June 11, 1935. A. A. THOMAS 2,004,735

LOUD SPEAKER

Filed July 27, 1928 2 Sheets-Sheet 1

Fig. 1

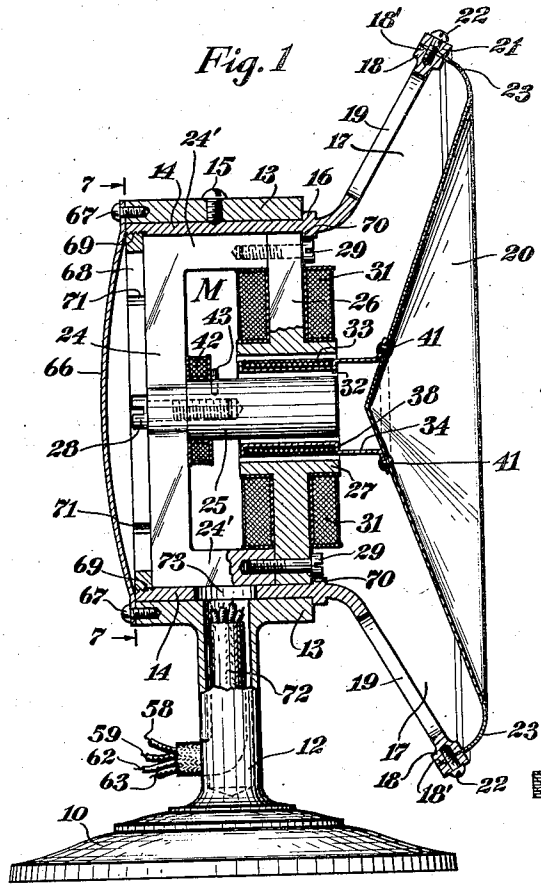



Fig. 4

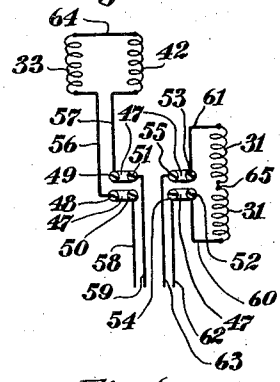



Fig. 6

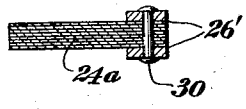



Fig. 2

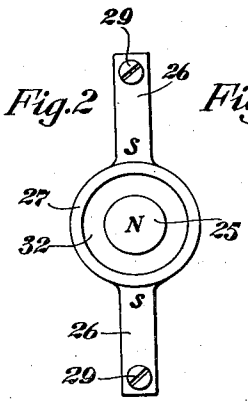



Fig. 5

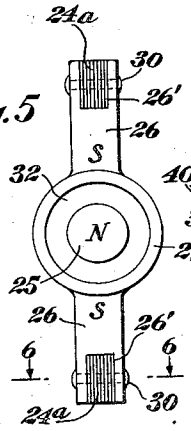
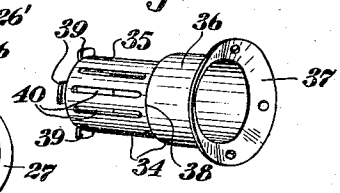



Fig. 3




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June 11, 1935. A. A. THOMAS 2,004,735

