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COAXIAL, DUAL UNIT, ELECTRODYNAMIC LOUD-SPEAKER

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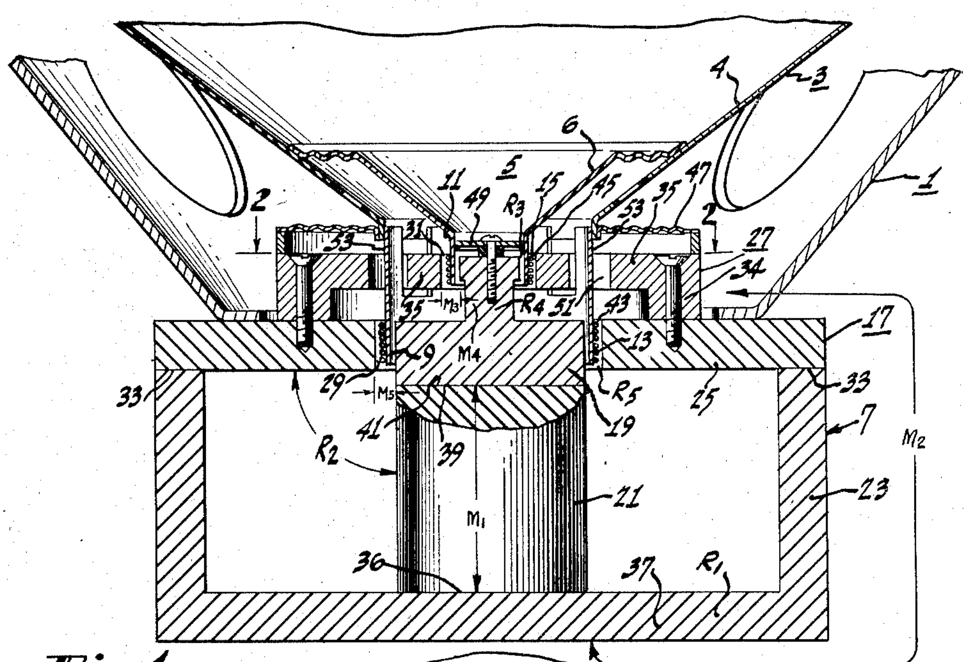

Fig. 1.

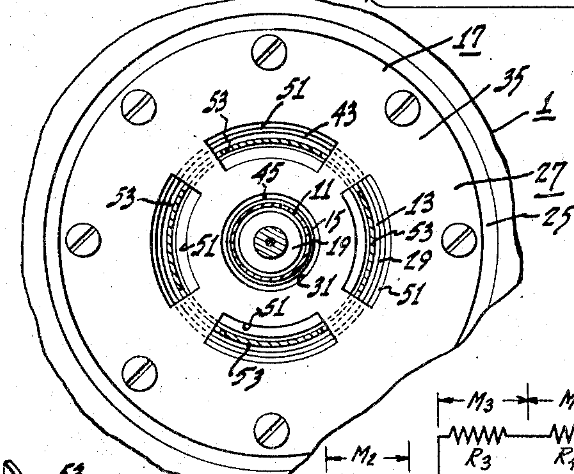

Fig. 2.

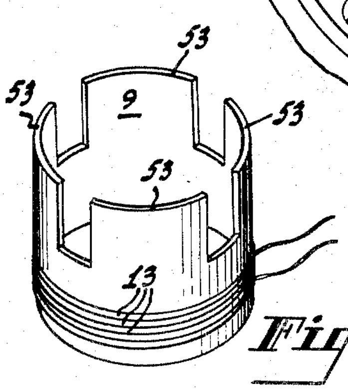

Fig. 3.

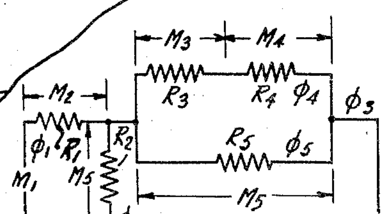

Fig. 4.

