Aug. 17, 1965 P. C. SURH 3,201,529

DYNAMIC SPEAKER

Filed Nov. 16, 1962 2 Sheets-Sheet 1

Fig. 1.

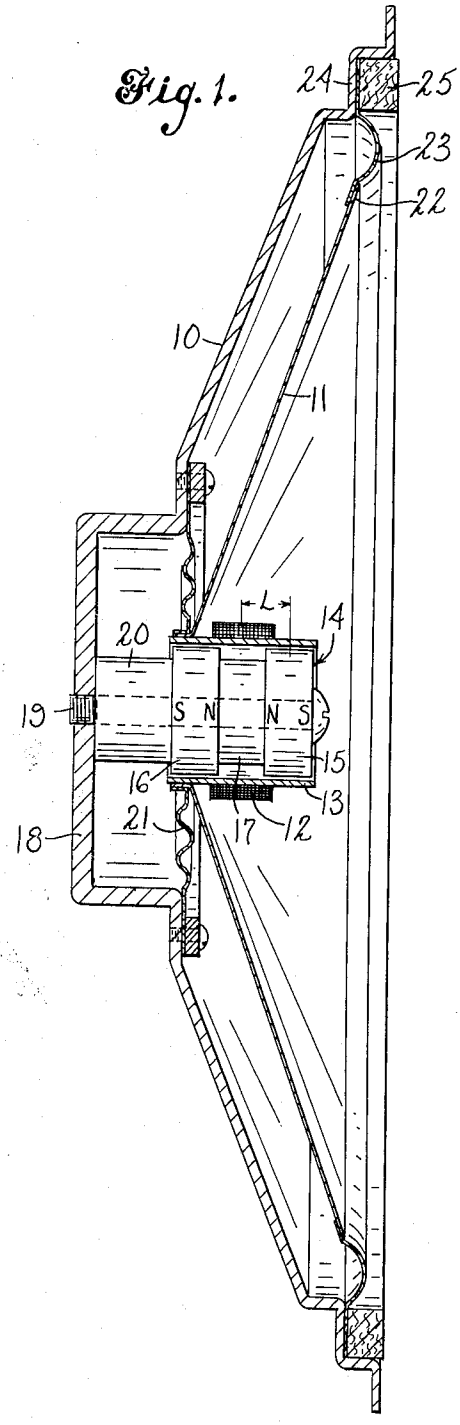

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Fig. 2.

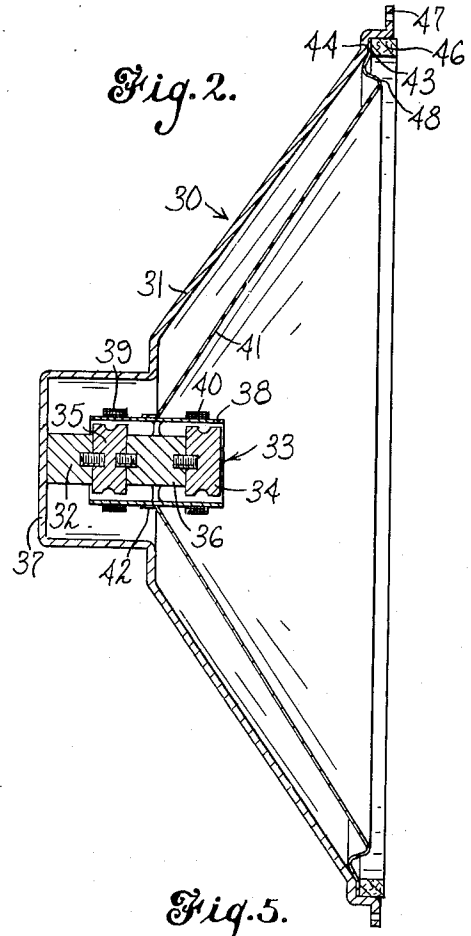

Fig. 3.

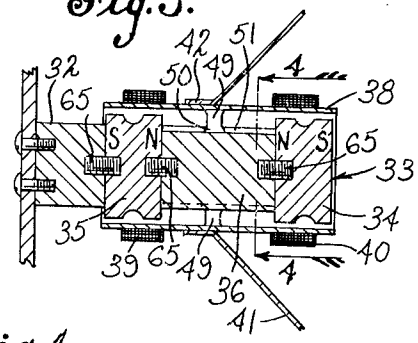

Fig. 4.

