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W. C. JONES

1,816,906

ELECTROMAGNETIC DEVICE

Filed Dec. 19, 1928

Fig. 1.

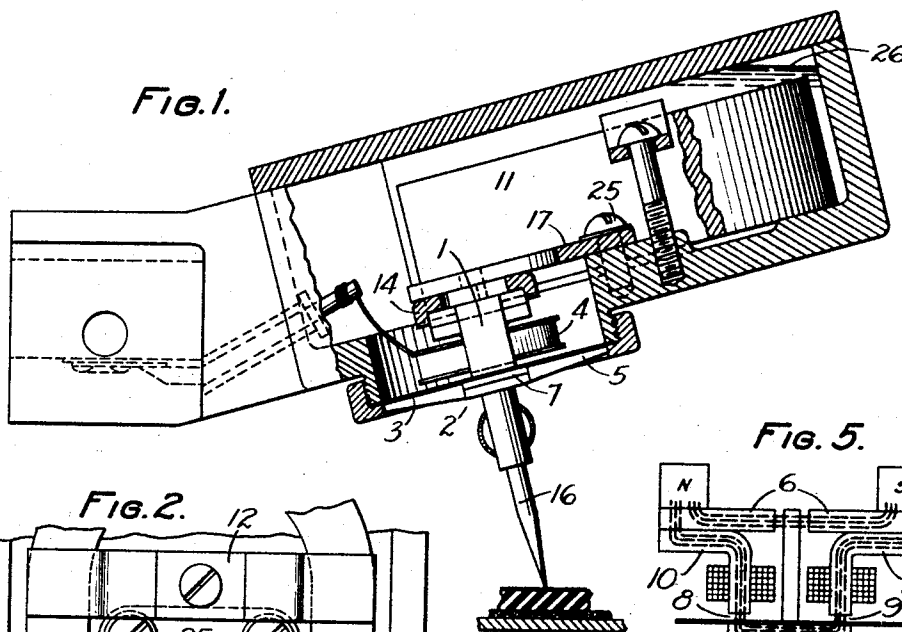


Fig. 2.

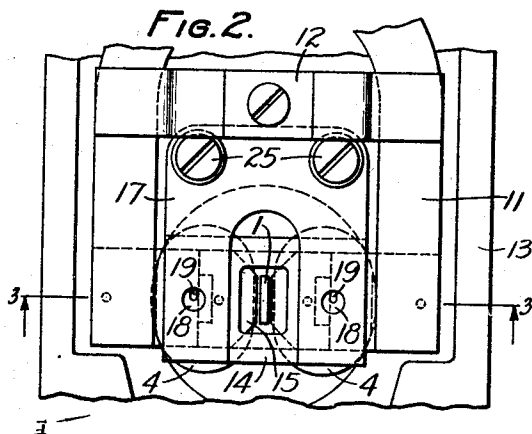


Fig. 5.

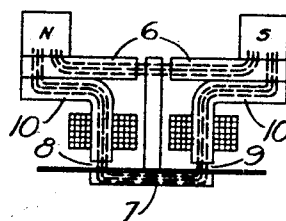


Fig. 4.

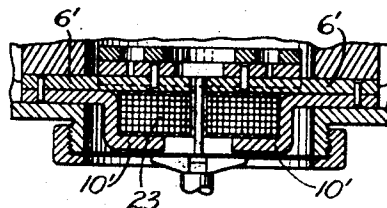


Fig. 3.

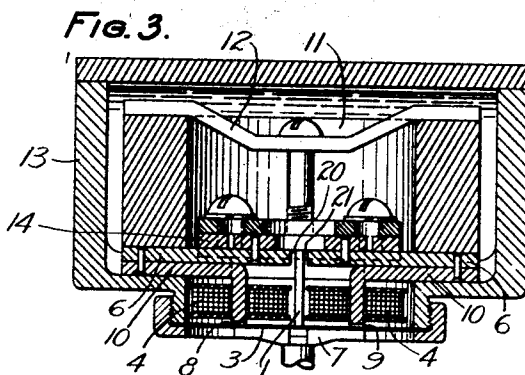


Fig. 6.

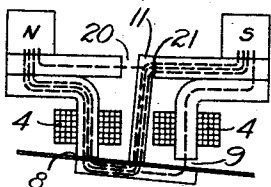


Fig. 7.

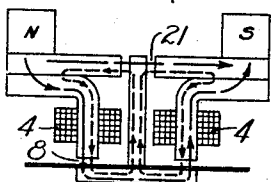
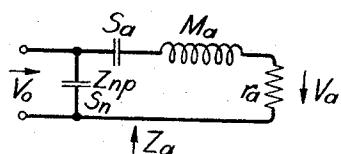


Fig. 8.