INVENTORS
HARRY F. OLSON
& JOHN PRESTON
BY Morris L. Rabkin
ATTORNEY

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COAXIAL, DUAL UNIT, ELECTRODYNAMIC LOUD-SPEAKER

Harry F. Olson, Princeton, and John Preston, Metedeconk, N. J., assignors to Radio Corporation of America, a corporation of Delaware

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6 Claims. (Cl. 179—115.5)

The present invention relates to loudspeakers, and more particularly to an improved magnetic structure for coaxial, dual unit, electrodynamic loudspeakers of the type disclosed, for example, in our copending applications Serial Numbers 51,962 and 90,464, the application secondly identified having issued as Patent No. 2,539,672 on January 30, 1951, filed, respectively, September 30, 1948 and April 29, 1949.

In sound translating apparatus of this kind, a plurality of diaphragms are employed, each of which functions to reproduce sound waves in a different frequency range. Voice coils, which are suspended in separate air gaps provided by a magnetic field structure, are attached to the diaphragms for producing vibratory movement thereof, the apparatus operating to reproduce sound in a manner well known in the art.

As disclosed in the aforesaid copending applications, it has been found advantageous to supply magnetic flux to two air gaps from a single magnetic source rather than from separate sources. Since the magnetic flux producing element is a major item in loudspeaker production cost, especially when it is of the permanent magnet type, it will be apparent that further advantages in lower cost production may be derived from increasing the efficiency of the magnetic structure and thereby reducing the size of the magnetic energizing unit required for a duo-cone loudspeaker having a given output.

Therefore, a primary object of the present invention is to provide an improved magnetic structure for a coaxial, dual unit, electrodynamic loudspeaker.

It is another object of the present invention to improve the efficiency of the magnetic circuit in a duo-cone, dynamic loudspeaker.

It is a further object of the present invention to provide an improved magnetic structure for a duo-cone dynamic loudspeaker which permits a greater percentage of useful flux to be distributed to the air gaps relative to that dissipated in leakage.

It is also an object of the present invention to provide an improved, simplified magnetic structure for a duo-cone, dynamic loudspeaker which is highly efficient in use, and which will effect a saving in cost of production.

The improved magnetic field structure is particularly useful for a dynamic loudspeaker having a plurality of separately driven, overlapping, nested cone type diaphragms. In accordance with this invention, there are provided a plurality of additional apertures in spaced array around the central aperture of one of two parallel, spaced apart outer pole piece members. Portions of the voice coil form associated with one of the diaphragms are inserted through the additional apertures to permit disposing the voice coil for that diaphragm within an air gap provided in the other outer pole piece member. With this arrangement, a closer spacing of the two outer pole piece members can be made with the result that the structure has greater magnetic efficiency.

The novel features characteristic of the present invention, as well as additional objects and advantages thereof, will be better understood from the following detailed description of a single, preferred embodiment thereof when read in connection with the accompanying drawing, in which

Figure 1 is a central, sectional view taken axially through a duo-cone, dynamic loudspeaker embodying the present invention, portions of the dishpan support and one of the diaphragms being cut away,

Figure 2 is a sectional view taken on the line 2—2 of Figure 1,

Figure 3 is a perspective view of the larger voice coil and voice coil form of the loudspeaker shown in Figure 1, and

Figure 4 is a wiring diagram of an electrical circuit corresponding to the magnetic network of the loudspeaker magnetic system shown in Figure 1.

Referring more particularly to the drawing, wherein similar reference characters designate corresponding parts throughout, there is shown a dynamic loudspeaker **1** comprising two nested, overlapping, truncated cone diaphragms **3, 5** mounted in concentric, spaced apart relation and a magnetic field structure **7**. The cone diaphragms **3, 5** are of different sizes, the large diaphragm **3** comprising a vibratory, sound generating section **4** which is particularly adapted for producing sound waves within a predetermined range of low frequencies, while the small diaphragm **5** comprises a vibratory, sound generating section **6** which is particularly adapted for producing sound waves within a predetermined range of high frequencies. The diaphragms **3, 5** also include voice coil sections consisting of cylindrical or tubular voice coil forms **9, 11** of relatively greater and lesser diameters and attached, respectively, to the apex ends of the diaphragms **3, 5**. Voice coils or windings **13, 15** are disposed respectively on and adjacent the voice coil forms **9** and **11** remote from the sound generating sections of the diaphragms. Any suitable support may be provided for mounting the diaphragms **3, 5** so that they can move substantially only in axial directions and be free to vibrate in well known manner to produce sound waves.

