Dec. 26, 1950 | J. J. ROOT | 2,535,757

PERIPHERALLY DRIVEN ELECTROACOUSTICAL TRANSDUCER

Filed June 25, 1946 | 2 Sheets-Sheet 1

FIG. 1.

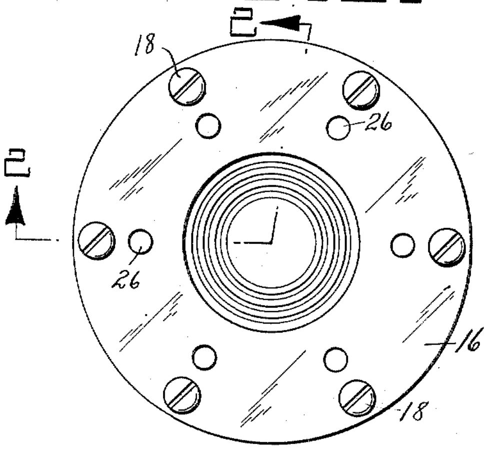

FIG. 2.

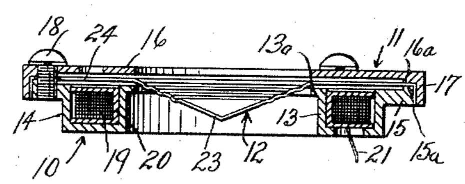

FIG. 3.

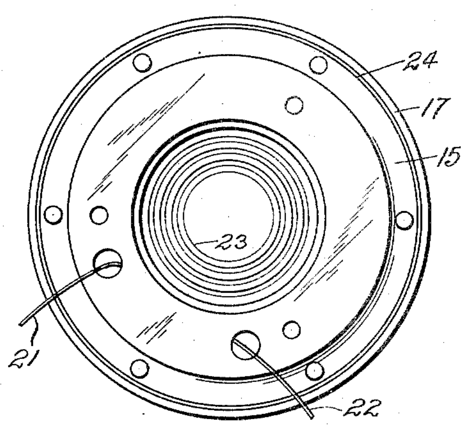

FIG. 4.

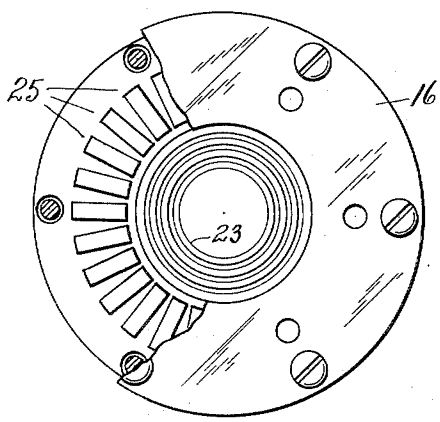

FIG. 5.

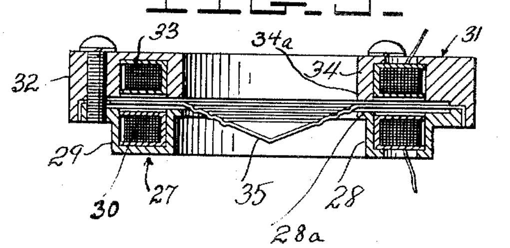

FIG. 6.

