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ELECTROMAGNETIC SOUND REPRODUCER

Filed Sept. 28, 1925

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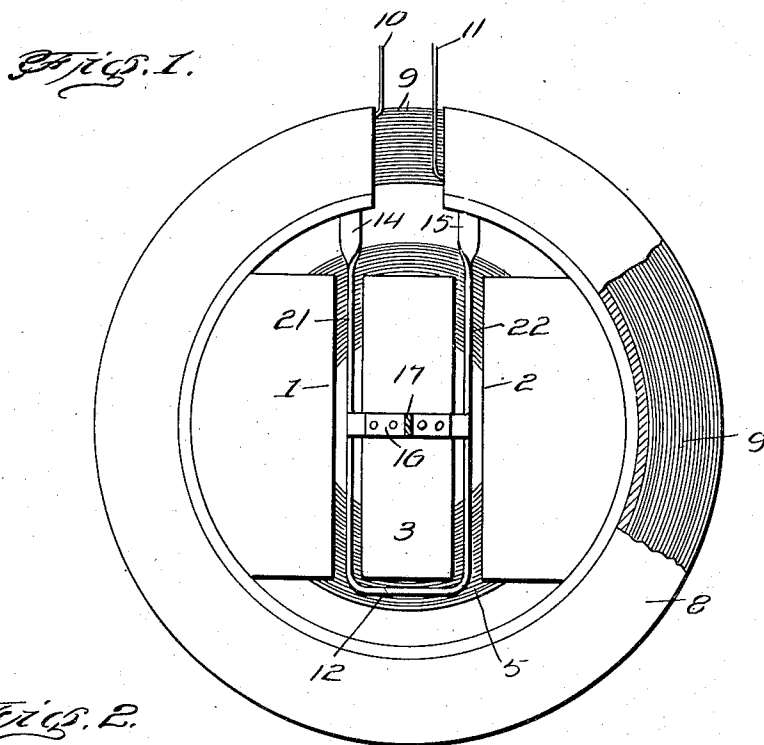


Fig. 2.

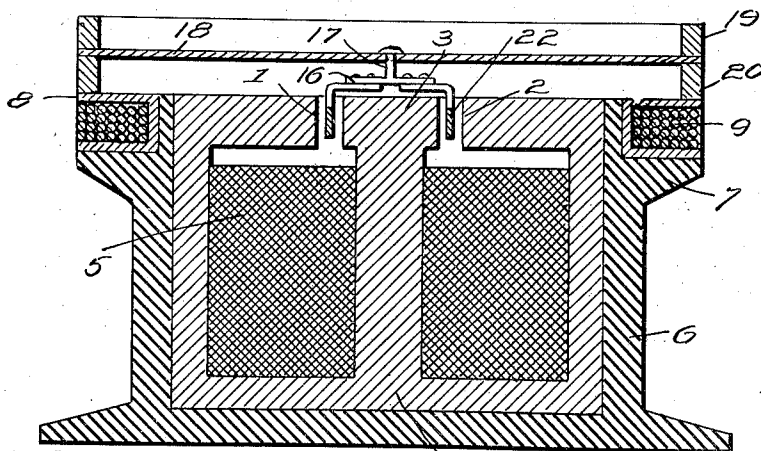
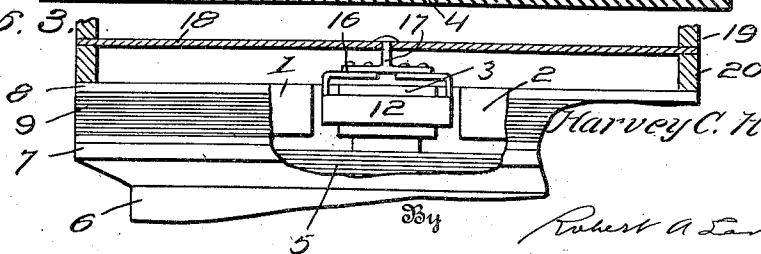


Fig. 3.



