May 14, 1946. A. HAZELTINE 2,400,305

ELECTRO-MAGNETIC SOUND RECORDER AND REPRODUCER

Filed June 13, 1944

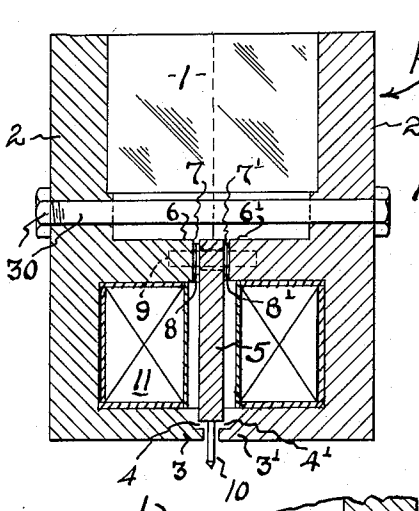


Fig. 1.

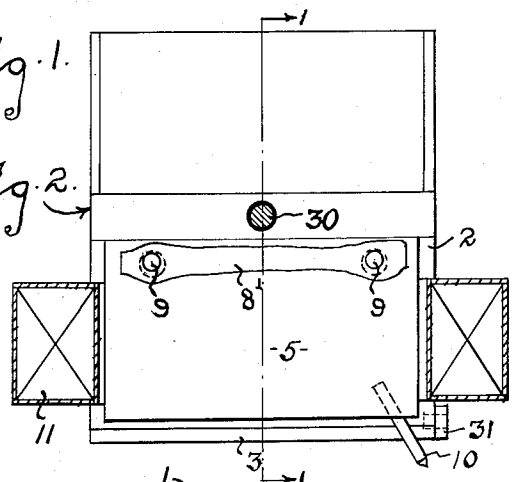


Fig. 2.

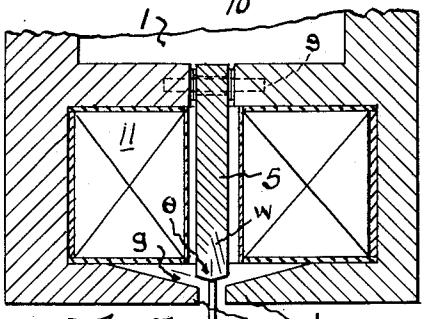


Fig. 3.

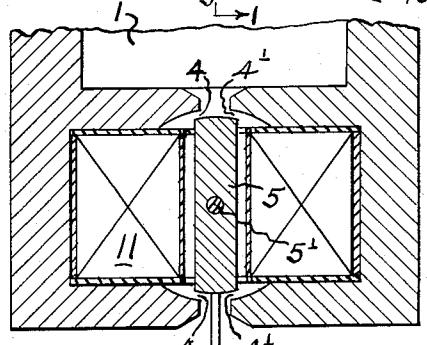


Fig. 4.

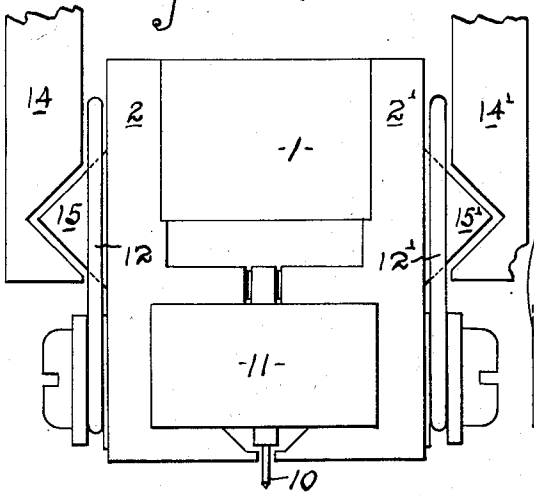


Fig. 5.

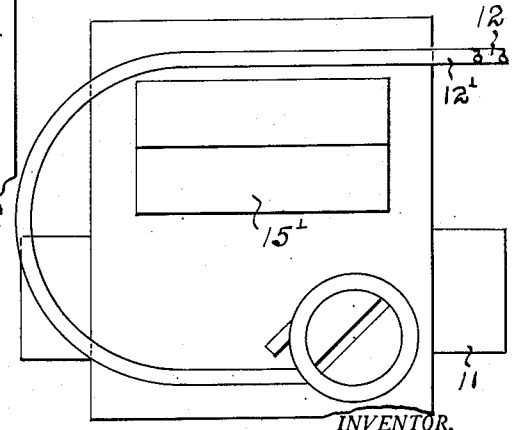


Fig. 6.