LOUD SPEAKER

Filed July 27, 1923 2 Sheets-Sheet 2

Fig.9

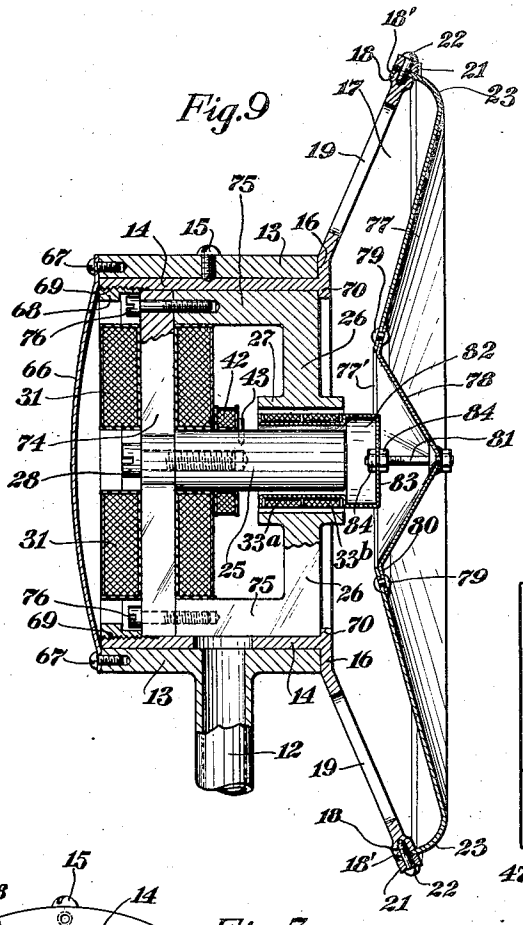



Fig.10

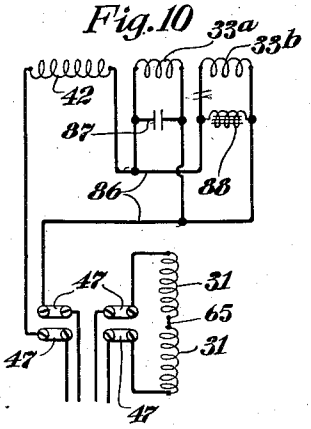



Fig.7

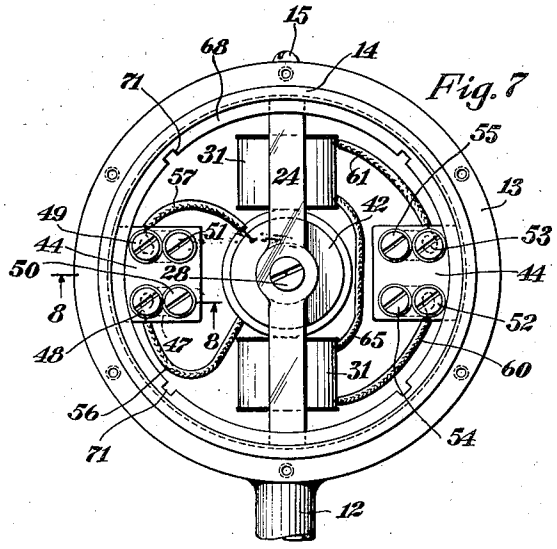
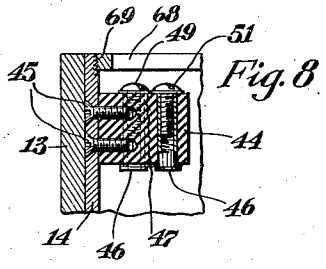



Fig.8




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# UNITED STATES PATENT OFFICE

2,004,735

## LOUD SPEAKER

Adolph A. Thomas, New York, N. Y., assignor to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application July 27, 1928, Serial No. 295,638

11 Claims. (Cl. 179—115.5)

My invention relates to loudspeakers of the so-called dynamic type, in which the diaphragm is operated by a speech coil movable in a magnetic airgap. In prior loudspeakers of this kind, there is a central pole piece which carries a fixed magnetizing coil, and a vibratory speech coil surrounds this pole piece. In other words, the two coils are mounted in axial alignment on the same magnetic core and are thereby closely coupled magnetically. Consequently, the variable magnetic flux produced by the current impulses in the speech coil reacts with maximum transformer effect on the field coil and causes a magnetic disturbance with resultant distortion in the acoustic reproduction.

One of the objects of my invention is to overcome the foregoing difficulty by eliminating or minimizing the inductive effect between the field coil and the speech coil of a dynamic speaker. For this purpose I provide a magnetic field structure in which the magnetizing coil is at right angles to the speech coil, whereby the inductive action of the latter on the field winding is reduced to a negligible quantity. If desired, a separate neutralizing coil connected in the talking circuit may be mounted on the central pole piece over which the speech coil vibrates. This neutralizing coil produces a variable magnetic flux adapted to oppose and neutralize as much as possible the electromagnetic reaction of the speech coil on the normal field flux passing through the pole piece.