The magnetic field structure **7** comprises an outer pole piece unit **17**, a central pole piece **19**, and a magnetic core **21** connecting the pole piece unit **17** and the central pole piece **19**. The outer pole piece unit **17** is constituted of a magnetically permeable material and comprises a yoke **23** and a pair of outer pole piece members **25, 27** having, respectively, central apertures **29, 31** of different diameters. The outer pole piece member **25**, sometimes referred to herein as "the first pole piece," has the larger diameter central aperture **29** and comprises an annular plate mounted to span the ends **33** of the yoke **23**, the pole piece **25** being fastened to the yoke **23** in any suitable manner. The other outer pole piece member **27**, sometimes referred to herein as "the second pole piece," comprises an inverted, cup-like member. The cup-like second pole piece **27** is mounted on the first pole piece **25** with the peripheral flange portion **34** thereof in contact with the upper side or face of the first pole piece **25**, as shown in Figure 1, its annular, plate-like portion **35** surrounding the central aperture **31** and being spaced from the first pole piece **25**. The central apertures of both pole pieces **25, 27** are aligned along a common axis which corresponds to the common axis of the diaphragms **3, 5**.

The magnetic core **21** comprises a cylindrical member of suitable permanent magnet material. The core **21** is mounted centrally within the yoke **23** with one end **36** thereof attached to the yoke base **37**. The central pole piece **19** comprises a member of magnetically permeable material having one end **39** thereof mounted on the opposite end **41** of the core **21**. The central pole piece **19** extends through both central apertures **29, 31** in spaced relation to the pole pieces **25, 27** so as to provide separate annular air gaps **43, 45** therebetween. Since the central apertures **29, 31** are, respectively, of greater and lesser diameters, the portion of the central pole piece disposed within the larger air gap **43** is larger in diameter than its opposite end portion disposed within the smaller air gap **45**. Thus, the central pole piece **19** may be said to comprise a member of inverted T formation in cross section, as shown in Figure 1.

The voice coil **13** mounted on the larger voice coil form **9** and the voice coil **15** mounted on the smaller voice coil form **11**, are suspended, respectively, within the larger and smaller air gaps **43, 45**. Flexible members **47, 49** are provided for supporting, respectively, the voice coil forms **9, 11** and for maintaining them centered within the air gaps while permitting them to move axially. Since the larger voice coil **13** is located on the opposite side of the smaller pole piece member **27** from that on which the larger diaphragm **3** is disposed, a plurality of additional apertures **51** are provided in the pole piece **27** in spaced array around the central aperture **31**. Web sections remain between the apertures **51**, as shown. As shown particularly in Figure 3, the end portion of the greater diameter voice coil form **9** to which the diaphragm **3** is attached is crenelated or cut away to form, at one end thereof, a plurality of circumferentially spaced, longitudinally extended portions or elements **53** of arcuate cross section. In assembly, the transversely arcuate extensions **53** are inserted through the apertures **51** so that the voice coil **13** is disposed within the larger air gap **43** located on one side of the outer pole piece member **27** and the free ends of the extensions **53** are on the opposite side of the outer pole piece member.

