May 13, 1930. E. W. KELLOGG 1,758,797

LOUD SPEAKER

Filed Aug. 2, 1926

Fig. 1.

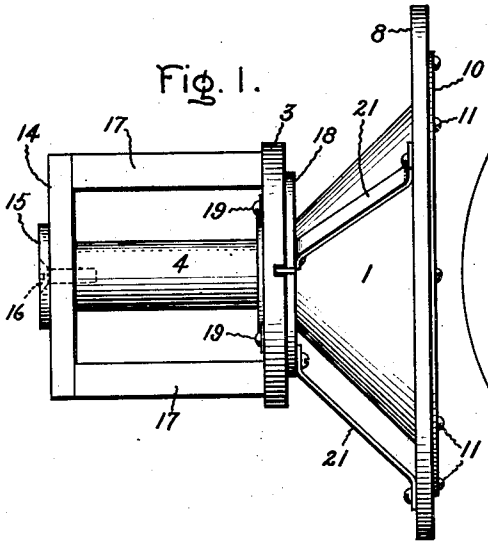


Fig. 2.

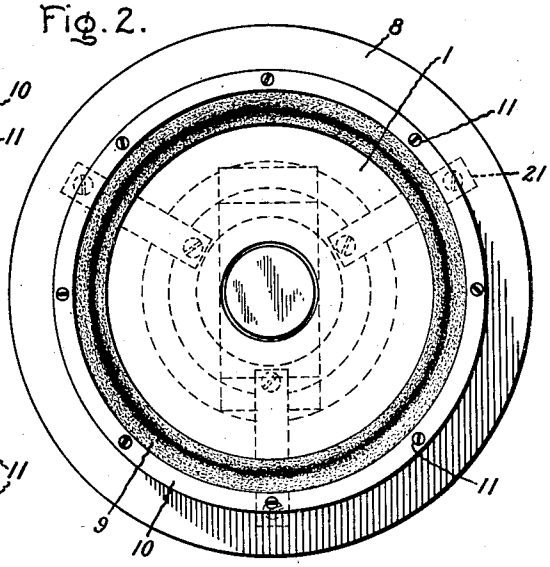


Fig. 3.

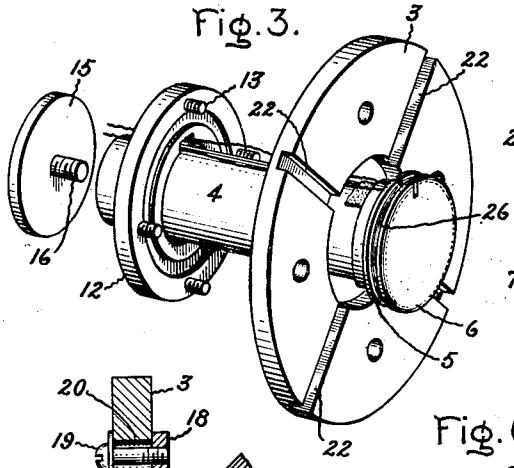


Fig. 4.

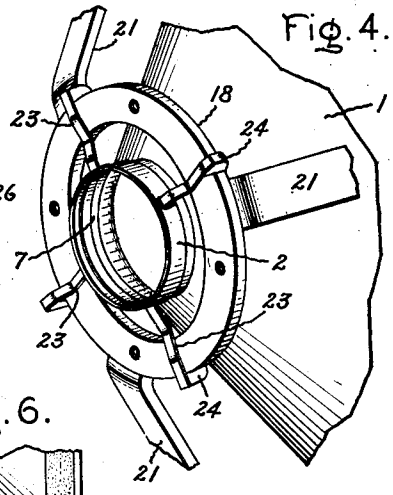


Fig. 5.

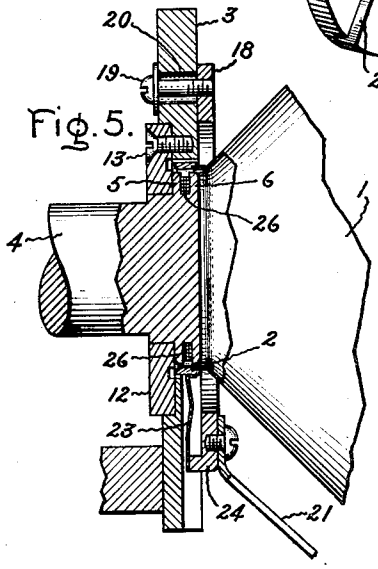


Fig. 6.

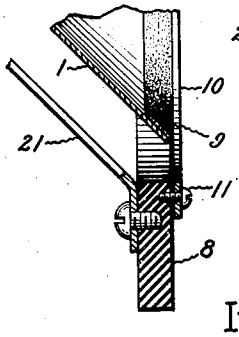
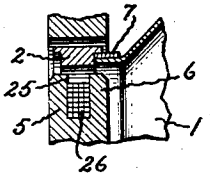


Fig. 7.