Another feature of my new loudspeaker comprises a speech coil with two windings adapted to accentuate, respectively, the upper and the lower tonal registers, so that the instrument reproduces the entire musical scale with substantially uniform efficiency. The speech coil is preferably mounted directly on the diaphragm and is held in operative position by a light non-magnetic shell of novel construction.

My invention also comprises a loudspeaking cone diaphragm of novel construction and improved operation. The central or main body of the cone is surrounded by a reversely bent flange which acts like an elastic ring to support the main body of the diaphragm for vibratory movement. This diaphragm may be a compound structure, having a central conical section in reverse relation to the surrounding conical section and preferably of different material. The central section responds best to the higher frequencies, and the outer section to the lower frequencies, so that the resultant reproduction covers the entire musical scale with practically equal fidelity.

Various other practical features and advantages of my invention will become apparent from a detailed description of the embodiments shown in the accompanying drawings, in which—

Fig. 1 shows a vertical cross-section of a loudspeaker constructed in accordance with my invention;

Fig. 2 is a detached face view of the field magnet frame embodied in Fig. 1;

Fig. 3 is a detached perspective view of the cylindrical mounting for the vibratory speech coil;

Fig. 4 indicates diagrammatically the circuit connections of the coils shown in Fig. 1;

Fig. 5 illustrates a detached face view of a modified construction of magnetic field frame in which the body of the magnet is laminated;

Fig. 6 is a plan or edge view of Fig. 5;

Fig. 7 shows a rear view on line 7—7 of Fig. 1;

Fig. 8 is a fragmentary view in section on the broken line 8—8 of Fig. 7;

Fig. 9 illustrates a modification, partly in vertical section; and

Fig. 10 is a diagram of circuit connections for the coils embodied in the construction of Fig. 9.

Referring to Fig. 1, there is a base 10 provided with a hollow post 12 which carries a cylindrical housing 13. The parts 10, 12 and 13 may be formed as a single casting of non-magnetic material, such as aluminum, brass, bakelite and others along the same line. To make the instrument stable, the flaring base 10 should preferably be weighted, or it can be made of heavy metal separate from the post 12 and housing 13. The base 10 and post 12 may be cast in one piece of heavy metal, like brass, and the housing 13 may be a separate casting of light metal, like aluminum. In that case, the post 12 and housing 13 can be separably connected by a screw-threaded joint. A cylindrical casing 14 fits snugly in housing 13 and is held in fixed position therein by a set-screw 15, or in any other practical way. An integral annular shoulder 16 on casing 14 forms a stop to limit the axial movement of the casing into the supporting housing 13. The casing 14 is provided with a conical extension 17, which terminates in a ring 18 having a face or contact edge 18' arranged at an angle with respect to the axis of the casing. The conical extension 17 may be solid, or it may have openings 19 for the emission of sound. The ring 18 is adapted to receive the edge of a cone diaphragm 20, and a conical ring 21 fits over the edge of the diaphragm to secure the same against the conical annular shoulder 18' of the flaring extension 17. Screws 22 or

other fastening members hold the ring 21 against the shoulder 18, so that the edge of the diaphragm is firmly clamped between those two parts. The casing 14 and its conical extension 17 are preferably cast or molded as a unit from any practical material, metal or composition, as examples of which I may mention aluminum and bakelite. It is also possible to form the casing 14 with its extension and shoulders from sheet metal, such as brass.