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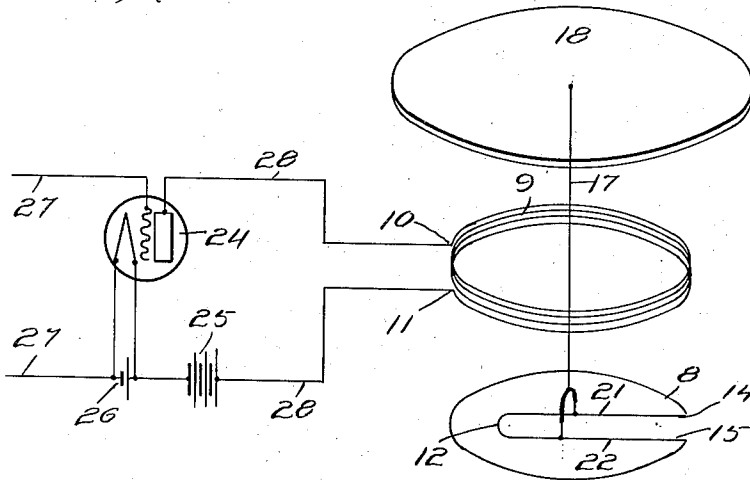
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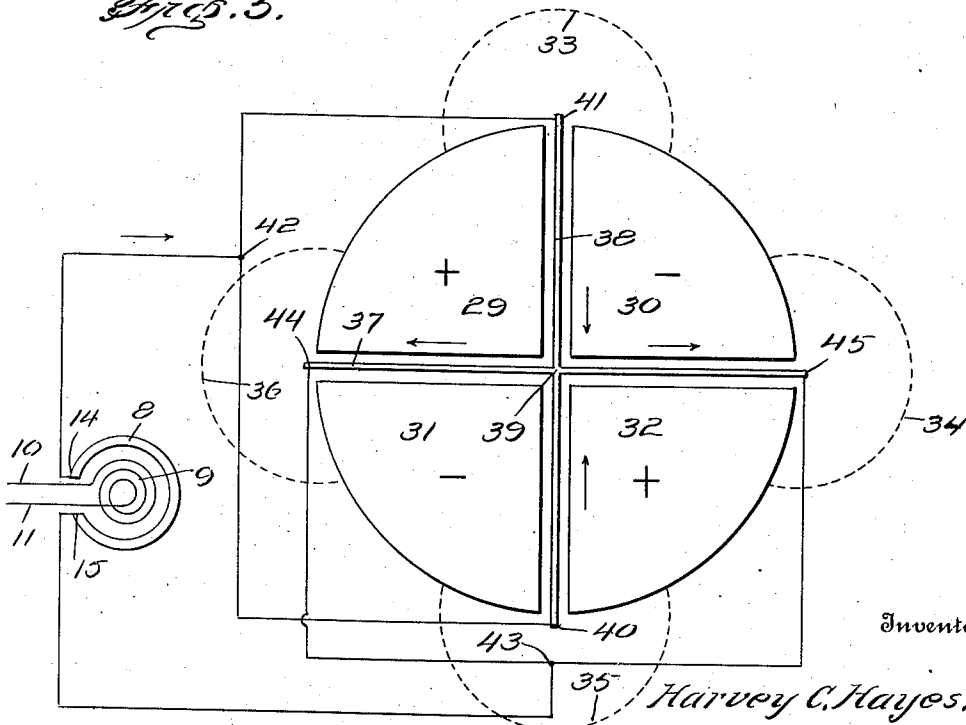
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UNITED STATES PATENT OFFICE.

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ELECTROMAGNETIC SOUND REPRODUCER.

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My invention relates broadly to a method and apparatus for transforming electrical energy into sound and more particularly to loud speakers for radio broadcast reproduction.

The art of telephony as also that of radio broadcasting demands for its perfection some mechanism for transforming sound into electrical energy and also a mechanism for transforming the electrical energy, usually amplified, back into sound. In order that the original sound may be faithfully reproduced it is necessary that both energy transformations should be accomplished without distortion. My invention relates to the second transformation, that of changing the electrical energy back into sound energy.

The transformation of electrical energy into sound energy in general requires some mechanism whereby a reciprocating motion can be imparted to a diaphragm through the action of a fluctuating or alternating electrical current. This motion may be imparted to the diaphragm directly, as in the case of the single pole or bi-polar telephone, or it may be imparted through a member linking the driven armature with the diaphragm for obtaining a multiplication of effort through a system of levers.