The magnetic circuit of the loudspeaker **1** may be represented by a circuit diagram as shown in Figure 4, in which:

M_1=magnetomotive force of the magnet, in gilberts;

M_2=magnetomotive force drop through the yoke and the outer portion of the larger outer pole piece up to the region where the smaller outer pole piece is supported on the larger outer pole piece, in gilberts;

M_3=magnetomotive force across the smaller air gap, in gilberts;

M_4=magnetomotive force drop through the central pole piece and the smaller outer pole piece, in gilberts;

M_5=magnetomotive force across the larger air gap, in gilberts;

R_1=reluctance drop in the yoke and the outer portion of the larger outer pole piece up to the region where the smaller outer pole piece is supported on the larger outer pole piece;

R_2=reluctance of leakage flux path across the space within the magnetic field structure and around the magnet exclusive of the larger air gap;

R_3=reluctance of the smaller air gap;

R_4=reluctance of the central pole piece and the smaller outer pole piece;

R_5=reluctance of the larger air gap;

ϕ_1=total lines of flux delivered by the magnet, in maxwells;

ϕ_2=leakage lines of flux across the space within the magnetic field structure and around the magnet exclusive of the larger air gap, in maxwells;

ϕ_3=total lines of flux through the two air gaps, in maxwells;

ϕ_4=total lines of flux through the smaller air gap, in maxwells;

ϕ_5=total lines of flux through the larger air gap, in maxwells.

The total flux through the two air gaps is represented by the equation:

$$\phi_3=\frac{M_1 R_2}{R_1 R_2+R_1 R_6+R_2 R_6} \qquad (1)$$

The reluctance of the combination of the smaller air gap in series with the central pole piece and this combination in shunt with the larger air gap is represented by the equation:

$$R_6=\frac{R_5(R_3+R_4)}{R_3+R_4+R_5} \qquad (2)$$

The equation representing the magnetomotive force of the larger air gap is:

$$M_5=\phi_3 R_6 \qquad (3)$$

The flux in the larger air gap is represented by the equation:

$$\phi_5=\frac{M_5}{R_5}=\frac{\phi_3 R_6}{R_5}=\phi_3\left(\frac{R_3+R_4}{R_3+R_4+R_5}\right) \qquad (4)$$

The flux in the smaller air gap is represented by the equation:

$$\phi_4=\frac{M_5}{R_3+R_4}=\frac{\phi_3 R_6}{R_3+R_4}=\phi_3\left(\frac{R_5}{R_3+R_4+R_5}\right) \qquad (5)$$

The flux density in the larger air gap is:

$$B_5=\frac{\phi_5}{A_5} \qquad (6)$$

where A_5=area of the larger air gap, in centimeters.

The flux density in the smaller air gap is:

$$B_3=\frac{\phi_4}{A_3} \qquad (7)$$

where A_3=area of the smaller air gap, in centimeters.

From the above equations, it will be recognized by persons skilled in the art that any practical ratio of flux densities may be obtained by a suitable selection of the values for R_4. With the arrangement of the outer pole piece members **25**, **27** as described above, the value of R_4 can be varied by altering the diameter of the portion of the central pole piece **19** below the small air gap. The magnetic efficiency of the structure is high because less flux is dissipated in leakage. Therefore, a greater percentage of useful flux will be supplied to each of the air gaps. The reason less flux is dissipated in leakage, as compared to other multiple gap structures, is that the large and small pole pieces and outer structures operate at substantially the same magnetic potential. With the increase in magnetic efficiency, it is not necessary to employ as large a magnet to produce equivalent flux densities in the two air gaps. A considerable saving in cost of production will result because a major portion of the material cost resides in the magnet.

Although there is illustrated and described but a single embodiment of the present invention, it will be recognized by persons skilled in the art that various modifications and changes are possible within the spirit of the invention. For example, it may be found desirable to make the large diaphragm and the large voice coil form an integral structure, in which case, portions of the voice coil form may be cut away intermediate the ends thereof. It may also be found desirable to provide slots in the small outer pole piece **27** which extend radially outwardly from the periphery of the large central aperture instead of arcuate openings. Other changes of like nature are possible within the spirit of our present invention. Therefore, it is desired that the particular form of the present invention described herein shall be considered as illustrative and not as limiting.