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UNITED STATES PATENT OFFICE

EDWARD W. KELLOGG, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK

LOUD-SPEAKER

Application filed August 2, 1926. Serial No. 126,465.

My present invention relates to apparatus for reproducing sound by means of electric currents, and more particularly to devices now commonly known as loud speakers.

The object of the present invention is to provide a device of the type described, whereby the reproduction of sound may be made with accuracy and fidelity.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, will best be understood from reference to the following specification taken in connection with the accompanying drawing in which Fig. 1 is a plan view of a loud speaker which embodies the features of my invention; Fig. 2 is a front elevation showing the diaphragm and mounting therefor; Fig. 3 is an exploded perspective view of the central core of the magnet and parts associated therewith; Fig. 4 is a rear perspective view of the diaphragm and the spring supporting means therefor; Fig. 5 is a view partly in section and partly in elevation of the magnetic system for actuating the diaphragm; and Figs. 6 and 7 are detail views illustrative of the means for supporting the outer end of the diaphragm and the armature respectively.

In my prior application, Serial No. 702,455, filed March 27, 1924, I have disclosed a sound reproduction device having a low natural period of vibration in which a coil, movable in a magnetic field, is employed to effect the vibration of the diaphragm. While attempts have been made to secure the results achieved by the apparatus described in the prior application by the use of devices having permanent magnets and an iron armature adapted to vibrate between the poles of the magnets, such attempts have encountered difficulties owing to the instability of the iron armature in the mid position. For example, if the iron armature in such a system is displaced slightly, the magnetic pull tends to increase the displacement, and this magnetic force, instead of increasing in linear relation with the deflection, rises very rapidly as the point of actual contact with the pole pieces is approached. Were the relation between magnetic force and displacement of the armature a linear relation, it would be possible to balance the magnetic force against the stiffness of a spring and in this manner obtain stability, together with small net stiffness. But since the relation between pull and displacement is not linear, the spring must have large excess stiffness in order to hold the armature in equilibrium.

In my copending application, Serial No. 152,475, filed Dec. 3, 1926, I have described different ways of approaching a balance between a spring action and a magnetic pull. While it is possible, by the use of such means, to obtain a good balance and to secure a sound reproducing device which has the low natural frequency of vibration essential for accurate sound reproduction, it is preferable to employ a magnetic system in which this natural instability is not present. Such a system is found in the arrangement presently to be described, in which an iron armature moves parallel to the pole faces and in such manner that the air gaps between the stationary pole piece and movable armature are constant in length but variable in area.

Referring to the drawing, I have indicated in Figs. 1 to 7 a construction whereby my invention may be carried into effect. The essential features in the device shown are a diaphragm 1, adapted to vibrate as a whole, and a movable annular iron armature 2, mounted on the diaphragm 1, and suspended in a pair of air gaps formed by two concentric magnetic members comprising an annular pole piece 3 and a core 4, the latter having at one end thereof a pair of coaxial pole pieces 5 and 6. Armature 2 is secured to a ring 7 which in turn is attached to diaphragm 1. A rigid annular member 8 of hard rubber, or other suitable material, is secured to the pole piece 3 in a manner to be presently described. A supporting ring 9 of flexible material, such as sheet rubber, is secured to the outer circumference of the diaphragm and is clamped to the ring 8 by a metallic ring 10 and a plurality of screws 11.

Core 4 is secured centrally in the pole piece 3 by means of a recessed copper centering ring 12. Ring 12 fits snugly around core 4

against the enlarged portion thereof which comprises pole pieces 5 and 6, and is secured in a circular recess in pole piece 3 by means of screws 13. A yoke 14 bears against the opposite end of core 4 and is provided with a screw threaded opening therein. A cap 15 bears against yoke 14. By means of a screw 16 extending through cap 15 and yoke 14 and engaging core 4, the latter may be placed under tension thereby drawing the enlarged portion of core 4 against the copper ring 12 and at the same time clamping magnets 17 between yoke 14 and pole piece 3.

An annular adjustable member 18 is secured to pole piece 3 by means of a series of screws 19 fitting in enlarged openings 20 in the pole piece 3, and is provided with a plurality of flat metal braces 21 which are secured to the ring 8 and serve to hold it rigidly in position. Pole piece 3 is provided with a plurality of radially extending grooves 22 spaced 90° apart and adapted to accommodate flat springs 23 which are secured at one end to flanges 24 on the annular member 18, and at the other end to the armature 2. The recess or slot 25 between pole pieces 5 and 6 is provided with a winding 26 adapted to be supplied with current for actuating the diaphragm 1.