The diaphragm 20 has a cone-shaped body with a reversely turned flange 23, which acts like an elastic ring for supporting the main or central section of the diaphragm for vibratory movement with substantially uniform amplitude over its entire surface. The diaphragm 20 may consist of suitable sheet material, such as paper, celluloid, varnished fabric, sheet metal like brass or aluminum, and other materials suitable for acoustic reproduction. It will be noticed that the inverted flange 23 turns backward at a substantial angle. The practical effect of this construction is to place the conical flange 23 under tension when the edge of the diaphragm is clamped to ring 18. Expressing this differently, I might say that the tensioned elastic flange 23 exerts an outward radial pull on the main body of the diaphragm, whereby the latter is held constantly under tension. The flange 23 may therefore be described as an annular tensioning support for the main body of the diaphragm, and it is preferably an integral resilient extension of the diaphragm, although it can be made separate and of a different material. For instance, the body of the diaphragm can be made of heavy paper or stiffened fabric, and the annular tensioning flange 23 may consist of thin sheet metal, which will hold the central non-metallic body constantly under tension in all kinds of weather. The diaphragm 20 may be less than nine inches across to give loudspeaker reproduction of adequate volume. The arrangement of the coacting conical rings 18 and 21 makes it very easy to attach and remove the diaphragm.

The casing 14 carries a field magnet structure indicated as a whole by M and comprising a U-shaped base frame 24 provided with lateral limbs 24', a central cylindrical pole piece 25, and a polar cross-arm 26 formed with a central ring 27. A screw 28 secures the central pole piece 25 to the U-shaped frame 24, and the cross-arm 26 is attached by screws 29 to the side limbs 24' of frame 24. The parts 24, 25 and 26 of the field magnet are preferably made of metal having a high magnetic permeability, and the screws 28 and 29 may also be of magnetic material. The cross-arm 26 with its central ring 27 is best made as a single casting, and the U-shaped frame 24 may be solid or laminated. If solid, this frame may be a casting, or bent into shape from a straight bar. If the frame 24 is built up of laminations, as shown at 24*a* in Figs. 5 and 6, the cross-arm 26 is attached to the laminated frame by providing the ends of the arm with slots 26' adapted to receive the ends of the frame in a tight fit, and bolts or rivets 30 secure the parts together.

Two magnetizing coils 31 are mounted on the cross-arm 26 on opposite sides of the central ring 27. These coils are connected in a circuit of substantially constant current to produce a magnetic field in which the cylindrical projection 25 constitutes one pole and the ring 27 the other pole. For convenience I have assumed in Figs. 2 and 5 that the polar projection 25 is a north pole, and the ring 27 a south pole, but the polarities may be reversed. The pole piece 25 and ring 27 are substantially concentric and provide an annular airgap 32 sufficiently wide to accommodate a coil 33 for axial movement therein. It will be convenient to refer to coil 33 as the speech coil to distinguish it from the magnetizing coils 31. I do not, of course, mean that coil 33 is confined to the reproduction of speech, but a speech coil is one that is connected in a circuit of variable current impulses which are to be translated into sound or other movements.

The vibratory coil 33 is mounted on a light cylindrical shell indicated as a whole by 34, and best shown in the perspective view of Fig. 3. The shell 34 comprises a main section 35, an enlarged extension 36 and a conical flange 37. The cylindrical sections 35 and 36 are separated by an annular shoulder 38, and the free end of section 35 terminates in lugs 39. It is desirable to make the shell 34 as light as possible, and it should be non-magnetic. This shell may be spun of sheet brass or aluminum as a single member, or it may be shaped in one piece from fiber, paper pulp, stiff paper, celluloid, bakelite, and other non-magnetic materials suitable for the purpose. If the shell is of metal, the section 35 is preferably slotted, as indicated at 40, to cut down the disturbing effect of eddy currents. The coil 33 is mounted directly on section 35 of shell 34, and is rigidly held between the shoulder 38 and lugs 39. Normally, the lugs 39 are axial extensions of cylinder 35, and they are bent laterally against the coil 33 after the latter has been slipped in place. This makes it possible to use a machine-wound coil. The coil-retaining means 39 need not be in the form of spaced lugs or projections, but may be a continuous lateral flange spun or turned over at the edge of shell 34 after the coil has been inserted. If desired, the coil 33 may be wound directly on shell 34 by mounting the latter on a mandrel in a winding machine. The conical flange or enlargement 37 serves as means for attaching the shell 34 to the cone diaphragm 20. Rivets 41 may be used to secure the flange 37 to the diaphragm, but it is possible to connect these parts by cement or otherwise, depending on the material of the diaphragm. The shell 34 is thus rigidly attached to the center of diaphragm 20 and held in axial alignment with the central pole piece 25, so that no portion of coil 33 and shell 34 shall strike the surrounding pole pieces. As seen in Fig. 1, the outer surface of coil 33 is substantially flush with the enlarged cylindrical extension 36 of the supporting shell 34.