INVENTOR

W. C. JONES

BY

G. M. Pampbell

ATTORNEY

UNITED STATES PATENT OFFICE

WARREN C. JONES, OF FLUSHING, NEW YORK, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

ELECTROMAGNETIC DEVICE

Application filed December 19, 1928. Serial No. 326,941.

This invention relates to electromagnetic translating devices and more particularly to sound reproducers and recorders of the oil damped type. The object of the invention is to increase the efficiency of such devices.

In accordance with the general features of the invention a four-pole magnetic structure and its associated coil are sealed in an oil filled casing by a flexible diaphragm. A T-shaped armature supported by the diaphragm vibrates with it as the stylus flexes the diaphragm about its diameter. The four-poles of the magnet system are arranged so that the magnetic circuit has four gaps with respect to the armature and so that the diaphragm does not form an essential part of it. The axis of flexure of the diaphragm is also the pivot axis for the armature, thereby effectively closing the oil chamber without damping the armature vibrations.

In the drawings Fig. 1 is a sectional elevation of a sound translating device incorporating the features of this invention. Fig. 2 is a partial plan view. Fig. 3 is a cross-section on the line 3—3 to show particularly the magnetic circuit and the provisions made for adjusting the air-gaps. Fig. 4 is a cross-section of an alternate arrangement of the magnetic circuit but embodying the same general ideas. Fig. 5 shows the flux distribution when the armature is in its neutral position. Fig. 6 shows the flow of flux when the device is actuated as a reproducer. Fig. 7 shows the flux distribution in the magnetic circuit just prior to the operation of the device when used as a recorder, and Fig. 8 is a representation of the analogs of the mechanical elements of this device used as a recorder, in the elements of a corresponding electrical network.

In Figs. 1, 2 and 3 the reed member 1 forming a part of the T-shaped armature 2 protrudes through the diaphragm 3 and between the coils 4—4 to a position midway between the pole pieces 6—6. The magnet member 7 also forming a part of the armature, is soldered to the diaphragm to form gaps 8 and 9 adjacent to the pole pieces 10—10. A member 5, extending over substantially the whole free portion of a diam-

eter of the diaphragm, is attached to it along the pivot axis to stiffen it against flexure at right angles to that axis. The pole pieces 6 and 10 are welded together or riveted, as indicated, and extend under the poles of the U-shaped magnet 11 which is firmly held in place by means of a clamp 12 secured to the casing 13. The spacing of the pole pieces is maintained by means of a brass channel piece 14 welded or riveted to them. A rectangular opening 15 in the channel 14 permits easy observation of the position of the armature in the gaps 20 and 21.

Since it is important for reasons given later to have the armature adjusted so as to be centrally located when the device is not in use, some convenient means for correcting any bias that may develop must be supplied. For this purpose there is provided a U-shaped member 17 secured to the casing at one end by screws 25—25 and resting on the channel piece 14 at the other. Circular holes 18—18 in this member, above and eccentrically located with respect to oblong holes 19—19 in the channel piece 14, are adapted to receive wrenches having circular shanks and smaller circular eccentric projections for engaging the holes 19—19. By twisting these wrenches (preferably two of them simultaneously) the pole pieces 6—6 and 10—10 may be made to slide with respect to the magnet and the casing so that the reed member 1 is accurately centered in the gaps.

When this adjustment has been made the corresponding gaps at either side of the axis of flexure will have the same reluctance so that no flux will flow in the reed member. This condition is illustrated in Fig. 5. The diaphragm, as already pointed out, is not utilized as an essential part of the magnetic circuit; instead the flux is conducted directly to the gaps by means of pole pieces 6 and 10. As shown in Fig. 5 the flux in the lower branch of the magnetic circuit traverses gap 8, magnetic member 7, gap 9 and the right hand pole piece 10 to reunite with the flux of the upper branch at the other magnetic pole. It is evident, therefore, that the passage of the flux through the diaphragm is purely incidental in this case and that there is no re-

sultant tendency to flex the diaphragm. The member 7 and the pole pieces 10—10 are preferably so proportioned that the lower gaps are located some distance from the axis of flexure. With such a construction there is considerable variation in the reluctance of these gaps as the diaphragm flexes and the overall efficiency of the device is thereby considerably increased.