Devices wherein the diaphragm is driven through a connecting link may be designed so as to avoid the serious weakness possessed by those of the single or bi-polar types wherein the diaphragm is only acted upon by a unidirectional force and depends upon the restoring forces of the distorted diaphragm itself to move it away from the magnets by providing a comparatively thick and massive diaphragm to bring into play sufficient restoring forces to cause it to reproduce all frequencies within the audible range. However, such a diaphragm is not only difficult to force into vibration but is strongly resonant at its natural and harmonic frequencies. Also, the damping of such diaphragms is difficult if not practically impossible. Such sound reproducing devices can be made to generate certain definite frequencies very efficiently but are unsuited for reproducing efficiently and without distortion over a wide band of frequencies.

Devices wherein the diaphragm is driven through a link can be designed so that it is subjected to both push and pull forces and

this permits of using light diaphragms that can more readily be forced into vibration. Reproducers of the push-pull types are of two general types, viz: Those wherein the armature is moved through the interaction of magnetic poles and those wherein the armature is moved through the direct action of the current traversing a coil suspended in a magnetic field. Those types which operate through the interaction of magnetic poles cannot give perfect reproduction because of two inherent weaknesses. First, the forces to which the armature is subjected are not proportional to the driving current because the permeability of the iron is not a constant and the reluctance of the magnetic circuit is for the most part due to the air gaps which vary as the armature moves. And second, the motion of the armature is not highly damped so that the armature which must have comparative large restoring forces to keep it centered between the permanent magnetic poles, will be highly resonant at some definite frequency or frequencies. Reproducers of this type can be made highly sensitive because the moving parts can be made comparatively light but their sound output is distorted from the original because they do not subject the diaphragm to forces proportional to the current and because of their resonance and insufficient damping.

The moving coil type of reproducer has certain definite advantages. First, the armature is subjected to no forces when it is not traversed by a current and thus the restoring forces can be made much smaller than in the case of the magnetic pole types. In fact, the restoring forces can be made so small that the natural resonant period is below the working range of frequencies. Second, the position of the armature can be varied somewhat up or down its path of travel without affecting its sensitivity and without causing it to chatter against the permanent pole pieces. Third, the forces tending to move the armature are at all times proportional to the current traversing its coil. Fourth, the armature is well damped since its motion through the magnetic field induces current in its coil in a sense opposing the motion. These favorable features are largely offset in practice by certain unfavorable features. First, the armature coil and its mounting is comparatively massive and cannot be readily forced

- into vibration. Second, in order to keep down as much as possible the armature mass, the impedance of the coil is made comparatively low so that an iron core audio transformer is interposed between the plate circuit of the last amplifier tube and the circuit of the reproducer. This results in distorting the sound, and distortion of the current by the iron of the transformer core.
- 10 Third, in order to accommodate the armature coil the air gap must be made so wide that a direct current must be used to maintain the magnetic field at sufficient strength to give good sensitivity.
- 15 This invention will be more clearly understood from the following specification, by reference to the accompanying drawings, in which:

- Figure 1 is a plan view showing the arrangement of the moving parts of the electromagnetic sound reproducer within the magnetic field system; Fig. 2 is a cross-sectional view through the sound reproducer; Fig. 3 is a partial side elevation of the electromagnetic sound reproducer partially broken away, partially shown in cross-section; Fig. 4 is a schematic view showing the connection of the electromagnetic sound reproducer in the output circuit of an electron tube system; and Fig. 5 shows schematically a modified construction of an electromagnetic sound reproducer embodying the principles of my invention.

- My invention employs the favorable features of the moving coil type of sound reproducer without including its weakness. It differs from the moving type in that the armature depends upon eddy currents for its operation and in that no iron is included in the electrical circuits. The electrical system can be understood from Fig. 1 wherein the permanent magnetic system is shown as having pole pieces 1 and 2 with an intermediate pole piece 3 extending from the permanent magnet system at 4. A field magnet 5 is employed for exciting the permanent magnet. The magnet system is disposed within a suitable housing 6 having an annular supporting flange 7 therearound.
- 50 Numeral 9 shows the direct current coil designed to have an impedance equal to the amplifier tube and which is connected in series in the plate circuit of tube 24 through terminals 10 and 11. This coil is wound in a copper or other highly conducting ring 8, the cross-sectional form of which is shown in Fig. 2. Due to the close coupling between coil 9 and ring 8 any change of current in 9 generates a corresponding change of eddy current in ring 8 of nearly equal ampere turns. These eddy currents are prevented from circling the ring directly, by a slot through which the coil 9 and terminals 10 and 11 shown in Fig. 2, and are forced to
- 65 traverse the shunt 12, 14 and 15. The two