A compensating coil 42 may be mounted on the magnetic pole piece 25 to neutralize or oppose the variable magnetic field set up by the current impulses in speech coil 33. Since the coils 33 and 42 are closely coupled magnetically by the pole piece 25, on which they are axially arranged, it is evident that, by winding the coils in opposed relation and connecting them in series or parallel, the flux disturbances set up in the magnetic core 25 by the current impulses in coil 33 are neutralized by the opposing flux produced in core 25 by the current impulses in coil 42. While the vibratory coil 33 is long and thin so as to operate in a narrow airgap, the compensating coil 42 may be wound flat and thick to occupy minimum space in an axial direction. The coil 42 is rigidly held in place by a pin 43, or in any other practical way.

Referring to Fig. 7, it will be seen that the cylindrical casing 14 carries a pair of insulating blocks 44 arranged diametrically opposite and

secured by screws 45, or otherwise. These blocks are preferably molded from suitable insulating material, like bakelite, porcelain, fiber, glass and so on. Each insulating block carries two pairs of screw-threaded metal sleeves 46, which are electrically connected at one end by a metal plate 47. Into the metal sleeves 46 are inserted connecting screws which I have indicated consecutively by the reference numerals 48—55. The screws 48—55 act as binding posts for conductors marked 56—63, respectively. These circuit connections are best shown in Fig. 4, where it will be seen that conductor 56 connects one end of the vibratory speech coil to binding post 48, conductor 57 connects one end of the compensating coil 42 to binding post 49, conductor 60 connects one end of magnetizing coils 31 to binding post 52, and conductor 61 connects the other end of those coils to binding post 53. The coils 33 and 42 are connected in series by conductor 64, and the magnetizing coils 31 are connected in series by conductor 65. If the compensating coil 42 is omitted, conductor 57 goes to the other end of speech coil 33. The leads 58 and 59 connect the coils 33 and 42 in the output circuit of an electric vibratory system in which electric impulses are translated into sound. The other pair of leads 62 and 63 connect the magnetizing coil or coils 31 in a circuit of substantially constant current for producing a magnetic field of the required strength. The binding posts 48—55 are fully accessible when the back cover plate 66 is removed from the cylindrical housing 13. Screws 67 secure the cover plate 66 in place and yet permit easy removal thereof. The cover plate 66 is preferably of non-magnetic sheet metal like brass, aluminum and the like.

The magnetic frame M is rigidly held in casing 14 by a ring 68, which is in adjustable screw-threaded engagement with the inner wall of the casing, as indicated at 69. By simply tightening the ring 68, the magnet frame is rigidly clamped within the casing 14 between the ring and the annular shoulder 70 of the casing. The inner shoulder 70 is in effect a continuation of the outer shoulder 16 previously referred to. The ring 68 is provided with recesses 71 to permit the insertion of a suitable tool for screwing the ring into and out of the casing. The supporting post 12 is preferably hollow to receive the circuit leads 58, 59, 62 and 63, which may be enclosed in an insulating tube 72 to form a single cable. The casing 14 has a hole 73 in line with the hollow post 12 to permit the insertion of the conductors into the casing for connection to binding posts 50, 51, 54 and 55.

The operation of the loudspeaker above described will be clearly understood by those who are familiar with the art of electric sound reproduction, and I need only say that, when current impulses pass through the speech coil 33, the latter vibrates axially in the annular magnetic airgap 32. The amplitude and direction of vibration depend on the strength and direction of the current flowing through the coil at any instance. Since the coil 33 is rigidly connected to the diaphragm 20, the vibratory movements of the coil are accompanied by corresponding movements of the diaphragm. As the magnetizing coils 31 are at right angles to the speech coil 33, the transformer or inductive effect between these coils is reduced to a minimum and can be practically eliminated in a properly designed instrument. The neutralizing action of coil 42 on core 25, as already explained in detail, supplements the neutralizing action of the right angled relation between coils 31 and 33 to eliminate the magnetic disturbances that would otherwise be produced by the variable currents in coil 33. Consequently, the resultant reproduction is not only free from distortion, but is of substantially equal efficiency over the whole audio-frequency scale.

