Dec. 24, 1935. R. B. COLTON ET AL 2,025,041

ELECTROMAGNETIC VIBRATOR

Filed March 9, 1931

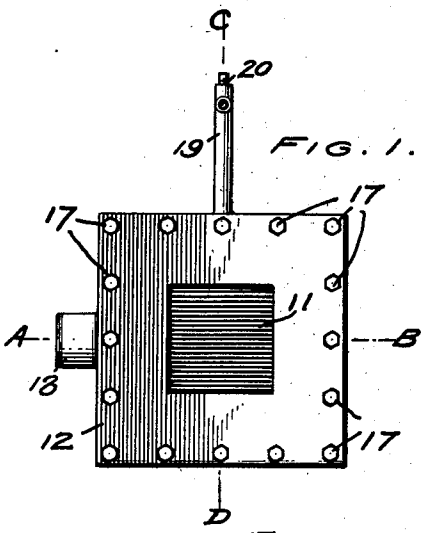


FIG. 1.

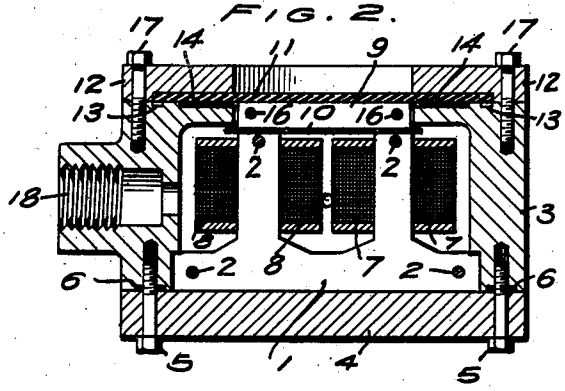


FIG. 2.

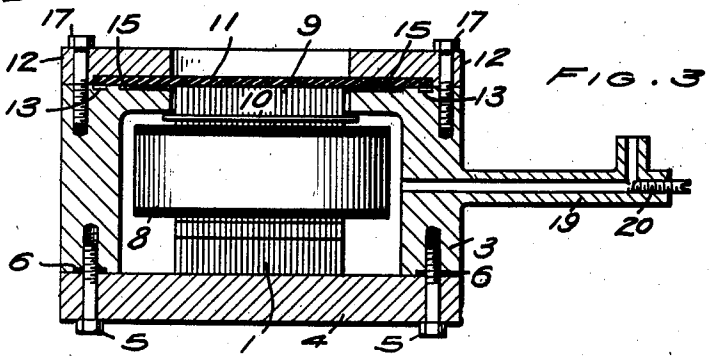


FIG. 3.

FIG. 5.