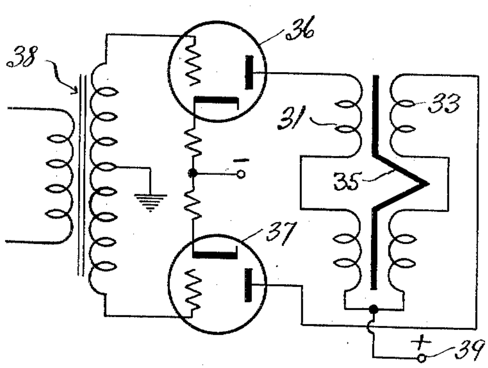

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FIG. 7

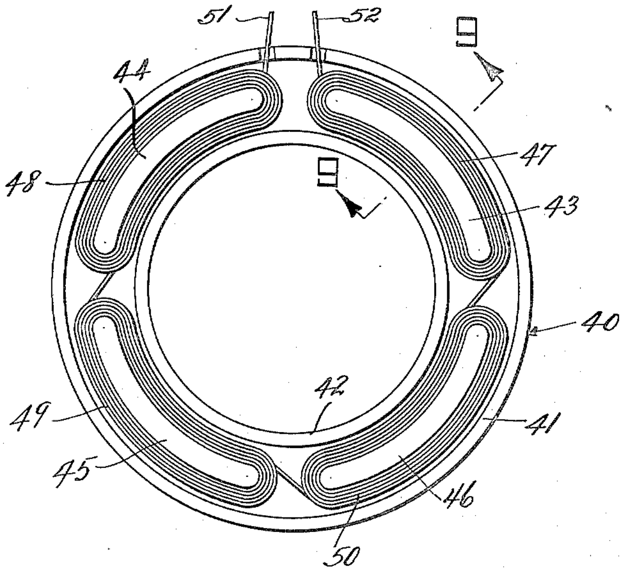


FIG. 8

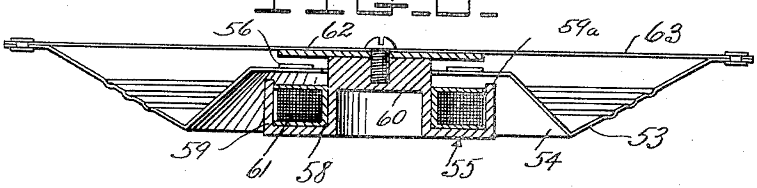
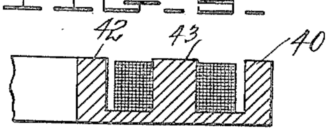


FIG. 9



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PERIPHERALLY DRIVEN ELECTRO-ACOUSTICAL TRANSDUCER

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8 Claims. (Cl. 179—115)

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The present invention relates generally to electroacoustic transducers and it is more particularly directed to improvements in loud speakers incorporating motors of the magnetic type.

The condenser type of speaker motor is one wherein mechanical forces result from electrostatic reactions. In effect, this motor is a large condenser having one flexible electrode free to move and act upon a diaphragm. The crystal type of speaker motor is one wherein mechanical forces result from deformation of a crystal having converse piezoelectric properties. Since only small displacements are possible without crystal fracture, mechanical levers are used when moderate diaphragm excursions are required.

In magnetic speaker motors, the mechanical forces are derived from magnetic reactions. This class includes both moving coil or electrodynamic speakers, and magnetic armature speakers. A moving coil motor is one wherein the mechanical forces result from the interaction between the field of the moving coil and the constant polarizing field in which it is disposed. The moving armature motor is one whose operation involves the vibration of a portion of a ferromagnetic circuit.

In speakers incorporating motors of the above described types it has heretofore been the general practice to impart the driving force from the motor to the center of the diaphragm and as a result these speakers have been found to suffer from various deficiencies. For example, in the electromagnetic speaker, the voice coil is customarily secured to the apex of a conical diaphragm. Consequently the speaker cone is required to be sufficiently massive and sturdy so as not to flex or bend under the force exerted by the voice coil. This requirement adversely affects the speaker efficiency inasmuch as the quality of lightness is requisite in a diaphragm in order to attain sensitivity and faithful high frequency response. Similarly, in the magnetic, moving armature type motor, the motor is ordinarily coupled through a lever to the apex of a conical diaphragm. This type of speaker is also subject to resonance of the driving lever which impairs the speaker tone quality.

Another important consideration in connection with loud speakers is their overall physical dimension and weight. Where the speaker construction is such that its cone is apex driven, this acts as a limiting factor in the reduction of speaker size. The reason for this is that the overall depth of the speaker assembly not only includes the depth of the cone but, in addition, that of the

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drive motor, the motor usually being mounted behind the apex of the cone. Moreover with conventional constructions, as the cone diameter is reduced, the low frequency response of the speaker is diminished accordingly so that non-linear distortion is introduced as the speaker is made smaller.

In the view of the foregoing, it is the principal object of this invention to obviate the above described limitations encountered in existing loud speakers by providing a loud speaker of relatively small size and weight, characterized by a high degree of sensitivity and uniform frequency response.

It is also an object of this invention to provide a loud speaker incorporating a magnetic motor wherein the speaker casing also functions as part of the ferromagnetic circuit, thereby effecting a saving in speaker weight and size.

Still another object of this invention is to provide a loud speaker incorporating a magnetic motor wherein a polarizing field is automatically established therein without requiring a permanent magnet or a separate field coil.

An additional object of this invention is to provide a loud speaker assembly where overall depth is substantially determined by the depth of its cone.

