I have found that when the cross section of the vibrating rod has dimensions which approach the order of magnitude of the length of the rod, dead areas will appear at the vibrating end of the rod. The entire end surface of the rod does not vibrate with equal amplitude, but there is a gradual diminution of amplitude from a maximum area to an area of substantially zero amplitude. I have found that these dead areas are produced by the transmission of transverse vibrations transversely across the rod in such a way that the transverse vibrations neutralize the longitudinal vibrations throughout the rod along certain nodal planes. This phenomenon greatly reduces the compressional wave energy which can be radiated from the end of the vibrating rod. The present invention provides an arrangement whereby such dead areas are completely eliminated.

The invention will best be understood from the following description taken with reference to the accompanying drawing in which Fig. 1 shows a perspective view of a magnetostrictive vibrating element of rectangular cross section embodying the present invention; Fig. 2 shows a modification of the vibrating element shown in Fig. 1; Figs. 3 and 4 show end elevations of cylindrical vibrating elements to which the present invention has been applied; and Fig. 5 shows a modification of the arrangement shown in Fig. 1 in which the acoustic damping means is applied only around the vibrational nodes.

Fig. 1 shows a prismatic block 1 of magnetostrictive material. In order to avoid the building up of large eddy currents, the block is made up of laminations which are clamped together by any suitable means as by wires 21 wrapped around the block and soldered together. The length of the block is preferably a half wave length of the frequency of vibration desired although it may be any multiple of the half wave length. Apertures 2 and 3 are cut in each of the laminations parallel to their long dimensions. An exciting coil 4 is conveniently wound through these apertures. Under the influence of the alternating electromagnetic flux produced by an alternating electric current of the desired frequency passed through the coil 4, the block is set into longitudinal vibration. The ends of the block, such as the end face 5, will then produce compressional wave vibrations in the medium in which it is placed. For submarine signaling purposes, for example, the block may be immersed in an oil-containing chamber closed on the side facing the face 5 by a sound transmitting membrane which is in contact with the sea water. The block is preferably supported at its node by means of the supporting tongues 6 and 7 extending transversely across opposite faces of the block. These supporting tongues may be formed integrally with the laminations, as shown, or other suitable means of supporting the vibrating element may be employed.

When the laminated element 1 is set into longitudinal vibration it will also tend to vibrate transversely in directions parallel to both of its short dimensions. The vibrations which are in the planes of the laminations are, however, suppressed by the apertures 2 and 3. On the other hand, the transverse vibrations which are set up in the direction of the thickness of the laminations, namely in a horizontal direction across the face 5 of the element as shown in Fig. 1, will tend to add up in such a way that they will neutralize the longitudinal vibrations along certain planes parallel to the planes of the laminations. It may be found, for example, that there are two narrow linear areas extending across the face 5 parallel to the direction of the laminations at which substantially no longitudinal vibrational amplitude will be found. Under such conditions the maximum compressional wave energy cannot be radiated from the end face of the vibrating element. This difficulty can, however, be overcome by inserting vibration damping material between adjacent laminations along the planes of the nodal areas. Thus, in Fig. 1 rubber, or the like, laminations are inserted at 8 and 9. These are of the same shape as the laminations themselves. With such rubber inserts the transverse vibrations are not able to build up to an amplitude sufficient to interfere

with the longitudinal vibration of the element. Consequently the amplitude of longitudinal vibration is substantially uniform all over the end faces of the vibrating element.

It may sometimes be inconvenient to cut longitudinal slots in the laminations, as shown in Fig. 1, but it may be desirable to wind the exciting coil around the whole of the block. Such an arrangement is shown in Fig. 2. In this case the transverse vibrations can build up in the vertical direction of the block as shown in Fig. 2, as well as in the horizontal direction. Consequently it is necessary in addition to the rubber inserts parallel to the planes of the laminations, as shown in Fig. 1, also to place rubber inserts in the horizontal planes where nodal areas would otherwise occur. Thus, in Fig. 2 in addition to the rubber inserts 8 and 9 horizontal rubber layers 10 and 11 are employed. It will be obvious that this simply means that the laminations are narrower than they would otherwise be and that the structure of Fig. 2 is readily built up from nickel strips which are narrow compared to their length. With the arrangement shown in Fig. 2 a longitudinal vibrating member is obtained which will vibrate longitudinally with uniform amplitude over the whole of the end faces.

It is sometimes desirable to build up the longitudinally vibrating rod to be cylindrical in shape. In such a case the rod may be formed of a sheet of nickel or other magnetostrictive material wound in a spiral as shown in Fig. 3, or it may consist of a bundle of rods, each of circular cross section as shown in Fig. 4. The exciting coil 4 is in each case wound around the outside of the rod. Such cylindrical longitudinally vibrating elements will also tend to vibrate radially. These radial vibrations act analogously to the transverse vibrations in the prismatic elements of Figs. 1 and 2.

Nodal zones where the longitudinal vibrations are substantially entirely suppressed will ordinarily be found at various radii from the center of the cylinder extending in cylindrical areas along the whole length of the element. Therefore, to obtain maximum longitudinal vibration and to obtain substantially uniform amplitude over the entire radiating end of the cylindrical member, it is necessary to insert sound damping material along the cylindrical areas where the radial vibrations tend to suppress the longitudinal vibrations. Thus, in Fig. 3 there are inserted two substantially cylindrical rubber layers 12 and 13. These consist simply of sheets of rubber which are wound between adjacent turns of the nickel sheet when the spiral is being wound. The ends of each rubber sheet are preferably arranged to lap over each other so that there will be a sufficient thickness of rubber at all points. The nickel sheet is shown in Fig. 3 passing between the ends of the rubber sheets at 14 and 15, respectively. It would, of course, also be possible to cut the spiral at the places where the rubber damping sheet is to be inserted, but the arrangement shown in Fig. 3 is a convenient construction.