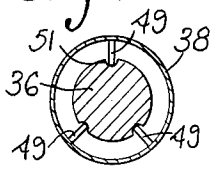

Fig. 6.

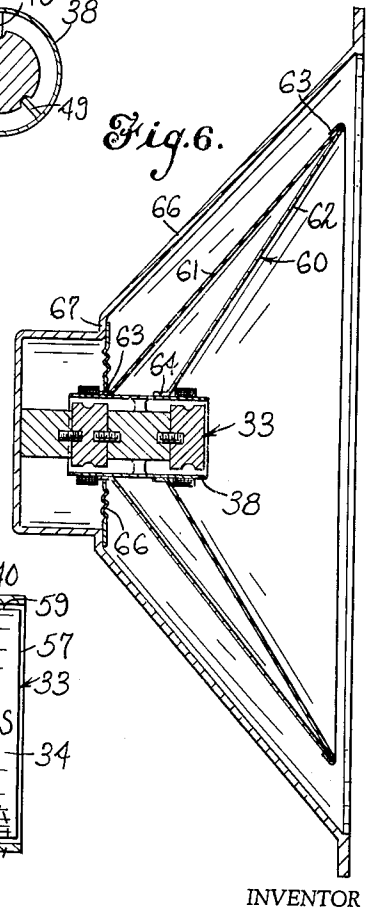

Fig. 5.

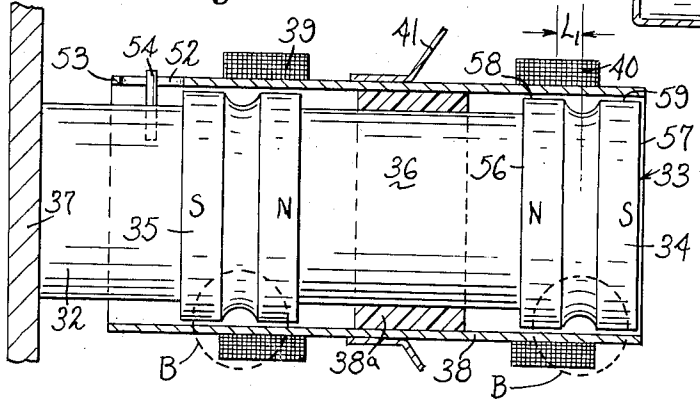

Fig. 7.

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DYNAMIC SPEAKER

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14 Claims. (Cl. 179—115.5)

This invention relates to loudspeakers, and more particularly relates to permanent magnet dynamic speakers.

The loudspeaker which finds most prevalent usage at the present time generally comprises a cylindrical permanent magnet, a magnetic flux return structure in flux conducting relation to the magnet and a voice coil wound on a form and positioned in a radial air gap defined between the magnet and the flux return structure. The magnetic flux return structure is usually a relatively large annular piece of mild steel of generally C-shape half abutting the magnet at one end thereof and defining an annular air gap about the magnet adjacent the other end thereof.

In the described construction, the voice coil-form with voice coil thereon resides in the air gap and the turns of the coil are essentially perpendicular to the magnetic flux traversing the annular air gap. When the coil carries current, a force is produced on the coil and hence the form tending to move the form perpendicular to the magnetic flux and out of the field of flux. This movement of the voice coil is due to the motor action of a current carrying conductor in a magnetic field.

This construction requires a large and relatively bulky and heavy loudspeaker due to the requirement of the flux return structure and additionally the air gap presents a limitation on the thickness of the voice coil and hence the number of turns thereof which limits the ampere turns of the voice coil and the moving force exerted on the voice coil.

The present invention provides a loudspeaker which does not require a magnetic flux return structure and hence does not have an air gap which limits the thickness and hence the turns of the voice coil. Elimination of the magnetic flux return structure decreases the weight and the bulk of the speaker structure. This invention further provides a new and improved dynamic speaker of simplified and economical construction wherein the voice coil is arranged to operate a new and improved push-pull arrangement with a permanent magnet assembly which relieves the rim compliance of the diaphragm of accommodating all diaphragm restoring functions and which in one form of the invention requires no supporting spider for the voice coil and the form upon which it is wound. The present invention provides a simplified dynamic speaker construction having no radial air gap wherein the voice-coil form is coaxially mounted about a permanent magnet assembly and movable axially therealong. The invention further provides an improved diaphragm structure which requires no supporting compliance or surround.