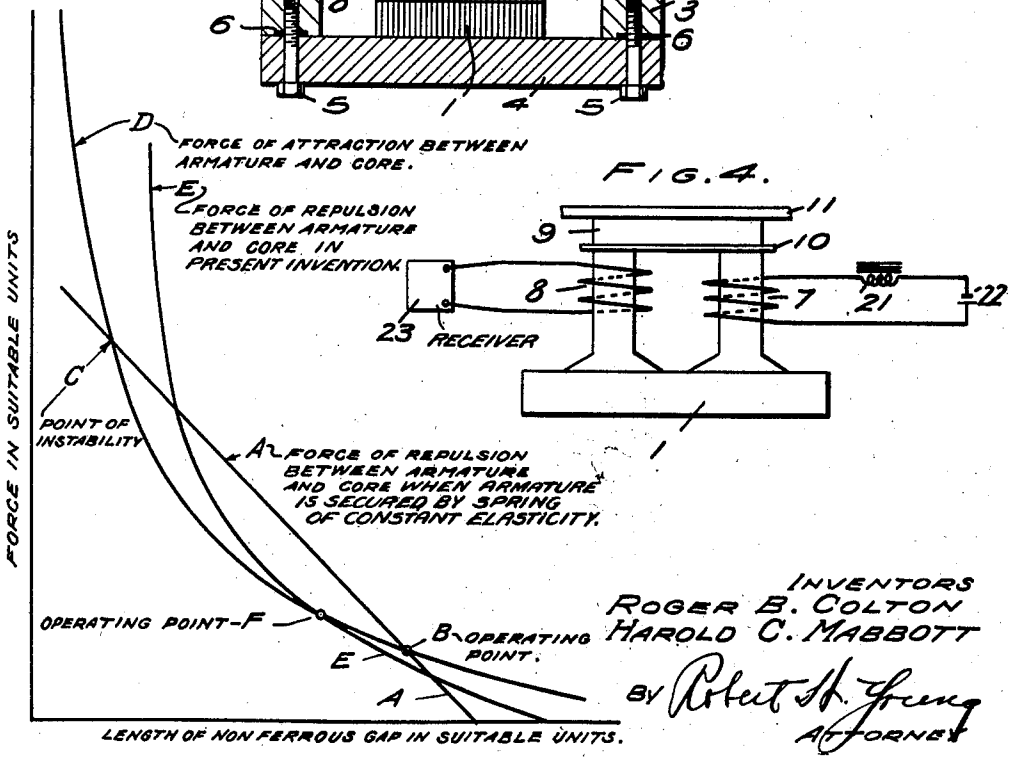


FIG. 4.

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ELECTROMAGNETIC VIBRATOR

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Application March 9, 1931, Serial No. 521,362

9 Claims. (Cl. 177—386)

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

The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to us of any royalty thereon.

This invention relates to electro-magnetic vibrators.

The invention has for its object improvement in the operation of electro-magnetic vibrators in the matter of faithfulness, efficiency and reliability in conversion of sound or mechanical energy into electrical energy and in the conversion of electrical energy into sound or mechanical energy.

The invention as regards one of its main features, is based on the fundamental idea that there is in such vibrators, when properly arranged, a magnetic force tending to increase the armature displacement, which may, over the working range, be balanced to any desired extent and which may outside the working range be enormously over balanced by the mechanical force tending to decrease the armature displacement, furnished by a proper material inserted between the armature and core. Such being the case, net mechanical stiffness of any desired amount may be secured over the working range while outside that range net mechanical stiffness may be made sufficiently great to insure certainty and stability of operation.

In order that there shall be no confusion it will be here explained that the term mechanical stiffness is to be taken to apply to the mechanical force of restitution while magnetic stiffness is to be taken to apply to the magnetic force of displacement, each being defined as the increase of the corresponding force per unit movement of the vibrator armature.

With the foregoing and other objects in view, the invention consists in the details of construction and combination of parts hereinafter set forth, an embodiment thereof being illustrated in the accompanying drawing, in which:

Figure 1 is a plan view of one form of device embodying the invention;

Figure 2 is a transverse section on the line A—B of Figure 1;

Figure 3 is a longitudinal section on the line C—D of Figure 1;

Figure 4 is a schematic wiring diagram of the form of the invention shown in Figures 1, 2, and 3; and

Figure 5 is a graph showing the manner in which mechanical and magnetic factors of stiffness combine in the present and comparative devices.

Referring to Figures 1, 2, and 3, 1 is a laminated core of magnetic material. The laminations are held together by the rods 2 which are upset at their ends in the manner customary in the art. The core is secured in place in the housing 3 by having its lower shoulders clamped by the base 4. The base is secured to the housing by screws 5 and the joint is made pressure tight by the gasket 6. Coils of insulated copper wire 7 and 8, are placed around the legs of the core. A soft rubber spacer 10 in the gap between the armature 9 and the core 1 and cemented to both, provides the necessary armature mechanical stiffness. A soft rubber diaphragm 11 is superposed upon the back of the armature and, extending under the diaphragm clamp 12, is compressed between the diaphragm clamp and the housing when the screws 17 are properly tightened, and its outer periphery therefore serves the purpose of a gasket and renders the joint between the housing and diaphragm pressure tight. A groove as at 13 extending around the housing provides space for flow of the material at the edge of the diaphragm and thereby assists in keeping the diaphragm flat. Thin spacers 14 and 15 of soft rubber resting in shoulders in the housing and abutting against the armature and secured by being clamped by the pressure of the diaphragm assist the spacer 10 and diaphragm 11 to hold the armature in position, but without contributing materially to the armature mechanical stiffness, which is provided by spacer 10. The armature is composed of laminated magnetic material and the laminations are held together by rods 16. The stuffing box 18, the details of which are omitted, provides a pressure tight means whereby insulated connecting wires (not shown) may be brought into the housing, while the drilled and tapped extrusion 19 provides means for evacuating the housing or filling it with compressed fluid; and the needle valve screw 20 provides a means of preventing or controlling ingress or egress of fluid to or from the housing.

