July 4, 1939. A. C. BARKER 2,164,374

SOUND REPRODUCING DEVICE

Filed Nov. 15, 1935 2 Sheets-Sheet 1

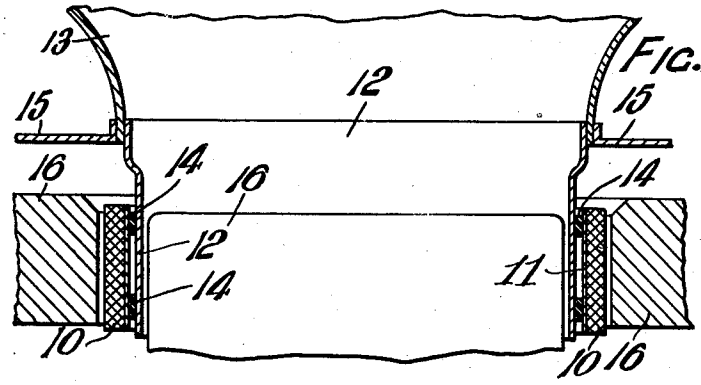

FIG. 1.

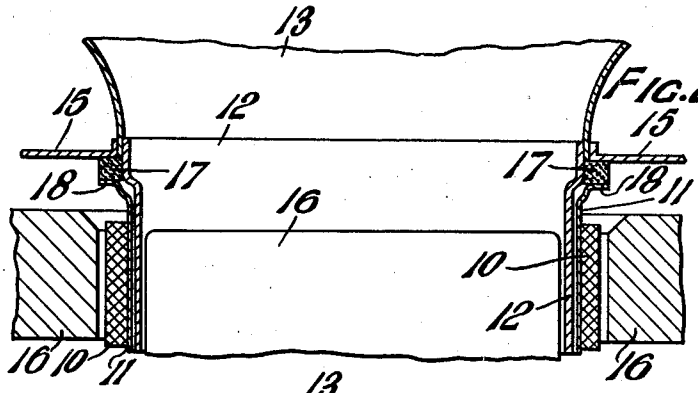

FIG. 2.

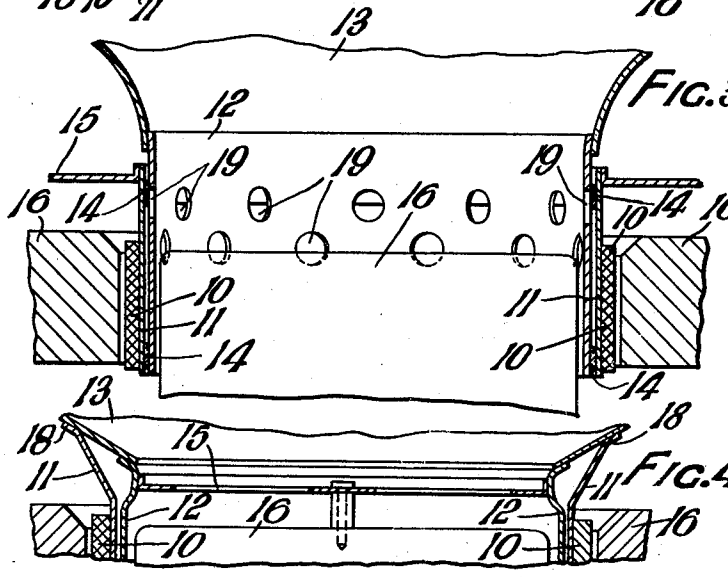

FIG. 3.

FIG. 4.