horizontal portions 21 and 22 of this shunt circuit pass through a magnetic air gap maintained by permanent poles 1, 2 and 3, of which 1 and 2 are alike and 3 is of opposite polarity. With this arrangement of poles the sense of the magnetic flux through the two gaps is such as to force both 21 and 22 of the shunt circuit in the same direction when it is traversed by the eddy currents and sense of the direction of this force is dependent upon the sense of the eddy currents. Thus the shunt circuit which is flexible at 14 and 15 exerts push and pull forces on diaphragm 18 through the action of the eddy currents which are always directly proportional to the current through coil 9. The diaphragm is linked to the armature through members 16 and 17 of which 16 is made of insulating material, preventing a short circuit across the shunt circuit 21—22. It will be seen that the moving parts are extremely light, that their form is such that the air gap can be made unusually narrow; and that because of the low resistance of the armature circuit large damping currents will be generated when the shunt vibrates. Experiments on several different shaped shunt systems show that the armature can be made aperiodic or dead-beat.

Fig. 2 shows the magnetic gap maintained by a local direct current and exciting field, but because of the narrowness of the air gap it has been found that the field can be maintained by means of hard magnets.

Fig. 3 shows a sectional view of Fig. 2 wherein the sense of coil 9 can be understood more clearly.

Fig. 4 gives a schematic view of the electrical circuits wherein coil 9 forms part of the plate circuit and wherein the eddy current circuit bearing numerals 14, 21, 12, 22 and 15 is shown directly beneath, while the diaphragm is shown above with its center 18 joined to the armature by the link 17. The tube 24 is represented as having input leads 27, filament heating battery 26 and high potential plate battery 25.

Fig. 5 shows schematically a modified form of my invention, wherein the eddy currents which are generated in the ring 8 are passed through an armature shaped like a cross. The current enters at opposite ends of the cross, say 40 and 41, and leaves by the other pair of ends, say 44 and 45. The center of the armature to which the link attaches is represented by numeral 39. The four pole pieces are represented by numerals 29, 30, 31 and 32 and the polarity is such that diagonally opposite poles are alike and adjacent poles are unlike. With this disposition of the poles it will be seen that all branches of the armature are forced in the same direction at any instant. The advantages of this shape of armature is

that it can be centered in a very narrow gap carrying but slight clearance with the assurance that it will stay in adjustment and not strike the pole pieces if it is jarred or otherwise misused.

A permanent magnetic flux is set up between the pole pieces by reason of the magnetic circuits interconnecting the pole pieces. In Fig. 5 the magnetic circuit between pole pieces 29 and 30 is represented at 33. The magnetic circuit between pole pieces 30 and 32 is represented at 34. The magnetic circuit between pole pieces 31 and 32 is represented at 35. The magnetic circuit between pole pieces 29 and 31 is represented at 36. A suitable electromagnetic field may be provided to maintain the magnetic system at the desired degree of magnetic saturation.

The embodiments of my invention shown herein have proven very practical in construction and successful in operation and have been found to efficiently reproduce a variable range of tone frequencies.

While I have described my invention in certain particular embodiments I desire that it be understood that modifications may be made and that no limitations upon the invention are intended other than are imposed by the scope of the appended claims.

What I claim and desire to secure by Letters Patent of the United States is:

1. An electromagnetic sound reproducer comprising in combination, a permanent field magnet system, magnetic gaps interposed in said field magnet system across which a permanent magnetic flux is established, a conductive broken ring like member having a portion of the conductive section thereof disposed between said magnetic gaps, and means for inducing variable currents in said ring member, whereby vibrations are imparted to that portion of said ring member which is situated between said magnetic gaps.

2. An electromagnetic sound reproducer comprising in combination a permanent magnetic field, a conductive broken ringlike member having a portion of the conductive section thereof interposed in said magnetic field, and means for inducing eddy currents in said ring member, whereby the portion of said ring member in said magnetic field is vibrated in accordance with the eddy currents induced in said ring member for the reproduction of sound.

3. An electromagnetic sound reproducer comprising in combination means for establishing a permanent magnetic field, a conductive broken ringlike member having a portion of the conductive section thereof situated in said magnetic field, a coil concentrically positioned with respect to said conductive ring and arranged to induce eddy currents in said ring in accordance with

variations in sound, whereby mechanical vibrations are imparted to said portion of said ring member situated in said magnetic field for the reproduction of sound.