As has been stated Figure 4 is a diagrammatic representation of a method of wiring up the device illustrated in Figures 1, 2, and 3. Referring now to Figure 4, 21 is a choke coil substantially passing only steady current; 22 is a battery furnishing current to coil 7 through the choke coil 21, and 23 is an electrical receiving apparatus or an electrical energy sink of desirable type, connected to coil 8.

Considering the device as described above, sound pressure exerted on the diaphragm 11 is transmitted to the armature 9 causing it to vibrate. Vibration of the armature causes the

rubber spacing sheet 10 to expand and contract, thus increasing and decreasing the reluctance of the magnetic circuit formed by the core, the armature and the gap between the armature and core, and since the current through coil 7 provides a steady magnetomotive force the flux through the magnetic circuit varies in response to the vibration of the armature, inducing in coil 8 a voltage and in circuit 8—23 a current which actuates receiving device 23.

Conversely, if the receiving device 23 is replaced by a source of variable electromotive force, the consequent current will produce a variable flux in the magnetic circuit and the armature will move due to the consequent variation of the force of attraction between the core and armature. The movement of the armature likewise causes a movement of the diaphragm and sound is emitted therefrom.

In the past in devices of this character the necessary restoring force has been supplied by spring action on the part of the diaphragm or by similar means. Under these conditions, it has been necessary to provide either an excessive mechanical stiffness or an excessive air gap or a very weak magnetic field to prevent adhesion of the armature to the core.

In the form of the present invention illustrated in Figures 1, 2, and 3 the restoring force is provided by the rubber sheet 10. Rubber has the characteristic that its coefficient of elasticity increases under increasing pressure; hence even though the device be subjected to very excessive forces the armature is always held away from the core and it is possible to use any desired physically obtainable value of the steady flux, length of nonferrous gap and residual mechanical stiffness. This point will be understood by reference to Figure 5. Curve D shows qualitatively the manner in which the force of magnetic attraction varies with the length of the nonferrous gap. This force increases more and more rapidly as the nonferrous gap (plotted as abscissa) decreases. Curve A shows the force of repulsion when the armature is secured by a true spring of constant elasticity. In this case the armature assumes equilibrium at the normal operating point B where the two forces are in balance, and has a residual mechanical stiffness in the vicinity of point B equal numerically to the difference of the ordinates of A and D divided by the difference between the corresponding abscissa and the abscissa of point B. However, if under the impulsion of any large force the armature reaches a point even slightly to the left of point C it will of necessity continue to decrease the nonferrous gap and "freeze" on the core, rendering the device inoperative, since the residual stiffness is now magnetic, i. e. the resultant force is henceforth away from B.

Now curve E represents the force of repulsion in a case when the armature and core are separated by a material that has a coefficient of elasticity increasing with pressure. In this case the armature assumes equilibrium at the normal operating point F and as this is the only point of intersection of curves D and E there is no point of instability (residual stiffness always being mechanical). Further, by suitably dimensioning the spacing material it is apparent that the operating point can be moved at will along curve D. It is also true that by either suitably dimensioning the spacing material, or by selecting a material of suitable characteristics the curve E may be given almost any desired shape, and hence any desired constant residual mechanical stiffness may be secured over a wide working range of gap length, while very large residual mechanical stiffness is provided outside the working range. It will frequently be found best and most convenient to shape curve E so that the residual mechanical stiffness is small but constant over a selected range each side of the operating point, beyond this range on the side of the core, i. e. on the side of decreasing nonferrous gap, increases rapidly with decreasing nonferrous gap, and beyond this range on the side away from the core is at least as large as over the selected working range each side of the operating point.