Still another object of this invention is to provide a loud speaker having a minimum of components, of rugged construction, and adapted to simple assembly and inexpensive manufacture.

For a complete understanding of this invention as well as other objects and features thereof, reference is had to the following detailed description of several preferred embodiments to be read in connection with the accompanying drawings. The scope of the invention will be pointed out in the accompanying claims.

In the drawings:

Fig. 1 is a top plan view of a first preferred embodiment of a loud speaker in accordance with the principles of the invention;

Fig 2 is a vertical cross section taken along line 2—2 of Fig. 1;

Fig. 3 is a bottom plan view of said first embodiment;

Fig. 4 is a view similar to Fig. 1 but partially broken away to illustrate various details of construction;

Fig. 5 is a vertical section of a second preferred embodiment of a loud speaker;

Fig. 6 is a schematic diagram illustrating the application of a loud speaker as in Fig. 6 to an electronic circuit;

Fig. 7 is a plan view of a modified energizing coil arrangement;

Fig. 8 is a vertical cross section of a third preferred embodiment of a loud speaker, and

Fig. 9 is a vertical cross section taken through line 9—9 in Fig. 7.

Referring now to the drawings and more particularly to Figs. 1 to 4, a preferred embodiment of a loud speaker is shown in various views, like numerals serving to identify like components in these figures. The speaker assembly is comprised mainly of an annular, cup-shaped base, generally designated by numeral 10, an annular cap adapted to cover said base, generally designated by numeral 11, and a circular diaphragm interposed and supported between base 10 and cap 11, said diaphragm being generally designated by numeral 12. Base 10 in combination with cap 11 also serve as the speaker casing and they are made of a ferromagnetic substance, such as steel. Diaphragm 12 is preferably fabricated of stiff paper or any other non-magnetic material having suitable acoustical properties.

Base 10 includes a reentrant column 13 and an outer cylindrical wall 14 having an outwardly extending flange 15, a shoulder 15*a* being formed on the border of the upper surface of the flange. Cap 11 is formed with an annular plate 16 having an outer collar 17, said collar, in assembly, encompassing flange 15. A shoulder 16*a* is formed on plate 16 at the juncture of plate 16 and collar 17, shoulder 16*a* being complementary to shoulder 15*a*. Cap 11 is attached to base 10, such as by means of a plurality of machine screws 18 received in threaded bores in flange 15.

Seated in the channel defined between column 13 and outer wall 14 is an energizing coil 19 wound about an annular insulating frame 20 which may be of Bakelite or similar material. A pair of leads 21 and 22 connected to energizing coil 19 are taken out through openings in base 10 to serve as the terminals of the speaker.

Diaphragm 12 consists of a central cone 23 which may be partially corrugated as indicated and whose base is formed with a planar brim 24 connected to the cone 23 and having an oblique angular relationship therewith. In the assembled device, cone 23 is disposed within column 13 of the base. To support diaphragm 12, the border of brim 24 is bent downwardly and clamped between collar 17 and flange 15.

Secured on the surface of brim 24 of the diaphragm are a plurality of discrete armature strips 25 of magnetizable metal. Strips 25 are symmetrically and circumferentially arranged on brim 24. One modified form of diaphragm 12 involves imbedding strips 25 therein by disposing the strips between two layers of a laminated diaphragm material. The strips 25 may in another form be sprayed on the diaphragm surface.

To operate the loud speaker from a vacuum tube amplifier, leads 21 and 22 are directly connected to the plate of the final power tube of the amplifier and the positive plate voltage terminal, respectively. It is desirable, of course, in order to obtain optimum speaker efficiency, to match the impedance of energizing coil 19 and the plate circuit of the power tube and this may be readily accomplished by proper design of coil impedance as by regulating the number of turns thereof.

When no audio signal is applied to the power tube, the direct current component of plate current flow therein serves to energize coil 19, thereby polarizing base 10 and cap 11 and establishing a constant magnetic field therebetween. Upon the introduction of an audio signal to the amplifier, an alternating current component corresponding to the signal appears in the output of the power tube. This produces corresponding variations in the magnetic field strength of the speaker as the alternating component adds to and subtracts from the direct current component.