In the modification of Fig. 9, the magnetizing coils 31 are mounted on an arm 74, to which the central pole piece 25 is connected. The polar arm 26 is in this construction provided with lateral extensions 75, which are connected to the ends of arm 24 by bolts or screws 76. By comparing Figs. 1 and 9, it will be seen that the field magnet structure is practically the same, except that in the first case the frame 24 is U-shaped and in Fig. 9 the polar arm 26 is U-shaped. Considered mechanically, however, the two constructions are substantially alike. By mounting the magnetizing coils 31 in Fig. 9 on the base member 74, they are still at right angles to the speech coil 33, and they have the additional advantage of being farther removed from the speech coil, so that the variable magnetic flux produced by the speech coil cannot interlink with the turns of the magnetizing coils, at least not to any appreciable extent. Since the mounting of the field magnet in Fig. 9 is the same as in Fig. 1, it will not be necessary to repeat a detailed description of that mounting. It is sufficient that corresponding parts in Figs. 1 and 9 are indicated by like reference numerals. The same remarks apply to like parts in the circuit diagrams of Figs. 4 and 10, the latter relating to Fig. 9.

The cone diaphragm 77 of Fig. 9 has a central conical portion 78 arranged reversely with respect to the main body of the diaphragm and preferably of different material. The purpose of the compound diaphragm 77—78 is to make it respond with equal efficiency to high and low frequencies. Thus, the main body of the diaphragm 77 may be made of stiff paper, or other material adapted to respond best at low frequencies, while the central conical portion 78 is made of thin sheet metal like brass, aluminum, or other material adapted to operate most efficiently on the higher frequencies. The central cone 78 covers an opening 77′ of the diaphragm and is secured to the surrounding body by rivets 79, or by cementing the two parts together. The conical section 78 has an outer flange 80 adapted to lie flat against the main portion of the diaphragm to permit the two parts to be securely connected in any practical way. The central cone 78 of the diaphragm carries a bolt or rod 81 to which a cylindrical shell 82 is rigidly connected. The shell 82 is similar to shell 34 of Fig. 3, except that, instead of a conical flange 37, it has a head 83 which is clamped between nuts 84 on bolt 81. Otherwise, what was said about shell 34 applies to shell 82.

The speech coil supported on shell 82 in Fig. 9 may be a single coil, but in certain constructions I prefer to make the speech coil of two windings, marked 33*a* and 33*b* in Figs. 9 and 10. These windings are connected in parallel between a pair of conductors 86 and in series with the compensating coil 42, if the latter is used. The winding 33*a* is shunted by a condenser 87, and the winding 33*b* is shunted by an inductance or choke-coil 88. This arrangement renders the windings 33*a* and 33*b* most efficiently responsive to low and high frequencies, respectively. In other words, we have here a speech coil composed of sections which operate individually with higher efficiency over certain bands of frequencies, so that the coil

as a whole reproduces to the musical scale with substantially uniform efficiency. By connecting such a coil to a diaphragm having different sections adapted to respond best at different frequencies, like diaphragm 77—78, we have a loudspeaker capable of reproducing low notes and high notes with equal fidelity and with the same degree of energy.

Although I have shown and described certain specific constructions, I want it understood that my invention is not limited to the details set forth. It is expected that changes and modifications will occur to those skilled in the art, without departing from the scope of the invention as defined in the appended claims.

I claim as my invention:

1. In a telephone instrument, a magnetic frame having three polar limbs, a magnetic arm connecting the two outer limbs, said arm being formed at the center with a ring, the third limb constituting a central pole piece projecting into said ring to form an annular airgap, and a magnetizing coil mounted on said frame at right angles to said central pole piece.