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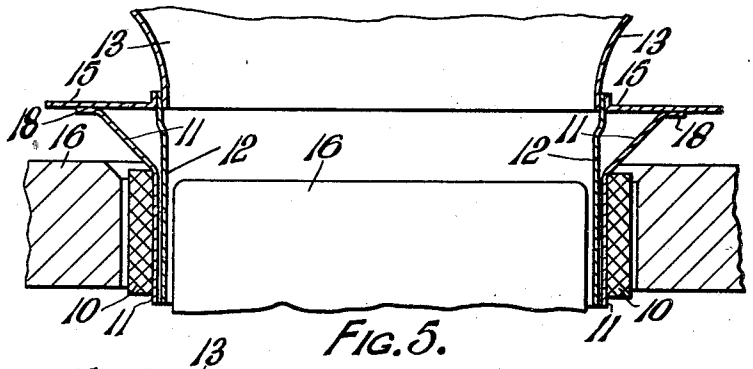

FIG. 5.

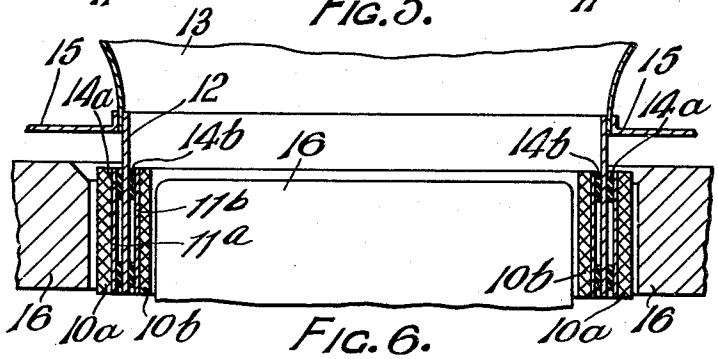

FIG. 6.

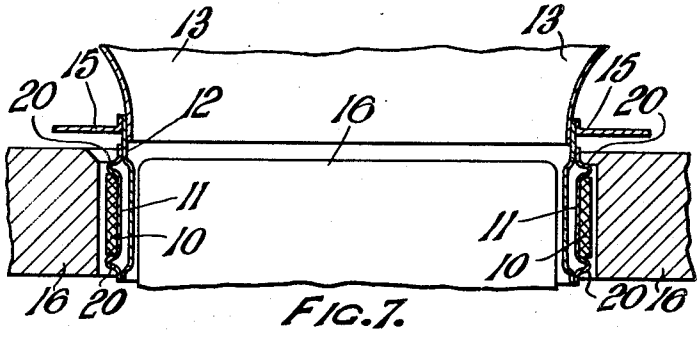

FIG. 7.

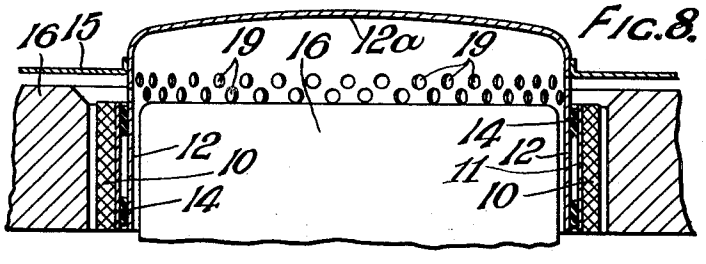

FIG. 8.

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SOUND REPRODUCING DEVICE

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Application November 15, 1935, Serial No. 49,945
In Great Britain December 5, 1934

9 Claims. (Cl. 179—115.5)

This invention relates to electro-mechanical apparatus of the electrodynamic type for the interchange of electrical vibrations into mechanical movement and vice versa and more particularly to acoustic apparatus such as loudspeakers, microphones, pick-ups and the like such an apparatus being hereinafter referred to as a reproducer and the invention has for its object to provide an improved form of such apparatus. In particular the invention has for its object to provide a loudspeaker or the like which has an extended frequency response and is capable of reproducing adequately both low and high audio frequencies.

In the past experiments have revealed the difficulty of making an electrodynamic reproducer respond at both low and high audio frequencies when only a single coil and diaphragm or armature are employed. It is found that though good response at the lowest frequencies can be obtained with careful design the high frequency response is poor. For example, in a loudspeaker a large and rigid diaphragm is desirable in order that the acoustic efficiency at low frequency should be as high as possible, and a comparatively large actuating unit is required to drive the diaphragm. At high frequency however, the inertia of this actuating unit limits the movement of the diaphragm, and the efficiency of the loudspeaker is therefore impaired.