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2,400,305

ELECTROMAGNETIC SOUND RECORDER AND REPRODUCER

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Application June 13, 1944, Serial No. 540,037

2 Claims. (Cl. 179—100.41)

This invention relates to sound recording and reproducing devices employing a record blank formed on a plastic film or sheet in which the sound record is reproduced by a like arrangement operating in reverse.

One example of a machine of this type is disclosed in full detail in United States Patent No. 2,296,870 granted September 29, 1942 to B. A. Proctor et al. for Sound recording and reproduction, wherein the recording and reproducing head of this invention may be employed.

Heretofore it has been the practice to employ an electromagnet in devices of this type in which a flat face of the armature is directly attracted to the flat face of a field pole. Such an arrangement introduces negative stiffness into the armature system because the attractive force on the armature increases as it approaches the field pole. This negative stiffness is directly related to the efficiency of conversion of electrical power to mechanical power, or the reverse, so that a high efficiency requires a relatively high negative stiffness. In order to balance out this negative stiffness the armature has to be controlled by a correspondingly stiff spring, to restore the armature to its neutral position. The presence of this relatively high stiffness is not particularly objectionable in a recording unit, but is a serious drawback in a reproducing unit, where the armature is moved by the force acting on the stylus by the walls of the record groove, and where high resultant stiffness would break down these walls and cause a new groove to be cut. It has therefore been the practice to design the reproducer with low stiffness and with correspondingly low efficiency. To obtain higher recording efficiency it has then been the practice to use a separate electromagnet designed for recording alone.

The main object of this invention is to provide a highly efficient electromagnet system for such devices having little or no negative stiffness, or preferably a low positive stiffness, so that little or no spring control is required, making it suitable for reproducing as well as for recording, and thus making it feasible to employ the same electromagnet system and stylus for both recording and reproducing, with consequent simplification and reduction in cost.

Another object of this invention is to provide a magnet system which is simple to construct and assemble, and which does not readily get out of order.

A further object of this invention is to provide a spring mounting for the recording and reproducing unit which on reproducing gives the appropriate normal pressure on the stylus and the appropriate lateral freedom, and which is readily clamped in position for recording, and in another position for removing the stylus from the record.

Other and more detailed objects of the invention will be apparent from the following disclosure of several embodiments thereof, as illustrated in the drawing.

This invention resides substantially in the combination, construction, arrangement and relative location of parts, as well as in the steps and series of steps of the method as defined in the claims.

In the accompanying drawing,

Figure 1 is a vertical, central, cross-sectional view on the line 1—1 of Figure 2;

Figure 2 is a central elevational view of Figure 1 along the juncture line of the magnetic structure showing the magnetizing winding in section;

Figure 3 is a view similar to Figure 1 of a modification of the device with some parts broken away;

Figure 4 is a view similar to that of Figure 1 of a still further modified form of the device with some parts broken away;

Figure 5 is a rear elevational view of the embodiment of Figure 1, showing a spring mounting in accordance with this invention for the unit; and

Figure 6 is a side elevational view of the structure of Figure 5.

As illustrated in Figures 1 and 2, the first embodiment of the invention comprises a pair of soft-iron pole pieces 2 and 2' of similar and complementary configuration having mounted therebetween a powerful permanent magnet 1. The parts are clamped together by means of a non-magnetic nut and bolt 30 which passes through the pole pieces as shown in Figure 1. A spacer bar 31, see Figure 2, extends across the side edges of the pole pieces to hold the pole tips 3 and 3' properly spaced when the bolt 30 is tight. If desired, another spacer may be used at the other side edge. These spacers are of non-magnetic material and are mounted in place by means of pins as shown, screws or the like. The pole pieces have two facing pole tips 3 and 3' forming the air gaps 4 and 4' with the armature 5. The pole pieces also have a second pair of pole tips 6 and 6' separated from the upper end of the armature 5 by means of the gaps 7 and 7' in which are placed highly elastic spacers 8 and 8' of soft rubber or similar material to hold the armature away from the pole tips 6 and 6'.