It will be evident that armature strips 25 are disposed within a small gap in the path of the magnetic lines of flux set up between base 10 and cap 11, annular plate 16 and the end face 13*a* of column 13 acting as opposing magnetic poles. It will further be apparent that the magnetic field assumes a circular pattern, the field being uniformly distributed with respect to the individual strips 25. Strips 25, being co-planar with plate 16, tend to assume the same magnetic polarity as the plate and therefore are attracted in the direction of end face 13*a*. The equilibrium position of diaphragm 12 is determined by the magnetc field intensity in the steady state. As the field strength undergoes variation according to the applied audio signal, the positions taken by armature strips 25 will concurrently shift therewith, thereby causing an axial vibration of diaphragm 12.

Shoulder 15*a* and shoulder 16*a* each serve to provide an air chamber on either side of diaphragm brim 24 which permits the excursion of the diaphragm from the equilibrium position, the air chambers also serving to dampen the diaphragm action. A plurality of circularly arranged ports 26 are formed in plate 16 which provide air columns communicating with the air chamber to prevent excessive vibration of diaphragm 12.

It is to be noted in the embodiment illustrated in Figs. 1 to 4, that diaphragm 12, by means of the action of the armature strips is driven at its peripheral area while its cone portion acts directly against the atmosphere. This technique has been found advantageous in that cone 23 is not subject to buckling with its attendant distortion such as results in an apex driven cone. Furthermore, there is no mechanical lever coupling between armature strips 25 and diaphragm 12, thereby eliminating the problem of objectionable lever resonance.

While the diameter of diaphragm 12 may be made very small, for example 3 inches, the low frequency response of the diaphragm is not seriously attenuated due to the relatively heavy mass inertia of the metal strips 25 around the peripheral area of the diaphragm. At the same time, however, the high frequency response is not materially affected due to the fact that the discrete strips 25 vibrate independently at high frequencies since the inertia of an individual strip is slight. Thus, a balance may be established between the low and high frequency response of diaphragm 12. If it is intended to emphasize the low frequency range, strips 25 may be interconnected in whole or in part. The described construction further offers an opportunity to provide volume control means. I have determined that this can be done by enlarging the gap in which the armature strips 24 operate. This, of course, varies the reluctance of the circuit and the driving power accordingly.

Since a polarizing field is created when energizing coil 19 is directly connected to the plate output circuit of an amplifier tube, it is not essential to provide either a separate source of field potential or a permanent magnet. In some instances, where the audio signal component is purely alternating current without a direct current superimposed thereon, the same arrangement illustrated in Figs. 1 to 4 may be employed except that armature strips 25 are permanently magnetized. Another method of providing a polarizing field is to have outer wall 14 permanently magnetized, the wall then being preferably made of hard steel or an alloy suitable for this purpose. The remaining portions of the casing structure may be made of soft iron which by contact with outer wall 14 become magnetized by induction. These methods may be necessary where the voltage supply of the amplifier is limited or to obtain a stronger polarizing field, if required.

It is also to be observed that by driving diaphragm 12 at its peripheral area, a substantial reduction is made possible in the space occupied by the speaker assembly without a sacrifice in speaker efficiency or quality. In apex driven cone diaphragms, the space surrounding the cone is necessarily vacant, the drive motor being ordinarily mounted behind the apex. As is apparent, the present invention fully utilizes the area surrounding the cone whereby the overall depth of the assembly hardly exceeds the cone depth alone. This feature, in addition to the ability of diaphragm 12 to afford good frequency response although of small diameter, and the use of a casing which also functions as a portion of the ferromagnetic circuit, combines to produce an effective miniature or physically flat speaker. It can be seen that the magnetic structure is built away from the central area of the diaphragm so as to permit the formation of a cone thereat.

Another embodiment of a loud speaker in accordance with the invention is illustrated in vertical cross section in Fig. 5 and schematically in connection with a push-pull amplifier in Fig. 6. This speaker operates in a push-pull manner. The advantages residing in the push-pull speaker are the cancellation of second harmonic distortion, the development of greater acoustical power and the elimination of the output transformer of the push-pull amplifier with which it is associated.

The speaker assembly, as shown in Fig. 5, comprises a base member 27, identical with base 18 in Fig. 2, base 27 including a reentrant column 28 and an outer cylindrical wall 29 having an outwardly extending flange. An energizing coil 30 is seated in the channel defined by column 28 and outer wall 29. A cap member 31 is provided, similar in construction to base 27 except that its outer wall 32 is extended and formed so as to encompass the flange on wall 29 when the device is assembled. An energizing coil 33 is received in the channel between outer wall 32 and the cylindrical column 34 of cap 31. Interposed between base 27 and cap 31 is a diaphragm 35, identical in construction with diaphragm 12 of Fig. 2 and including like armature strips.