In an attempt to improve the high frequency response of a reproducer of this type, as an alternative to using two loudspeakers of differing frequency characteristics, two connected coils have been attached to different parts of the same diaphragm and arranged in separate air gaps of the magnetic assembly, or two diaphragms of different sizes have been attached to one coil.

In a loudspeaker embodying the present invention two coils are employed. Only one of these, however, is connected to the circuit supplying energy to the loudspeaker, and this coil is attached to the diaphragm not directly but through a resilient coupling in such a manner that the diaphragm is capable of slight movement relative to this coil. The other coil is a much lighter coil, preferably consisting of a single turn or a ring of aluminium or other high conductivity material inductively coupled with the first coil and is directly attached to the diaphragm. It is believed that at low frequencies the two coils and the diaphragm move together as a unit, but at high frequencies the heavier and connected coil takes little or no part in causing the diaphragm to vibrate, the diaphragm being vibrated by the light coil in which currents are produced by induction. This is possible owing to the resilient coupling between the heavier coil and the diaphragm and owing to the fact that the amplitude of movement at high audio frequency is very small.

The present invention consists broadly of an actuating element for an electrodynamic reproducer comprising two moving conductors having a resilient coupling between them, wherein the two conductors are inductively coupled so that one conductor has current generated therein from the other.

The invention also consists of an electrodynamic reproducer comprising a diaphragm or the like, a moving conductor rigidly connected thereto and a second moving conductor resiliently connected therewith, the two conductors being inductively coupled.

In the accompanying drawings are illustrated various embodiments of the invention. Figures 1 to 7 are each fragmentary sections of the diaphragm, actuating element and pole piece arrangement of an electrodynamic loudspeaker, while Figure 8 is a corresponding section of an electrodynamic microphone.

In the embodiment of the invention shown in Figure 1 a moving coil 10 which may be of a single turn of strip conductor or a number of turns of wire is wound upon a thin paper support 11 of preferably not substantially greater length than is necessary to support the coil 10. The coil so wound is then attached to a preformed ring 12 of very thin aluminium, of the order of 5 mils thick. In the construction of a ring of such thin material it is difficult to obtain a tube with such thin walls, particularly as the tube should preferably be seamless. Further, difficulty is encountered in cutting lengths from a tube with walls so thin and so far it has been found most satisfactory to stamp aluminium foil into a cup and then to remove the base of the cup. It may, however, be desirable to form the aluminium ring 12 by applying the metal foil to paper by a metal spraying or electroplating process or to employ other methods, but it is necessary that the ring so formed should have the ends thereof joined to form a closed electrically conducting circuit. The ring is suitably shaped at its one end to facilitate its connection to the diaphragm 13 of the apparatus.

The attachment of the ring so formed to the coil is effected through a resilient coupling device. In this embodiment of the invention, rubber bands 14 are employed, but it should be

pointed out that care is necessary in the selection of the rubber. Experiments have shown that the operating coil of a loudspeaker of this type may reach a comparatively high temperature when in use and as the rubber is very closely arranged to the coil it must be of a quality which will retain its resilience at temperatures of the order of 150° Fahrenheit. A suitable anti-oxidizing agent may be included in the rubber to assist in attaining this object.

The resilient coupling is preferably formed by applying the rubber, where this is employed, to the exterior surface of the aluminium ring. A continuous coating, because of the comparative closeness of the two parts between which it is arranged, is found in some cases to be too rigid and I therefore prefer to have two spaced bands 14 of rubber applied to the aluminium ring. These bands of rubber are not entirely satisfactory when made by the usual methods, and they are more suitably made by dipping, using a glass mandrel, by painting or by electro-deposition, and they may be formed directly upon the aluminium ring. When made separately before being applied to the aluminium ring, the bands are retained upon the ring by their own resilience. The rubber should not be under appreciable tension, since this causes deterioration of the rubber. If an adhesive of a rubber solution is employed, it is very important that the adhesive and the rubber should have the same ageing characteristic.