What is claimed is:

1. A loudspeaker comprising an inner diaphragm and an outer diaphragm, each diaphragm including a voice coil supporting section, means to mount said diaphragms for movement in directions along a common axis, and a magnetic field structure including a central pole piece and a pair of outer pole pieces, said outer pole pieces each having a central aperture therein, the portions of said outer pole pieces defining said central apertures being disposed in spaced relation to each other with their central apertures aligned along said common axis, said central pole piece extending through each of said central apertures in spaced relation to said outer pole piece portions to provide air gaps therebetween, one of said pole pieces having a plurality of additional apertures in spaced array around its said central aperture, portions of said voice coil supporting sections being disposed in separate ones of said air gaps, and other portions of said voice coil supporting section of said outer diaphragm extending through said additional apertures in said one pole piece.

2. A loudspeaker comprising an inner diaphragm and an outer diaphragm, each diaphragm including a sound generating section and a voice coil section connected to said sound generating section, means to mount said diaphragms with their longitudinal axes in common, and a magnetic field structure comprising a core, a pair of pole pieces mounted in axially spaced relation to each other, said pole pieces each having central apertures and being disposed in axially spaced relation to and around said core to provide separate axially spaced inner and outer air gaps, one of said pole pieces having a plurality of openings therein in spaced array around its central aperture, said voice coil sections being disposed each within a separate one of said air gaps, said voice coil section of said outer diaphragm being disposed within said inner air gap, at least a portion of said voice coil section of said outer diaphragm extending through said openings of said one pole piece.

3. A coaxial, dual unit loudspeaker comprising an inner diaphragm and an outer diaphragm, each diaphragm including a voice coil supporting section, means for mounting said voice coil supporting sections for movement in directions along a common axis, and a magnetic field structure including a central core, a first outer pole piece hav-

ing a plate portion provided with a relatively large central aperture, a second outer pole piece having a plate portion spaced from said first mentioned plate portion and provided with a relatively small central aperture, said apertures being axially aligned, and said central core being disposed within each of said central apertures in spaced relation to said first and second outer pole pieces to provide, respectively, first and second air gaps therebetween, said second outer pole piece having a plurality of additional apertures therein in spaced array about its central aperture, at least a portion of said coil supporting section of said inner diaphragm being disposed within the air gap provided by said second outer pole piece, the voice coil supporting section of said outer diaphragm having at least a portion thereof disposed in the other of said air gaps and at least another portion thereof extending through said additional apertures.

4. A loudspeaker having a pair of nested inner and outer diaphragms, each of said diaphragms having a tubular extension, a voice coil on each extension, a magnetic field structure having a central pole piece, said tubular extensions being disposed over said central pole piece, a second pole piece of opposite magnetic polarity with respect to said central pole piece surrounding said central pole piece and the tubular extension of said inner diaphragm, a third pole piece of opposite magnetic polarity with respect to said central pole piece surrounding said central pole piece and the tubular extension of said outer diaphragm, said second pole piece having a plurality of circumferentially spaced arcuate slots having a common center of curvature, web sections remaining in said second pole piece between said slots, said tubular extension of said outer diaphragm having axially disposed apertures therein, and said apertures accommodating said web sections between said spaced slots.

5. A loudspeaker having a diaphragm, said diaphragm having a tubular extension, a voice coil on said extension, a magnetic field structure having a central pole piece, said tubular extension being disposed over said pole piece, a second pole piece associated with said magnetic structure, said magnetic structure having a third pole piece of opposite magnetic polarity with respect to said central pole piece surrounding said central pole piece and the tubular extension of said diaphragm, said second pole piece having a plurality of circumferentially spaced arcuate slots having a common center of curvature, web sections remaining in said second pole piece between said slots, said tubular extension of said diaphragm having axially disposed apertures therein, and said apertures accommodating said web sections between said spaced slots.

6. A diaphragm having a body portion and a tubular extension for use in a loudspeaker, said tubular extension extending along the axis of said body portion, said tubular extension having a plurality of circumferentially arranged longitudinally disposed open slots, and said tubular extension being joined to said body portion substantially at the ends of said open slots.

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