Referring now to Fig. 6, the final power stage of a push-pull amplifier is shown, the circuit including a pair of triodes 36 and 37 and a push-pull input transformer 38. The secondary winding end terminals of transformer 38 are connected to respective grid electrodes of tubes 36 and 37. One terminal of energizing coil 31 is connected to plate of triode 36, the other terminal being connected to the positive plate voltage terminal 39. In a like manner, one terminal of energizing coil 33 is connected to plate of triode 37, the other terminal being connected to positive terminal 39. Whereas coils 31 and 33 are each shown in Fig. 6 schematically as having two separate sections, they are each in actuality a continuous coil, the separation being made to facilitate the schematic representation of diaphragm 35.

As is characteristic of such push-pull behavior, triodes 36 and 37 are displaced 180 degrees out of phase in operation, hence coils 31 and 33 are energized in opposing phase relation. A constant composite magnetic field is developed between the end face $28a$ of column 28 and the end face $34a$ of column 34, these faces serving as opposing magnetic poles which are in aiding relationship in respect to actuation of the armature strips. The magnetic field intensity is modulated by audio signals. The armature strips are disposed intermediate end faces $28a$ and $34a$ and are vibrated in accordance with the varying field to actuate diaphragm 35. It is to be noted that the polarity of the magnetic poles alternate as coils 31 and 33 are alternately energized thereby providing a push-pull diaphragm action. It will be observed that this construction eliminates the push-pull output transformer in the amplifier which generally has been considered indispensable. In the embodiment of Figs. 1 to 4 the energizing coil 19 will be connected between the plate of a single output tube and the voltage supply in a manner similar to the schematic representation of Fig. 6.

In small speaker designs, that is, in those utilizing diaphragms of less than five inches in diameter, the use of a single energizing coil, as for example, coil 19 of Fig. 2, is fully satisfactory for developing a magnetomotive force ample to drive the diaphragm. However, in large speakers, because large coils have less ampere turns ratio, it becomes desirable to devise a coil arrangement for the speaker enabling a greater ampere turns ratio within the same space taken by a single solenoid. One such arrangement is shown in plan view in Fig. 7 and in vertical section in Fig. 9. An annular base 40 of magnetizable metal is provided having a cylindrical outer wall 41 and a cylindrical inner wall 42. Intermediate walls 41 and 42 are four, evenly spaced core members 43, 44, 45 and 46 integral with base 40. Wound about cores 43 to 46 are energizing coils 47, 48, 49 and 50, respectively. The coils are all serially connected, input leads 51 and 52 serving as the speaker terminals. When coils 47 to 50 are equally energized from an electrical source, base 40 becomes magnetically polarized, all of cores 43 to 46 assuming one polarity and walls 41 and 42, the opposite polarity.

The magnetomotive force developed by this arrangement is greater than obtainable with a single coil occupying the channel between walls 41 and 42. The manner in which the magnetic field developed by base 40 is applied to an armature depends on the nature of the assembly design. It is obvious that any one of the polarized walls may be extended to form a magnetic field of circular pattern in the manner indicated in Fig. 2 or 5. It is to be understood that while base 40 has been described as incorporating four energizing coils, the number thereof can be varied as desired.

A third preferred embodiment of a loud speaker is shown in Fig. 8. An acoustical diaphragm 53 is provided having a truncated conical form, the head portion 54 of the diaphragm being made reentrant to accommodate a magnetic motor. The magnetic motor comprises an electromagnet 55 adapted to actuate a plurality of discrete armature strips 56 circumferentially arranged on the head surface 57 of the diaphragm.

Electromagnet 55 includes a cup-shaped base 58 of magnetizable metal, having a cylindrical outer wall 59 and a central post 60 about which is wound an energizing coil 61. Post 60 extends through a central opening in head portion 54 and serves to support a magnetizable disc 62 having substantially the same diameter as outer wall 59. When electrical fluctuations are applied to energizing coil 61, a magnetic field is set up between the end face 59a of outer wall 59 and disc 62, the field assuming a circular pattern. Armature strips 56 are uniformly distributed in the path of the magnetic field and thereby cause axial vibration of diaphragm 53 in accordance with the applied electrical fluctuation. Diaphragm 53 may be corrugated, as indicated, and is supported about the periphery of the base of the cone by frame member 63.