4. An electromagnetic sound reproducer comprising in combination a permanent magnetic field system, magnetic gaps in said field system, a trough shaped ring member open at one side thereof and having an inwardly extending conductive ring disposed between said magnetic gaps and bridging the adjacent ends of said trough shaped ring, a winding carried in said trough shaped ring and arranged to induce eddy currents in said trough shaped ring variable in accordance with variations in the current in said winding whereby mechanical vibrations are imparted to said inwardly extending conductive ring for the reproduction of sound vibrations.

5. An electromagnetic sound reproducer comprising in combination a permanent magnetic field system, magnetic gaps in said permanent magnetic field system, an electrically conductive ring member having its ends turned inwardly at one side thereof and electrically connected together with the inwardly turned portion thereof disposed in said magnetic gaps, a winding for inducing variable eddy currents in said conductive ring member in accordance with sound vibrations whereby mechanical vibrations may be imparted to said inwardly turned portion of said conductive ring member for the reproduction of sound.

6. An electromagnetic sound reproducer comprising in combination a permanent magnetic field system, magnetic gaps interposed in said permanent magnetic field system, a conductive ring surrounding said magnetic field system with its ends separated by an air gap at one side thereof an inwardly extending conductor of reduced cross-section connected with the adjacent ends of said conductive ring, said conductor being disposed in said magnetic gaps, and a winding arranged in coupled relationship with said conductive ring for producing eddy currents in said conductive ring and in said inwardly extending conductor for imparting mechanical vibrations to said inwardly extending conductor for the reproduction of sound.

7. An electromagnetic sound reproducer comprising in combination a permanent magnetic field system, magnetic gaps interposed in said permanent magnetic field system, a conductor disposed in said magnetic gaps and connected at opposite ends with a single turn of conductor, a winding coupled with said single turn of conductor and arranged to produce variable eddy currents in said conductors for imparting mechanical vibrations to said first mentioned conductor for the reproduction of sound.

8. An electromagnetic sound reproducer comprising in combination a permanent magnetic field system, magnetic gaps provided therein, a conductor of relatively large cross-section having its opposite ends adjacent each other and bridged by another conductor of relatively smaller cross-section with the ends thereof resiliently connected with the ends of the first mentioned conductor, said last mentioned conductor being disposed between said magnetic gaps, and means for inducing eddy currents in said conductors for causing mechanical vibrations of said last mentioned conductor for the reproduction of sound.

9. An electromagnetic sound reproducer comprising in combination a permanent magnetic field system, a plurality of magnetic gaps in said permanent magnetic field system, a conductor disposed between said magnetic gaps and resiliently mounted at the ends thereof for movement in said gaps, the metallic member connecting the ends of said conductor, a winding coupled with said metallic member for inducing eddy currents therein for establishing a circulating current in said conductor, whereby mechanical vibrations may be imparted to said conductor for the reproduction of sound.

10. An electromagnetic sound reproducer comprising in combination, a winding for the passage of currents variable in accordance with sound vibrations, a conductive ring member of relatively large cross-section inductively coupled with said winding and having the opposite ends thereof bridged by an inwardly extending conductor of relatively small cross-section, a sound reproducing

diaphragm, a connection between said diaphragm and a point along said inwardly extending conductor, whereby a relatively large variable current at small electromotive force is generated in said inwardly extending conductor for setting up mechanical vibrations for the reproduction of sound.

11. An electromagnetic sound reproducer comprising in combination a winding for the passage of currents variable in accordance with sound vibrations, a conductor substantially conforming with the shape of said winding inductively coupled with said winding and having a portion thereof resiliently connected with another portion thereof, a sound reproducing diaphragm and a connection between the resiliently connected portion and said sound reproducing diaphragm, whereby eddy currents may be induced in said conductor for mechanically actuating the resilient portion thereof for imparting sound vibrations to said diaphragm.

12. An electromagnetic sound reproducer comprising in combination a winding for the passage of currents variable in accordance with sound vibrations a conductor inductively coupled with said winding and having its ends closed by a shunt circuit which is resiliently connected with said conductor, a sound reproducing diaphragm linked with said shunt circuit, whereby said winding induces a relatively large current at relatively small electromotive force in said shunt circuit for imparting vibrations to said diaphragm for the reproduction of sound.

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