The ring, with the rubber bands applied, is a close fit within the wound coil, and the ring is expanded slightly to cause it to be securely attached to the coil. This may be done by spinning, or by an expanding mandrel. Alternatively a close-fitting rubber stopper may be inserted in the ring and then compressed to produce the desired expansion of the ring. The ring and coil thus attached are secured to the diaphragm of the apparatus, which is preferably of the usual conical type. The diaphragm assembly is mounted, together with the usual centering spider, terminals and so forth in the annular air gap between the poles 16 of a magnetic circuit which may be of conventional form. Current is fed only to the wound coil, which drives the diaphragm through the resilient coupling and also induces currents in the ring, which is directly coupled to the diaphragm.

The care attendant upon the use of rubber for the resilient coupling has already been pointed out, and in one embodiment of the invention, shown in Figure 2, felt is used as the resilient material. In this arrangement the ring 12, diaphragm 13 and centering spider 15 are secured together and the moving coil 10, wound on its paper support 11, is arranged as a free fit upon the ring 12. An annulus 17 of felt is attached to the ring or the spider or both by adhesive and the end of the paper support, bent outwardly to form a flange 18 at right angles to the axis of the coil, is attached by adhesive to the felt annulus 17. There should be a clearance between the coil and the ring to avoid chatter.

In the embodiment of the invention described with reference to Figure 1 the centering spider 15, which serves to locate the coil accurately within the annular air gap is attached directly to the diaphragm 13 or to the ring 12 which is secured thereto. In a further embodiment of the invention, shown in Figure 3, I arrange the moving coil 10 upon a paper support 11 as before but extend the support and attach the centering spider to the extended part of the paper support. The aluminium ring attached directly to the cone is located within the paper support by the rubber bands as previously described. The damping effect of the spider at the highest frequencies is therefore decreased as it is connected to the cone only through the resilient coupling.

In the construction shown in Figure 4, the diaphragm itself provides the resilient coupling. In this case the spider 15, which, as in the other embodiments of the invention, may be an inside spider, the cone 13 and ring 12 are secured together and the paper support for the coil 11 is provided with the outwardly extending flange 18, the periphery of which is attached to the diaphragm 15 by adhesive at a point some distance from the point at which the ring is secured. Clearance between the ring and the coil is necessary in this case also.

In a somewhat similar construction, shown in Figure 5, instead of securing the flange 18 to the cone, it is attached to the spider, and the spider is employed as the resilient coupling between the coils.

While for constructional reasons it is generally more convenient to provide the connected moving coil in one section, the coil may be arranged in two parts, and such a construction is shown in Figure 6 of the accompanying drawings. In this construction the aluminium ring 12, cone 13, and spider 15 are arranged in a manner similar to that described with reference to Figure 1. The ring 12 is, however, provided with rubber bands 14*a*, 14*b* or like resilient couplings on both the inside and outside, to which are secured by suitable adhesive the paper supports 11*a*, 11*b* for the coils 10*a* and 10*b*. These coils 10*a* and 10*b* may be fed in series or parallel from a single circuit or independently from separate circuits.

In Figure 7 of the drawings is shown a further method of forming the resilient coupling between the coils which is found to be satisfactory in practice. In this embodiment of the invention the paper support 11 for the moving coil 10 is provided with two ridges or crimps 20. These ridges are of sufficient height as to permit slight movement of that part of the support which lies between them and upon which the coil is disposed. More than two such crimps, which may divide the coil into a number of sections, may be provided. When the resilient coupling is formed in this manner, the ring 12 may suitably be shaped as indicated.