It will be apparent to one familiar with the art that curve E, having been determined by selecting and dimensioning of the spacing material, can be further altered by application to the armature of forces other than those supplied by magnetic action and by the elasticity of the spacing material. For this purpose and since it is sometimes desirable, as when working at great depths in water, to provide a means of balancing in whole or in part or in excess outside pressure, the device is made pressure tight and the extrusion 19 fitted with the needle valve 20 is provided so that fluid may be introduced into or extracted from the device. If a light gaseous fluid is used within the housing and the space within is large, addition or extraction of fluid has substantially no effect on the shape of the stiffness curve, the only effect being to translate the curve parallel to itself along the gap length coordinate. However, if fluids having a high elastic coefficient are used, or if the space within the housing is small, addition or extraction of fluid both displaces the mechanical stiffness curve and changes its shape.

In the form of the device shown in Figures 1, 2, and 3, core losses have been reduced by laminating the core and armature, but this construction it not always essential.

In order that there may be no confusion, it is here explained that the term "magnetic material" as hereinbefore or hereinafter used should be taken to mean a material having magnetic qualities similar to those of iron and that the term "nonferrous" should likewise be taken to mean "not having the magnetic qualities of iron".

When the construction of Figures 1, 2, and 3 is used, and an excess of pressure is used within the housing, it may be advisable to cement or vulcanize the diaphragm 11 to the armature, or other means, may be used, to prevent collection of fluid between the armature and diaphragm and to insure contact between the diaphragm and armature.

While it has been stated that the spacer 10 is cemented to the armature and to the core, such procedure is not essential if the armature is otherwise held in position by any means that does not prevent the maintenance of the desired armature residual mechanical stiffness curve, as for instance by means of spacers 14 and 15. Cementing of spacer 10 is, however, in general advantageous since contact of the spacer 10 with both armature and core is thereby assured and at the same time the armature is held in position transversely to its operative movement.

As has been stated previously, curve E, Figure 5, may be shaped by the application of additional forces other than those supplied by the spacing material. Such shaping by means of fluid pressure has already been discussed, but other means may be used. When such means of shaping the mechanical stiffness curve is used, one familiar

with the art will understand the proper procedure from the discussion previously given.

Hereinbefore it has been stated that sheet 10 may be of any elastic material whose coefficient of elasticity increases with increasing pressure. It is intended, of course, that this process be reversible, i.e., that the coefficient of elasticity of the material shall likewise decrease with decrease of pressure. In other words, sheet 10 may be composed of any elastic material having a coefficient of elasticity proportionate to pressure. Further, in order that there be no doubt or confusion, it is now stated that when the phrase "Material having a coefficient of elasticity proportionate to pressure" is hereinbefore or hereinafter used, it should be interpreted to mean "Material such that when during operation the pressure on said material increases or decreases, its coefficient of elasticity likewise increases or decreases but not necessarily in linear proportion to the increase or decrease of pressure on said material, no rate of increase or decrease of said coefficient or manner of variation of said rate with pressure on said material being excluded except as may be dictated by the particular circumstances of use of said material as a matter of design or operation."

What is claimed is:

1. In an electro-magnetic vibrator, a fluid-tight casing subject to external and internal fluid pressure; means for varying and controlling said internal pressure; an electro-magnetic core; an electro-magnetic vibratory element; electro-magnetic means for superposing upon said element an additional force component; and elastic members for mounting said element in vibratory relation with the core, said members comprising plate-like sheets embracing said vibratory element on opposite faces, one of said sheets being in contact with the core said sheets having a coefficient of elasticity proportionate to pressure and reacting against fluid pressure to maintain a free vibratory relation and net mechanical stiffness between armature and core.

2. In an electro-magnetic vibrator adapted for sub-aqueous use, a core of magnetic material; a vibratory element of magnetic material; electro-magnetic means for superposing a biasing magnetic flux on said element; a housing formed with a fluid-tight chamber subject to external and internal fluid pressure; elastic means for mounting said element in vibratory relation with the core, said means comprising a diaphragm for driving the vibratory element and including an elastic sheet interposed between said core and vibrating element, said sheet being in communication with said chamber and being of a material having a coefficient of elasticity proportionate to pressure; and means for regulating the balancing pressure in said chamber against varying degrees of external water pressure and reacting against said elastic sheet to maintain a net mechanical stiffness between the core and vibratory element.