When such a magnetic circuit is employed in a reproducer and the stylus 16 is vibrated by engaging the grooves of a record the flux distribution will no longer be as outlined above. If as shown in Fig. 6, the stylus is first actuated so that the top of the reed member 1 is moved to the right, the reluctance of gaps 8 and 21 is decreased and the reluctance of gaps 9 and 20 is increased. While this movement is taking place the downward flux in the left-hand coil 4 is building up to a density greater than normal and at the same time the upward flux in the right-hand coil 4 is decreasing to a density below normal. This change in flux linkages induces an electromotive force in the coils 4—4 which are connected to give a cumulative effect in the external circuit. If the top of the reed member 1 is moved to the left the upward flux through the right-hand coil 4 is increased and the downward flux in the left-hand coil 4 is decreased so that the electromotive forces induced are in the opposite direction to those of the previous case. The magnitude and frequency of these flux variations will therefore correspond to the relative amplitude and frequency of the recorded sounds as represented by the movements of the stylus needle.

The operation of this device when used as a recorder may be more easily understood by referring to Fig. 7. In such a case the currents representing the sounds to be recorded will be conducted to the coils 4—4. When no current is flowing the flux distribution due to the magnet 11 will be as indicated in Fig. 5 and is represented in this case by long dashes. Assume a current pulse through the coils in such a direction as to give rise to a downward flux through each coil as indicated by short dashes. Under this condition it is evident that the flux in gaps 8 and 21 is increased while the flux in gaps 9 and 20 is decreased so that the armature will tend to move in a clockwise direction. A current through the coils in the reverse direction similarly will cause the armature to move in a counterclockwise direction. The amplitude and frequency of this motion will, therefore, correspond at all times to the strength and frequency of the currents in the coils.

The alternate construction shown in Fig. 4 differs from that already described essentially in that a single coil 23 surrounds the armature and replaces the two coils 4—4. The lower pole pieces 10'—10' are, therefore, modified to pass around the coil as shown.

When the moving system is in its neutral position a steady flux will flow in the pole pieces 6'—6' and 10'—10' as in the previous case. When used as a reproducer a deflection of the reed member to the right will cause flux to flow upward and a deflection to the left will cause flux to flow downward in the reed member as before. These variations of flux will induce electromotive forces in the coil 23 which obviously will correspond to the movements of the stylus.

When used as a recorder, the currents corresponding to the sounds to be recorded in traversing the coil 23 will set up a flux as indicated in Fig. 7 by the short dash lines. Inasmuch as the operation is essentially the same as that already described for the preferred form, it is believed that the operation of this modified form of the device will be clearly understood without further explanation.

The necessary damping for this device is provided preferably by substantially filling the casing with a viscous medium 26 as indicated, which impedes the oscillations of the moving system and thereby prevents undue response at resonant frequency.

The importance of properly choosing this damping medium according to the use to which the device is to be put will appear from the following considerations: It is well known in the art that devices of this kind have a different frequency response characteristic when used as recorders than when used as reproducers. During recording the soft wax offers but slight opposition to the cutting stylus so that only slight stresses are set up in the stylus needle and the shunting effect of the stiffness may be neglected. The resonant frequency of the device is therefore determined only by the stiffness of the diaphragm and the mass of the moving system and usually occurs near the middle of the frequency range. On the other hand, during reproduction, the record grooves drive the device at the needle point thereby developing much higher stresses in the needle so that the effect of the needle point stiffness is considerable. This stiffness is in shunt with the above constants as shown in Fig. 8 so that the resonant frequency in this case occurs much higher in the frequency range, usually near the upper limit. A difference of more importance with respect to the choice of the damping medium, however, is that the peak in the recorder curve is much more pronounced than the peak in the reproducer curve. This fact may be demonstrated mathematically by developing the ratios of the response of the device, both as a recorder and as a reproducer, at resonant frequency as compared with the response at some other frequency in the more nearly uniform portion of the characteristic and comparing these ratios.

This may be done most conveniently by treating the mechanical constants of the vibrating system as the analogs of the elements of a corresponding electrical network in accordance with the present usual method of studying mechanical systems. This method is discussed in such well known texts as Electrical Vibration Instruments by A. E. Kennely and in various patents such as 1,678,116 to Harrison, July 24, 1928. The ratio for the device operating as a recorder will be the reciprocal of the impedance ratio or

$$\frac{V_2}{V_1} = \frac{r_a + j\left(\omega_1 M_a - \frac{S_a}{\omega_1}\right)}{r_a}$$

where V_2 and V_1 are the needle point velocities at resonant frequency and lower frequency respectively,

r_a is the mechanical resistance or damping, M_a and S_a are the mass and stiffness of the moving system, and

ω_1 is 2π times the lower frequency at which the response is considered.