In applying the present invention to a microphone the moving conductor which is unconnected may be formed integrally with the diaphragm of the apparatus. In such a case the combined ring and diaphragm may conveniently take the form shown in Figure 8, in which the ring and diaphragm are in the form of a cup, of which the sides 12 are arranged in inductive relation to the moving coil 10, but is separated therefrom by the resilient connection 14 or by one of the resilient couplings previously described, while the base 12*a* of the cup forms the diaphragm. When pressure waves fall upon the diaphragm at low frequencies the coils 10 and 12 move together in the magnetic field and thereby generate a voltage at the terminals of the coil. At high frequencies, however, the inertia of the coil 10 is sufficient to prevent adequate movement thereof, but the coil 12 is not so prevented and induces in the coil 10 voltages which are fed

to the external circuit. Thus the frequency range of the device is appreciably extended.

In all the constructions described it may be desired to increase the resistance of the aluminium ring at that part which is not usefully employed in the air gap of the magnetic circuit and this may be effected by forming the ring with a series of slits or apertures in the manner indicated at 19 in Figure 3. This has the effect in practice of increasing both the bass and top response of the loudspeaker.

It may be desirable to form the apparatus with a dust tight air gap, in which case the construction may be correspondingly added to or modified.

Apart from the improved reproduction of sound which is obtained from a loudspeaker or microphone embodying this invention, it is to be noted that the impedance of the moving coil remains more constant than with a more conventional arrangement, and this holds over a wide range of frequencies.

This provides a more constant load on the output of the amplifier supplying the loudspeaker, and the average efficiency of transfer of energy is therefore improved.

From the above description it will be noted that the closed circuit forming conductor is in all cases connected rigidly with the diaphragm, and that the cooperating audio frequency coil or conductor is inductively related to the first conductor and compliantly connected to the diaphragm, either through a compliant connection with the diaphragm or through a compliant connection between it and the first conductor. The outer or audio frequency coil is comparable to the conventional diaphragm actuating coil wound with copper wire, and is adapted to be connected through suitable means to a source of audio frequency current. The inner conductor is for convenience formed of a thin aluminium cylinder which can be rigidly cemented to the diaphragm.

From the above it will be seen that the coupling between the closed circuit conductor and the audio frequency conductor is both mechanical and inductive, and as a result they produce a driving force upon the diaphragm which varies with the frequency of the current impressed upon the audio frequency coil. In the case of low frequencies, the audio frequency excited conductor will drive the diaphragm through its compliant connection therewith, while at these low audio frequencies no appreciable current will be induced in the closed circuit forming conductor.

At the higher frequencies (above 5000 cycles) the mechanical driving forces provided for the diaphragm by the audio frequency coil will, because of the compliant connection, become less and less, and at the highest frequencies the audio frequency coil will remain practically stationary. At this point, however, high frequency currents will be induced in the closed circuit forming conductor with increasing transfer efficiency, and as a result of the compliant coupling, this conductor will respond to and drive the diaphragm at the higher frequencies. As the result of the above characteristics, the diaphragm actuating means here disclosed satisfies all of the requirements for successful operation, as it provides a strong driving force for reproduction of the low audio frequency signals when it must move as a whole, and a light moving system for the reproduction of the high audio frequency signals.

While I have, for the sake of clearness and in order to disclose the invention so that the same can be readily understood, described and illustrated specific devices and arrangements, I desire to have it understood that this invention is not limited to the specific means disclosed, but may be embodied in other ways that will suggest themselves to persons skilled in the art.

It is believed that this invention is new and it is desired to claim it so that all such changes as come within the scope of the appended claims are to be considered as part of this invention.

What I claim and desire to secure by Letters Patent is:

1. An actuating element for the diaphragm of an electro-dynamic sound reproducer, comprising two movable diaphragm actuating conductors disposed in inductive relation with each other in a magnetic air gap, one of said conductors forming a closed circuit being coupled directly to said diaphragm and having a resilient connection with the other conductor, whereby said other conductor will be compliantly connected through the first conductor to said diaphragm so that when said other conductor is energized the movable conductor which is directly connected to the diaphragm will drive the diaphragm in response to currents generated therein by induction from the other movable conductor.