The movable armature 2 overlaps each of the pole pieces 5 and 6, providing in this manner a pair of long narrow areas of overlap or working edges which are desirable in order to obtain a proper degree of sensitivity. To obtain the best results it is advisable that the total length of this working edge should exceed 10 cm. I have found that if the useful flux alone is instrumental in causing inductance of the alternating current winding 26, the power output per A. C. volt ampere input is proportional to the total length of the working edge. This neglects the effect of the mass of the moving iron which, however, in the present case is considerably less than the mass of the diaphragm 1 to which it is attached. As a further requisite for sensitivity the overlap or air gap width should be small. It should, however, exceed by a substantial margin the maximum vibration displacement of armature 2 and should also slightly exceed the air gap length, that is, the clearance between a pole piece 5 or 6 and armature 2. Any increase in overlap beyond the limits indicated adds nothing to the force per ampere turn of winding 26 but does increase the inductance of the latter winding.

The clearance between armature 2 and pole pieces 5 and 6 also enters into the question of sensitivity. If the clearance is increased but the field magnetizing force increased at the same time so as to give the same mean flux density, the force per ampere turn remains the same while the inductance of the winding is decreased. It is, therefore, not desirable to work with extremely small clearance but to use as large a clearance as is compatible with full magnetic strength and a moderate amount of magnetic material. A clearance of .015 inches and an overlap of .020 inches are indicative of dimensions which may be employed to obtain satisfactory results.

The air gaps on the two sides of the armature are in series making a total gap of .030 inches. With cobalt steel magnets about five inches long a good magnetic density (about 10,000 gausses) may be obtained across the gaps and owing to the small overlap the total flux is not excessive and a large cross section of the permanent magnets is, therefore, not required.

The armature 2 is strongly held and centered between the pole pieces 3 and 4 by springs 23 so that the armature cannot pull over to one side. This arrangement is readily compatible with great flexibility in the direction of useful motion. In the present instance the springs 23 are in the plane of the ring armature 2. A slight bending of the springs permits motion in a useful direction but the spring material would actually have to be stretched to permit any lateral motion. A slight bow is made in each of the springs 23 as indicated in Figs. 4 and 5. This considerably increases the permissible amplitude of vibration without impairing the ability of the springs to hold the iron ring 2 in a central position.

The flexible supporting member 9, which is attached to the outer end of the diaphragm, and springs 23 are disposed in planes substantially perpendicular to the direction of motion of the diaphragm 1 and cooperate to prevent any lateral movement of the diaphragm while at the same time permitting motion in a longitudinal direction.

With a device of the type described, the quality of reproduction obtained approaches that obtained with the moving coil drive described in my prior application, Serial No. 702,455, filed March 27, 1924. Although the present device is slightly less responsive to the high frequencies, I obtain a flexibility sufficient to bring the fundamental natural frequency or resonance to a frequency which is less than 150 cycles per second when using a six inch diameter cone of .007" paper, and this resonance frequency can readily be made as low as 100 to 125 cycles.

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

1. In an apparatus for reproducing sound, a diaphragm adapted to vibrate as a whole, an annular armature of magnetic material mounted thereon, a magnetic member cooperating with the armature, a winding mounted in a groove on said member adapted to actuate said armature and diaphragm, the air gaps between said member and armature being constant in length but variable in area.

2. In an apparatus for reproducing sound,

a diaphragm adapted to vibrate as a whole, an armature of magnetic material mounted thereon, a plurality of pole pieces cooperating with said armature, a winding associated with said pole pieces and adapted to actuate the diaphragm, said armature overlapping each of said pole pieces by an amount greater than the maximum vibratory displacement of said diaphragm.

3. In an apparatus for reproducing sound, a diaphragm adapted to vibrate as a whole, an armature of magnetic material mounted thereon, a plurality of pole pieces cooperating with said armature, a winding associated with said pole pieces and adapted to actuate the diaphragm, said armature overlapping each of said pole pieces by an amount greater than the distance between a pole piece and said armature.

4. In an apparatus for reproducing sound, a diaphragm, an annular armature of magnetic material mounted thereon, a core of magnetic material cooperating with said diaphragm, said core having an annular recess at one end thereof, a winding in said recess, said armature overlapping each side of said recess by an amount greater than the maximum vibratory displacement of said diaphragm.

5. In an apparatus for reproducing sound, a diaphragm, an annular armature of magnetic material mounted thereon, a core of magnetic material cooperating with said diaphragm, said core having an annular recess at one end thereof, a winding in said recess, said armature overlapping each side of said recess by an amount which is greater than the distance between said core and armature.