A similar arrangement is employed in the modification of Fig. 4 in which the longitudinal vibrating element is built up of a bundle of rods. A first group of rods 16 forms the central portion of the vibrating element. This group is surrounded by a rubber cylinder 17 and is in turn surrounded by a further group of rods 18 followed by the rubber sheet 19 and the outer layer of rods 20.

Thus, in both the modifications of Figs. 3 and 4 radial vibrations are effectively interrupted to such an extent that the compressional wave radiating ends of the vibrating elements will vibrate uniformly over their entire areas.

It will be evident that while in all of the arrangements shown only two parallel rubber inserts are employed, as many as necessary should be used to remove whatever nodal planes may develop. The number of such nodal areas is dependent upon the relation between the cross sectional dimensions of the vibrating element and its length. The greater the cross sectional dimensions with respect to the length of the element, the more nodal areas will be found and consequently the more acoustic damping layers will have to be used. In other words, the vibrating unit must be broken up into elements whose transverse dimensions are small compared to the half wave length of the frequency of longitudinal vibration.

While the damping material has been shown extending throughout the whole length of the vibrating unit, it will be understood that since the transverse vibrations have their maximum amplitude at the longitudinal vibrational nodes in accordance with Poisson's ratio, it would be sufficient in most cases to place the damping material only in the vicinity of such nodes. However, it is usually more convenient and leads to somewhat better results to isolate completely the elements of the vibrating unit as shown. This is indicated in Fig. 5 where the damping material 30 is placed only at the node 6 between the group of laminations 31, 32 and 33, the rest of the space preferably being left vacant as indicated.

Having now described my invention, I claim:

1. A magnetostrictive vibratable member comprising a plurality of magnetostrictive elements of the same length whose cross sectional dimensions are short in comparison with their length, means for holding said elements together with their longitudinal axes parallel and vibration damping means inserted between said elements adapted to prevent the transmission of vibrations between one element and the next in all transverse directions.

2. A magnetostrictive vibratable member comprising a plurality of magnetostrictive elements of the same length whose cross sectional dimensions are short in comparison with their length, means for holding said elements together with their longitudinal axes parallel and vibration damping means inserted between said elements in the vicinity of each longitudinal vibrational node whereby the transmission of transverse vibrations from one element to the next is avoided.

3. A magnetostrictive vibratable member comprising a plurality of magnetostrictive elements of the same length whose cross sectional dimensions are short in comparison with their length and each of which elements is formed of a group of laminations, means for holding said elements together with their longitudinal axes parallel and vibration damping means inserted between said elements whereby the transmission of transverse vibrations from one element to the next is avoided.

4. A magnetostrictive vibratable member comprising a plurality of magnetostrictive laminations, each having a length equal to a multiple of the half wave length of the frequency of longitudinal vibration desired and a width which is

not small compared to said half wave length, longitudinal apertures in each of said laminations extending substantially along the entire length of the laminations and spaced to divide the laminations into portions measured in the direction of the width of the laminations short compared to the said half wave length, means for holding said laminations together and vibration damping means inserted between groups of laminations, said groups being sufficiently small to make the combined thickness of the laminations in each group small in comparison with the said half wave length.

5. A magnetostrictive vibratable member made up of laminations and comprising a plurality of rectangular magnetostrictive elements having a length equal to a multiple of the half wave length of the desired frequency of longitudinal vibration and a width small compared to said half wavelength, said laminations being assembled in groups such that the combined thickness of the laminations in each group is small compared to said half wave length, means for holding a plurality of such groups of laminations together to form a single longitudinally vibratable member and vibration damping means inserted between each group of laminations and the next.

6. A magnetostrictive vibratable member comprising a closely wound spiral of magnetostrictive material having a width equal to a multiple of the half wave length of the desired frequency of vibration and vibration damping means inserted between successive convolutions of the spiral for a complete revolution thereof and spaced at such successive radii from the center of the spiral that the radial distance from one damping layer to the next is small in comparison to the said half wave length.

7. A magnetostrictive compressional wave signaling device comprising a half wave length laminated longitudinally vibratable member, means for dividing the laminae into sections and acoustically insulating each from the other whose dimensions are small in comparison to said half wave length in all directions transverse to the longitudinal direction, means for supporting said vibratable member at its longitudinal vibrational node and an electromagnetic coil adapted to produce and respond to longitudinal vibrations of said member.

8. A magnetostrictive vibratable member of prismatic shape comprising a plurality of rectangular laminations of magnetostrictive material separated into groups by means of thin rubber sheets, the combined thickness of the laminations in each group being small compared to the half wave length of the desired frequency of longitudinal vibration of said member.

9. A cylindrical magnetostrictive longitudinally vibratable member having a laminated structure, said member tending also to execute radial vibrations which interfere in places with the longitudinal vibrations and means for suppressing said radial vibrations comprising vibration damping material inserted within the body of said member between groups of laminated elements to divide them into groups having radial dimensions small compared to the half wave length of the desired longitudinal vibration frequency.

10. A magnetostrictive vibratable member comprising a plurality of half wave length longitudinally vibratable magnetostrictive units, means acoustically insulating said units from each other and having a combined radiating face area whose dimensions are large with respect to the length of said longitudinal vibrations.

11. A magnetostrictive vibratable member comprising a plurality of half wave length longitudinally vibratable units of laminated magnetostrictive material, each of said units having a radiating end area of rectangular shape at least one dimension of which is small compared to the wave length of said longitudinal vibrations and means for combining said units into a single longitudinally vibratable member with said units acoustically insulated from one another.

EDWIN E. TURNER, JR.