2. In an electrodynamic sound reproducing device, the combination of a diaphragm, pole pieces forming a magnetic air gap adjacent said diaphragm, a metallic cylinder forming a closed-circuit conductor rigidly attached to said diaphragm and extending into said air gap, a coil supporting means connected to said cylinder, and a coil winding adapted to be excited with an audio frequency current compliantly mounted upon said coil supporting means and in inductive relation to said closed-circuit conductor.

3. In an electrodynamic sound reproducing device, the combination of a diaphragm, a pair of spaced magnetic poles forming an electromagnetic air gap adjacent said diaphragm, a current conducting cylinder forming a short-circuited conductor rigidly attached to said diaphragm and extending into said air gap, and an audio frequency current winding disposed in said air gap and compliantly mounted upon and in inductive relation with said current conducting cylinder.

4. In an electrodynamic sound reproducing device, the combination of a magnetic field frame having an annular air gap, a diaphragm mounted adjacent said air gap, a metallic cylinder rigidly attached to said diaphragm extending into said air gap and forming a short-circuited conductor, an audio frequency current coil disposed in said air gap, and means for compliantly mounting said coil upon and in inductive relation with said metallic cylinder.

5. In an electrodynamic sound reproducing device of the character described, the combination of a pair of spaced magnetic poles having an annular air gap therebetween, a diaphragm yieldingly supported adjacent said air gap, a metallic conductor rigidly secured to said diaphragm and forming a closed electrical circuit in said air gap, an audio frequency current winding disposed in concentric relation with the closed electrical circuit forming metallic conductor, and resilient means between said conductor and said winding for compliantly securing said winding upon said conductor in said air gap.

6. In an electrodynamic sound reproducing device of the character described, the combination of a pair of spaced magnetic pole pieces forming

an annular air gap, a coil supporting cylinder of insulating material having a winding thereupon disposed in said air gap, a flexible centering spider for yieldingly supporting said coil support and winding concentrically in said air gap, a closed-circuit conductor forming member compliantly mounted upon said coil supporting cylinder in inductive relation with said winding, and a diaphragm secured to said conductor independently of said flexible centering spider.

7. In an electrodynamic sound reproducing device of the character described, the combination of a pair of spaced magnetic pole pieces forming an annular air gap, a coil supporting cylinder of insulating material having a winding thereupon disposed in said air gap, a flexible centering spider for yeildingly supporting said coil support and winding concentrically in said air gap, a closed-circuit conductor compliantly mounted upon said coil supporting cylinder and in inductive relation with said winding, and a diaphragm rigidly secured to said closed-circuit conductor.

8. In a sound reproducing device of the character described, the combination of spaced magnetic poles having an annular air gap therebetween, a diaphragm of the conical type disposed in axial alignment with said air gap, a centering spider mounted upon one of said pole pieces and secured to said diaphragm for centering the diaphragm concentrically in said air gap, a metallic conductor secured to said diaphragm and extending into said air gap to form a closed-circuit conductor therein, an audio frequency current winding disposed in said air gap and in inductive relation with said metallic conductor, and means secured intermediate the mounting of said centering spider and its point of attachment to said diaphragm for supporting said winding in said air gap, whereby a portion of said centering spider will serve as a compliant connection between said metallic conductor and said current winding to permit relative movement therebetween.

9. In an electrodynamic sound reproducing device of the character described, the combination of an inner and an outer magnetic pole piece having an annular air gap therebetween, a diaphragm yieldingly supported adjacent said air gap, a cylindrical metallic member secured to said diaphragm and extending into said air gap to form a closed-circuit conductor therein, an audio frequency current winding disposed concentrically in inductive relation along the inside of said cylindrical metallic member, a second current winding disposed in concentric relation outside of said cylindrical member, and resilient means between each of said windings and said cylindrical member for compliantly securing said windings in inductive relation upon said cylindrical member.

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