6. In an apparatus for reproducing sound, a diaphragm and an armature of magnetic material mounted thereon, a magnetic member cooperating with said armature, a winding on said member adapted to actuate the diaphragm, said armature overlapping said magnetic member by an amount not greater than twice the clearance between said member and armature.

7. In an apparatus for reproducing sound, a magnet, a stationary annular winding mounted adjacent one end thereof, a diaphragm, an annular armature of magnetic material mounted on said diaphragm and adapted to be actuted by said winding, said armature being movable in a coaxial direction with respect to said winding.

8. In an apparatus for reproducing sound, a diaphragm, and means for actuating said diaphragm, said means comprising magnetic members having oppositely disposed pole faces cooperating to provide an air gap, and an armature of magnetic material attached to said diaphragm and movable in said air gap in a direction substantially parallel to said cooperating pole faces, the natural period of vibration of this diaphragm being less than 150 cycles per second.

9. In an apparatus for reproducing sound, a diaphragm, an armature of magnetic material mounted on said diaphragm, means for actuating said armature, said means including a magnet provided with concentric pole faces, said armature being movable between and substantially parallel to said pole faces.

10. In an apparatus for reproducing sound, a cone shaped diaphragm, means for supporting the outer end of said diaphragm, an armature of magnetic material mounted on the inner end of said diaphragm, means for actuating said diaphragm, said means comprising a magnet provided with a pole piece having an annular pole face, and a magnetic core having a pair of coaxial pole pieces at one end thereof, said coaxial pole pieces being concentric with the annular pole face, a winding mounted between said coaxial pole pieces and means whereby current may be applied to said winding to actuate said armature.

11. In an apparatus for reproducing sound, a diaphragm, means for actuating said diaphragm, said means comprising a magnet, said magnet including a core having an annular recess providing a pair of pole pieces at one end thereof, a winding in said recess, an armature of magnetic material mounted on said diaphragm and movable in a direction parallel to the faces of said pole pieces, and means whereby current may be supplied to the winding to thereby actuate the armature.

12. In an apparatus for reproducing sound, a diaphragm, an annular armature of magnetic material mounted thereon, means for vibrating said diaphragm, said means comprising an annular pole member and a concentric core member cooperating therewith to provide an annular air gap, and a winding on one of said members.

13. In an apparatus for reproducing sound, a diaphragm, an armature mounted thereon, means for actuating said diaphragm said means including a pair of pole pieces, and means comprising a bowed spring for preventing lateral movement of the armature while permitting movement thereof in an axial direction.

14. In an apparatus for reproducing sound, a pair of concentric pole pieces, a diaphragm, an annular magnetic armature mounted on said diaphragm and movable between said pole pieces, and means mounted in the plane of said armature for preventing lateral movement of the armature while permitting movement thereof in an axial direction.

15. In an apparatus for reproducing sound, a pair of pole pieces, a diaphragm, an armature of magnetic material mounted thereon and movable parallel to the faces of said pole pieces, said armature and dia-

phragm being suspended in such a manner that their natural period of vibration is below 150 cycles per second.

16. In an apparatus for reproducing sound, a diaphragm, an armature of magnetic material mounted thereon, a magnetic member cooperating with the armature, a winding on said member adapted to actuate said armature and diaphragm, the air gaps between said member and said armature being constant in length but variable in area, and means for supporting the diaphragm and armature in such a way that the restoring force applied thereto has such relation to the mass of the diaphragm and armature that the natural period of vibration of the diaphragm as a whole will be less than 150 cycles per second.

17. In an apparatus for reproducing sound, a diaphragm, an armature of magnetic material attached thereto, a plurality of pole pieces, said armature being movable in a direction parallel to the faces of said pole pieces and overlapping each of said pole pieces to provide one or more working edges having a total length of at least 10 centimeters.

18. In an apparatus for reproducing sound, a diaphragm, a magnetic armature attached thereto, means including a plurality of pole pieces for actuating said armature in a direction parallel to the faces of said pole pieces, and means for preventing lateral movement of the armature, said latter means comprising flexible members attached to the diaphragm and disposed in a plurality of planes which are substantially perpendicular to the direction of motion of the diaphragm.

19. In an apparatus for sound reproduction, a vibratory diaphragm and means for producing vibrations thereof comprising a magnetic structure having a pair of air gaps, an armature structure of magnetic material having portions extending into both of said air gaps by an amount greater than the maximum vibratory displacement of said diaphragm, said armature structure being so mounted that it is free to move only in a direction substantially parallel to the pole faces which form said air gaps and an actuating coil associated with said magnetic structure in such a way that currents supplied thereto cause a decrease in the total flux in one air gap and at the same time cause an increase in the total flux in the other air gap.

In witness whereof, I have hereto set my hand this thirtieth day of July, 1926.

EDWARD W. KELLOGG.