Thus, there has been shown what at present are considered preferred embodiments of the invention. It will be obvious that many changes and modifications are possible therein without departing from the scope of the invention. For example, while the embodiments have described diaphragms of circular shape, other shapes such as elliptical may be employed, if desired, in accordance with well known design practice to obtain emphasis of certain frequency bands. Therefore, it is intended in the following claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. An electroacoustic transducer comprising in combination a conical acoustical diaphragm, discrete and symmetrically spaced armature means disposed peripherally of said diaphragm, and magnetic means to actuate said armature means, said diaphragm being actuated by said armature means whereby sound waves are radiated from a central area of said diaphragm.

2. In a transducer device a diaphragm comprising a nonmagnetic conical central area, a peripheral area, and a plurality of mutually spaced magnetic means on said peripheral area whereby magnetic action on said peripheral area drives said conical central area to produce sound radiations therefrom.

3. An electroacoustic transducer comprising in combination an acoustical diaphragm having a conical portion and an integral peripheral portion extending angularly from the base of said conical portion, a plurality of discrete ferromagnetic members disposed in symmetrically spaced relation on said peripheral portion, and magnetic means having an air gap formed therein, said members being disposed in said air gap so as to serve as armatures therein, said magnetic means being adapted to have alternating currents of audio frequencies applied thereto whereby said armature members are actuated accordingly, said integral conical portion being driven by the action of said armature members whereby sound radiation is produced from said conical portion.

4. An electroacoustic transducer comprising in combination an acoustical diaphragm having a conical portion and a peripheral portion extending integrally from the base of said conical portion, and a magnetic motor to actuate said diaphragm, said motor comprising a ferromagnetic casing serving to support said diaphragm at the outer edge of said peripheral portion, said casing having opposing pole faces adjacent opposite surfaces of said peripheral portion, an energizing coil responsive to electrical fluctuations for polarizing said casing whereby a magnetic field is established between said pole faces, the intensity of said field corresponding to said electrical fluctuations, and a plurality of discrete armature strips symmetrically disposed on said peripheral portion so as to be within said magnetic field, the axial position of said armature strips being controlled by the intensity of said magnetic field whereby said diaphragm is actuated in an axial direction in response to an audio fluctuating magnetic field to produce sound radiation.

5. An electroacoustic transducer comprising in combination an acoustical diaphragm having a central conical portion and a peripheral portion extending integrally from the base of said central portion, a magnetic motor for actuating said diaphragm, said motor comprising a ferromagnetic casing having annularly arranged opposite poles adjacent opposite surfaces of said peripheral portion, an energizing coil adapted to be actuated by an alternating current superimposed on a direct current whereby said coil may be connected between the plate of an electronic tube and the direct current voltage supply therefor so as to produce a varying magnetic field between said poles in response to variations in the electron stream of said tube, and a plurality of spaced armature strips radially arranged on said peripheral portion so as to be between said poles and within said magnetic field, said armature strips being thus adapted to be actuated axially by said varying magnetic field so as to radiate acoustical energy in response thereto.

6. An electrical transducer according to claim 5 wherein said diaphragm is of non-metallic material, said armature strips being discrete, metallic members and being imbedded in said nonmetallic diaphragm.

7. An electroacoustic transducer comprising in combination a conical acoustical diaphragm, a plurality of discrete ferromagnetic members disposed peripherally of said diaphragm, and magnetic means to actuate said members, said magnetic means being adapted to have a direct current superimposed with an alternating current applied thereto whereby said members are driven according to said alternating current said diaphragm being actuated by said driven members whereby sound radiation is produced therefrom.

8. In an electroacoustic transducer, an acoustical diaphragm including a conical portion and a peripheral portion extending integrally from the base of said conical portion, and a plurality of discrete metallic strips affixed to the peripheral portion at symmetrically spaced positions and annularly arranged thereon, said strips being adapted to be actuated upon by a varying magnetic field so as to produce corresponding actuation of said conical portion, the mass inertia of said strips being such as to render said diaphragm responsive to a low audio frequency range, the individual inertia of such strips being such as to enable each to vibrate independently in a higher audio frequency range whereby both low and high audio frequencies may be reproduced by said diaphragm when actuated.

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