As will be seen from Figure 2 the pole pieces 2 and 2' have a width a little greater than the

width of the armature 5 so that the pole tips 3 and 3' and 6 and 6' have a length at least equal to the width of the armature 5. The armature is supported on a pair of non-magnetic pins 9 which extend between the pole tips 6 and 6' and pass loosely through holes in the armature which is thus free to rock on the pins.

The rocking motion of the armature changes the dimensions of the air gaps 4 and 4' which may be called the active gaps, without appreciably changing the dimensions of the gaps 7 and 7', which may be called inactive. The armature will be attracted downwardly towards the pole tips 3 and 3', and is held away from these pole tips by the pins 9. A suitable stylus 10 is mounted on the armature as indicated.

The voice coil 11 rests in a pocket between the sets of pole tips and surrounds the armature, as is clear from the drawing. The magnetic circuit for the voice coil is completed through the armature 5, the active air gaps 4 and 4', the pole pieces 2 and 2', and the inactive gaps 7 and 7'. The combination of the voice coil 11 and the magnetic parts constitutes an electromagnet in which on recording the armature is rocked to one side or the other in accordance with the direction of the current supplied to the voice coil, thus moving the stylus to form the record, and in which in reproducing the motion of the stylus in following the groove in the record blank produces corresponding movements of the armature to induce corresponding voltages in the voice coil.

The active air gaps 4 and 4' are arranged and constructed as disclosed so as to change predominantly in sectional area for magnetic flux rather than in length along the flux upon movement of the armature. In the form of the invention illustrated in Figure 1, the lengths of the active air gaps do, in fact, remain substantially constant. With this form of the structure the armature tends magnetically to center itself so as to give equal sectional areas for the two active gaps 4 and 4'. The meaning of this is that the electromagnet system has positive stiffness. Such magnetic stiffness, however, will exert forces small in comparison with the forces due to the current normally supplied to the voice coil, as required to form a record. The control stiffness due to the highly elastic spacers 8 and 8' is preferably still smaller, and in any case exerts forces small in comparison with the forces required to form a record.

In Figure 3 the active faces of the armature and the pole tips 3 and 3' are slightly beveled instead of being square, but the predominant change in the flux path is still one of change in sectional area. The beveling of the pole tips lowers the magnetic stiffness of the system, and if sufficient can make this negative. The formula for the magnetic stiffness S_m is

$$(1)\quad S_m=\tfrac{1}{2}M^2\left[\frac{(D_s\Lambda)^2}{\Lambda_t}-\tfrac{1}{2}D_s^2\Lambda\right] \text{ newtons per meter}$$

where

M ampere-turns is the magnetomotive force between the pole tips 3 and 3',

Λ henries is the permeance of one active gap,

Λ_t henries is the total permeance from one pole piece, as 2, to the armature 5, and

D_s and D_s^2 denote respectively the first and second derivatives with respect to the transverse linear displacement s meters of the end of the armature, taken at the central position of the armature.

The "newton" is the meter-kilogram-second unit of force and is equal to 100,000 dynes. Its definition is given in many recent text books of which may be cited: Smyth and Ufford, "Matter, Motion and Electricity," McGraw-Hill, 1939, p. 74; Slater, "Microwave Transmission," McGraw-Hill, 1942, p. 89.

With the notation as partially indicated on Figure 3, the approximate formulas for the derivatives are:

$$(2)\quad D_s\Lambda=\frac{\mu b}{g}\left(\frac{w}{g}\cos\theta+\sin\theta+\frac{2}{\theta}\cos\theta\right)$$

and

$$(3)\quad \tfrac{1}{2}D_s^2\Lambda=\frac{\mu b}{g^2}\left(\frac{w}{g}\cos\theta+\sin\theta+\frac{1}{\theta}\cos\theta\right)\cos\theta$$

Here

$\mu=10^{-6}$ 1.257 henry in a meter cube is the absolute permeability of air,

b meters is the axial breadth of the armature (as viewed in Figure 2, horizontally),

g meters is the length of the active gap, normal to the faces,

w meters is the width of the active gap and should not be less than g, and

θ radians is the angle of bevel.