2. A loudspeaker comprising a field magnet frame having pole pieces arranged to form an annular airgap, a speech coil movable axially in said airgap, a magnetizing coil mounted on said field frame at right angles to said speech coil, and a diaphragm operated by said speech coil.

3. In a loudspeaker, a field magnet structure comprising a substantially rectangular frame which includes a pair of cross-arms and a central pole piece connected to one of said arms, the other cross-arm being provided with a ring into which said pole piece extends to form an annular airgap, a speech coil movable axially in said airgap, a magnetizing coil mounted on one of said cross-arms at right angles to said speech coil, and means for converting the vibrations of said speech coil into sound.

4. In a loudspeaker, a field magnet structure comprising a substantially rectangular frame which includes a pair of cross-arms and a central pole piece connected to one of said arms, the other cross-arm being provided with a central enlargement in the shape of a ring into which said central pole piece extends to form an annular airgap, a speech coil movable axially in said airgap, a pair of magnetizing coils mounted on one of said cross-arms on opposite sides of said central pole piece and at right angles to said speech coil, and a diaphragm operated by said speech coil.

5. In a loudspeaker, the combination of a field magnet structure having a central cylindrical pole piece and a surrounding annular pole piece, so that said pole pieces form an annular airgap, a speech coil mounted to vibrate axially in said airgap, a magnetizing coil mounted on said field structure at right angles to said speech coil, a fixed compensating coil mounted on said central pole piece and connected in circuit with said speech coil in magnetically opposed relation, and a diaphragm operated by said speech coil.

6. In a loudspeaker, a diaphragm carrying a shell provided with axial slots, a coil mounted on said shell, and a magnetic field structure having an annular airgap in which said coil vibrates.

7. As a means for supporting a vibratory coil in loudspeakers of the moving coil type, a one-piece non-magnetic shell having a rigid head at one end for attachment to a diaphragm and laterally adjustable lugs at the other end, an annular shoulder on said shell between its ends, said lugs and shoulder forming an annular space for a coil which is locked in place by said lugs and shoulder, said lugs being normally axial to permit mounting of the coil on the shell, whereupon said lugs are bent laterally to engage the adjacent end of the coil.

8. A loudspeaker comprising a base, a cylindrical housing on said base, a cylindrical casing removably mounted in said housing and rigidly held therein, an electromagnetic field frame supported in said casing, said frame being slidable as a unit into and out of said casing, an adjustable member removably mounted on one end of said casing for holding said field frame rigidly in position, polar projections on said frame arranged to provide an annular airgap, a conical extension on the other end of said casing, a cone diaphragm secured at its edge to said extension, and a coil connected to said diaphragm and movable axially in said airgap.

9. A loudspeaker comprising a base, a cylindrical housing on said base, a unitary casting having a cylindrical body and a conical extension, said body forming a casing adapted to fit into said housing, a shoulder on said casting arranged to engage said housing to determine the position of said casing in the housing, releasable means for locking said casing in the housing, an electromagnetic field structure mounted in said casing, a fixed inner shoulder at one end of the casing and a removable screw-threaded ring at the other end, said field structure being rigidly held between said shoulder and said ring, polar projections on said field structure to provide an annular airgap in axial alignment with said cylindrical casing, a diaphragm connected to said conical extension, and a coil mounted on said diaphragm and arranged to vibrate axially in said airgap.

10. A loudspeaker comprising a cylindrical casing provided with a conical extension, a diaphragm carried by said extension, a magnetic field frame mounted in said casing and rigidly held therein, said magnetic frame having pole pieces to provide an annular airgap, a coil connected to said diaphragm and arranged to vibrate in said airgap, and means whereby said frame is insertable into and removable from said casing as a unit without disturbing said coil and diaphragm.

11. As a means for attaching a coil to a cone diaphragm in loudspeakers of the moving coil type, a one-piece non-magnetic form comprising a cylindrical body provided at one end with an integral conical extension adapted to be attached to the central portion of a diaphragm, said cylindrical body being shaped of sheet material of substantially uniform thickness and having an offset portion adapted to receive a coil, and integral shoulders on said form arranged to engage opposite ends of the coil and thereby lock the same in place.

ADOLPH A. THOMAS.