3. An electro-magnetic vibrator adapted for use in an aqueous medium, comprising a fluid-tight casing subjected to external and internal fluid pressure; means for varying and controlling the internal pressure; an electro-magnetic core; an electro-magnetic armature; electro-magnetic means for superposing upon said armature an additional force component; and elastic means interposed under positive stress between the core and armature for retaining said armature in fluid-tight and vibratory relation with the core regardless of pressure variations of said medium.

4. In a sub-aqueous electro-magnetic vibrator, comprising in combination a fluid-tight casing subjected to external and internal fluid pressure and having an acoustic chamber formed in said casing; means for varying and controlling the internal pressure; a magnetic core and an armature forming a magnetic circuit, said circuit being energized with magnetic flux; means for mounting said armature in vibratory relation with the core and in fluid-tight communication with said chamber, said means comprising elements of elastic material and contacting said armature on its opposite faces, one element being interposed between the core and armature and acting to permit a free vibration of the armature irrespective of the net balance of pressure between said chamber and the external medium.

5. A sub-aqueous electro-magnetic vibrator including a body portion formed as a casing subjected to external and internal fluid pressure and adapted to encompass a fluid-tight chamber, comprising in combination a magnetic core and an armature in magnetic circuit relation, said circuit being energized with magnetic flux; means for varying and controlling the internal pressure; means comprising sheets of elastic material for mounting said armature in vibratory relation with the core, one of said sheets functioning as a diaphragm; means for retaining the sheets under initial pressure, and including elements to clamp said diaphragm in sealed contact with a portion of the casing; and a channel in said casing to provide space for expansion of the elastic material of the diaphragm under pressure.

6. In an electro-magnetic vibrator, a fluid-tight casing subject to external and internal fluid pressure; means for varying and controlling said internal pressure; a core of magnetic material; a vibratory element of magnetic material; electro-magnetic means for superposing an additional force upon said element; and elastic material for mounting said element in vibratory relation with the core, comprising a sheet functioning as a diaphragm and including a sheet interposed between said core and vibratory element, said sheets having the inherent quality of maintaining a free vibratory relation between said element and core independently of pressure changes.

7. In an electro-magnetic vibrator, a fluid-tight casing subjected to external and internal fluid pressure; an electro-magnet having a core rigidly mounted in the casing; an armature operative with the core; electro-magnetic means for superposing an additional force component upon said armature; elastic material for mounting said armature in vibratory relation with the core, comprising members in sheet form, one of said members being interposed between core and armature; means for securing the other member to the casing to form a fluid-tight chamber therein; and means to vary and control the pressure in said chamber and reacting against extraneous forces to maintain a free vibratory relation and net mechanical stiffness between armature and core over the working range.

8. A device of the character described, comprising a fluid-tight casing subject to external and internal fluid pressure, said casing being formed with a chamber therein; means for varying and controlling said internal pressure; a core; an armature operative with the core; electro-magnetic means for superposing a biasing magnetic

flux on the armature; and means for mounting said armature in vibratory relation with the core and in fluid-tight relation with said chamber, said means including elements of elastic insulating material contacting said armature on its opposite faces, one element being interposed between core and armature to prevent adhesion of said armature under stress, and said sheets acting to maintain a net mechanical stiffness between core and armature and irrespective of the pressure of the external medium.

9. A sub-aqueous electro-magnetic vibrator comprising a fluid-tight casing subject to external and internal pressure; means for varying and controlling the internal pressure; a magnetic core and an armature operative therewith; electromagnetic means for superposing a biasing magnetic flux on said armature; and means for mounting the armature in vibratory relation with the core, said means including elastic insulating elements supporting the armature on opposite faces and reacting under fluid pressure to furnish a mechanical restitutive force-displacement ratio of the armature substantially equal to the primay magnetic repulsive force-displacement ratio of said armature.

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