In accordance with this invention, θ will be not much less than $\frac{1}{2}\pi$. So $\cos\theta$ is small and $\sin\theta$ is nearly 1. Formulas 2 and 3 then reduce roughly to

$$(4)\quad D_s\Lambda=\frac{\mu b}{g}$$

and

$$(5)\quad \tfrac{1}{2}D_s^2\Lambda=\frac{\mu b}{g^2}\cos\theta$$

So (1) reduces roughly to

$$(6)\quad S_m=\tfrac{1}{2}M^2\frac{\mu b}{g^2}\left[\frac{\mu b}{\Lambda_t}-\cos\theta\right]$$

Now

$$\frac{\Lambda_t}{\mu b}$$

will commonly lie between 10 and 20, causing S_m to be zero when $\cos\theta$ has a certain value between 0.1 and 0.05. For larger values of $\cos\theta$, the magnetic stiffness S_m will be negative, as in the ordinary form of air gap, where the face of the armature moves directly toward the pole face. For smaller values of Cos θ, S_m will be positive; and in the limiting case of Figure 1, where $\cos\theta=0$, Equation 6 reduces to

$$(7)\quad S_m=\tfrac{1}{2}M^2\frac{\mu b}{g^2}\frac{\mu b}{\Lambda_t}$$

Thus by suitable choice of θ, the designer may employ positive magnetic stiffness (acting largely in place of elastic control), or zero magnetic stiffness, or negative stiffness (to be overbalanced by elastic control). But in any case, if $\cos\theta$ is small, so that on motion of the armature the active air gap changes predominantly in sectional area rather than in length, in accordance with this invention, then the forces exerted by the magnetic stiffness can be kept small in comparison with the forces required to form the record.

In the structure of Figure 4 the armature 5 is pivoted at its center, as indicated at 5', forming active air gaps 4 and 4' at both ends. It will be seen that the faces of the pole tips adjacent the armature are circular in cross-section and con-

centric with the grooved end edges of the armature. In this arrangement the magnetic stiffness is made zero by the use of these cylindrical faces on the armature and pole tips, all having their axes at the axis of rotation of the armature. This form of the structure permits of a wide displacement of the armature and the use of active gaps at both ends gives greater working forces, but the necessity of accurately centering the armature to avoid friction due to magnetic side thrust on the armature pivots introduces a practical difficulty which however is not too serious.

In Figures 5 and 6 a supporting arrangement for a sound recording and reproducing head which is of particular utility with the structures herein disclosed is clearly illustrated. The magnetic system is shown suspended by two relatively flexible wire springs 12 and 12' whose ends are to be suitably attached to some adjacent part of the machine so that the unit is supported by these springs. These springs are arranged to give suitable lateral freedom on reproducing so that the stylus will find a groove in the record and at the same time provide a suitable downward pressure of the stylus on the record. On recording, the bars 14 and 14' form part of a yoke supported on the machine in any suitable manner, which move downwardly so as to engage the triangular projections 15, 15' attached to the sides of the pole pieces. This arrangement effectively clamps the unit so that lateral motion is prevented and increased pressure is exerted by the stylus on the record blank. The yoke, including the bars 14 and 14' may be rigidly or elastically supported, but in either case the unit is held much more tightly in recording than in reproducing because in reproducing the yoke is raised so that the unit is supported entirely by the spring arms 12 and 12'. When supported by these springs the unit has relative freedom and moves laterally and vertically, restrained only by the springs 12 and 12' except for excess movements, in which case the arms 14 and 14' limit such movement.

If desired the separation between the projections 15 and 15' and the notches in the bars 14 and 14' may be made unequal so that on releasing the yoke, including the bars 14 and 14' to play back a record, the stylus will move back over one or more grooves thus reproducing the latter part of the record just made without requiring a separate back spacing mechanism for this purpose. In other words, if the lower face of the notch in the bar 14' is closer to the associated face of the projection 15', then at the other side of the device when the yoke is raised the unit will be given a side thrust to the left, Figure 5, which may be in a back spacing direction with respect to the record.

When the stylus is to be completely disengaged, as when changing recording blanks, the yoke 14—14' can be moved a sufficient distance vertically to raise the unit away from the record the necessary distance.

From the above description it will be apparent to those skilled in the art that the subject matter of this invention is capable of detailed variation without departure from the novel subject matter herein disclosed. I do not, therefore, desire to be strictly limited to the disclosure as given herein but only as required by the appended claims.

What is claimed is:

1. An electromagnetic recording and reproducing unit comprising a permanent magnet structure, a voice coil mounted thereon, an armature lying within said coil, a relatively flexible spring mounting for said unit, and means for clamping said unit in recording position, said clamping means including a yoke engaging lateral projections on the side of the unit.

2. In the combination of claim 1, said yoke having notches of triangular cross-section and said projections being of complementary shape.

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