Considering now the reproducer network as shown in Fig. 8

$$\frac{V_{a1}}{V_o} = \frac{Z_{np1}}{Z_{np1} + Z_{a1}}$$

where V_o and Z_{np1} are the velocity and impedance of the needle point respectively, at frequency f_1 and V_{a1} and Z_{a1} are the armature velocity and impedance at frequency f_1 . Similarly

$$\frac{V_2}{V_o} = \frac{Z_{np2}}{Z_{np2} + Z_{a2}}$$

From this it follows that

$$\frac{V_2}{V_1} = \left\{ \frac{Z_{np2}}{Z_{np2} + Z_{a2}} \right\} \times \left\{ \frac{Z_{np1} + Z_{a1}}{Z_{np1}} \right\}$$

where V_2 and V_1 are the armature velocities at resonant frequency f_2 and frequency f_1 respectively, and subscripts associated with the impedances also refer to the particular frequency at which they are considered.

Expanding the above equation

$$\frac{V_2}{V_1} = \frac{-j\frac{S_n}{\omega_2}}{-j\frac{S_n}{\omega_2} + \left[r_a + j\left(\omega_2 M_a - \frac{S_a}{\omega_2}\right) \right]} \times \frac{-j\frac{S_n}{\omega_1} + \left[r_a + j\left(\omega_1 M_a - \frac{S_a}{\omega_1}\right) \right]}{-j\frac{S_n}{\omega_1}}$$

where S_n is the stiffness of the needle point, and ω_1 and ω_2 are 2π times f_1 and f_2 respectively.

The denominator of the first part of this equation may be written

$$r_a + j\left(\omega_2 M_a - \frac{S_a + S_n}{\omega_2}\right)$$

which at resonant frequency f_2 is simply r_a and the equation then becomes

$$\frac{V_2}{V_1} = \frac{-j\frac{S_n}{\omega_2} \left[r_a + j\left(\omega_1 M_a - \frac{S_a + S_n}{\omega_1}\right) \right]}{r_a \times \left(-j\frac{S_n}{\omega_1} \right)} \quad (1)$$

canceling out $-jS_n$ from the numerator and denominator and substituting

$$\frac{f_1}{f_2} \quad (2)$$

for

$$\frac{\omega_1}{\omega_2} \quad (3)$$

this becomes

$$\frac{r_a + j\left(\omega_1 M_a - \frac{S_a + S_n}{\omega_1}\right) \frac{f_1}{f_2}}{r_a} \quad (4)$$

Comparing this result with the recorder ratio above it is seen that two factors contribute to making the latter the larger ratio. It is evident that, due to the stiffness of the needle in the reproducer equation, the net reactive component is smaller and that the total impedance is further reduced by the ratio

$$\frac{f_1}{f_2} \quad (5)$$

since, as already pointed out, f_2 is near the upper end of the frequency range.

As a result of the very considerable difference in the above response ratios it requires much more damping to obtain a satisfactory recorder characteristic than is necessary for uniform response as a reproducer. However, the moving system of this invention has a large damping area as compared with many previous devices, due to the large surface of reed member, so that in general a damping medium of somewhat lower viscosity than that commonly used heretofore should be satisfactory.

A reproducer of the type described, when properly damped, will give substantially constant response over a wide range of frequencies. The outstanding advantage over previous devices, however, is that it operates at considerably higher efficiency without the sacrifice of quality. Only two embodiments of the invention have been shown and described but it is intended to limit the invention only by the following claims.

What is claimed is:

1. In a vibration translating device, a casing containing viscous matter, a magnetic structure having four working gaps within the casing, an armature and a diaphragm forming a closure for the casing and a pivot for the armature substantially equidistant from all the gaps.

2. In a vibration translating device, a casing containing viscous matter, a diaphragm forming a closure for the casing,

a magnetic circuit having four working gaps independent of the casing and the diaphragm and an armature pivoted on the device by means of the diaphragm and operating in the gaps of the circuit.

3. In a vibration translating device, a casing containing viscous matter, a diaphragm forming a closure for the casing, a stylus for flexing the diaphragm, a winding and a magnetic circuit including bifurcal polar extensions and a T-shaped armature in operative relation to the winding and pivoted on the reproducer by means of the diaphragm so as to form a plurality of gaps with the polar extensions.

4. In a vibration translating device, a magnet system including bifurcal pole-pieces in spaced relation, a T-shaped armature between the pole-pieces and means for simultaneously adjusting the pole-pieces with respect to the armature without disturbing the spaced relation.

5. In a vibration translating device, a magnet system including a plurality of bifurcal polar extensions in spaced relation, a diaphragm, an armature pivoted on the device by means of the diaphragm to form gaps with the polar extensions substantially equidistant from the pivot and means for adjusting the gaps without disturbing the spaced relation.

In witness whereof, I hereunto subscribe my name this 17th day of December, 1928.

WARREN C. JONES.