An object of this invention is to provide a new and improved dynamic speaker of simplified and economical construction.

Another object of this invention is to provide a dynamic speaker of a construction which requires no magnetic flux return structure.

A further object of this invention is to provide a dynamic speaker which has a new and improved push-pull movement of the voice coil form and the diaphragm mounted thereon.

A further object of this invention is to provide a new and improved dynamic speaker of a construction which requires no supporting spider for the loudspeaker voice coil or alternately, no supporting structure for the outer periphery of the diaphragm.

The novel features of the invention are pointed out with particularity in the claims appended to and forming part

of this specification. However, the invention, both as to its organization and operation, together with further objects and advantages thereof may best be understood by reference to the following detailed description taken in conjunction with the drawings wherein:

FIG. 1 is a side elevation, in section, of a dynamic speaker embodying the invention;

FIG. 2 is a side elevation, in section, of another dynamic speaker embodying the invention;

FIG. 3 is an enlarged view of a portion of the speaker of FIG. 2;

FIG. 4 is a view taken along section 4—4 of FIG. 3;

FIG. 5 is a view, similar to FIG. 3, in section of a modified form of the invention;

FIG. 6 is a side elevation, in section, of a dynamic speaker embodying the invention and also illustrating a diaphragm construction in accordance with the invention; and

FIG. 7 is an enlarged view, in section, of a diaphragm assembly embodying the invention.

To illustrate a first preferred embodiment of the invention, FIG. 1 illustrates a dynamic speaker comprising a frame 10, a frustro-conical diaphragm 11, a voice coil 12 on a cylindrical voice-coil form 13 and a magnet assembly 14. Voice-coil form 13 is formed of a material selected for rigidity and light weight. Magnet assembly 14 comprises a pair of axially spaced similar magnets 15 and 16 of generally disc configuration with similar poles adjacent. Magnets 15 and 16 are axially spaced apart with a washer-like spacer 17 of a nonmagnetic material. The magnet assembly may be mounted on base portion 18 of frame 10 as by means of a bolt 19 which axially passes through magnets 15 and 16, spacer 17 and another spacing member 20 of nonmagnetic material which magnetically isolates frame 10 from magnet assembly 14. The voice-coil form 13 is supported coaxially about magnet assembly 14 from frame 11 by a flexible spider 21.

The outer periphery 22 of diaphragm 11 is secured to a flexible surround or compliance 23 which is received between shoulder 24 of frame 10 and an annular gasket or cushioning ring 25.

The magnets 15 and 16 produce magnetic fields which are in opposition to each other. As illustrated, magnets 15 and 16 have the North N poles adjacently directed and their South S poles oppositely directed. Moreover, since the magnets 15 and 16 are of equal strength there will be a sharp definition between the fields of the magnets between adjacent poles of the individual magnets. When the current passes through voice coil 12, a magnetic field will be set up in opposition to the field of one of the magnets and additive or attractive with respect to the field of the other of the magnets. Then as the current through the voice coil varies the magnetic field set-up thereby, varies with the result that the additive and oppositive effect of the magnetic field of the coil with the magnetic fields of the magnets varies causing the voice-coil form 13 upon which voice coil 12 is wound to be attracted or pulled toward one magnet and repelled or pushed from the other magnet thereby producing movement of air by diaphragm 11 and resulting reproduction of sound.

It will be noted that in the position shown in FIG. 1, the position of the voice coil 12 is symmetric with respect to magnets 15 and 16 which is its normal position when the amplifier to which the voice coil is connected is drawing only quiescent current or is not operating. The maximum possible excursion of voice coil 12 and form 13 is defined by the dimension L between the midpoint of the axial length of the voice coil and the magnetic center of the magnets.

If desired, a dust cover may be provided over the magnet assembly or alternately, a dome radiator or small cone-type diaphragm could be mounted on the extending

end of voice-coil form 13 for better reproduction of higher frequencies.

It may be seen that the interaction of the opposed magnets and the varying magnetic field set-up varying current through the voice coil produce a push-pull effect on the voice coil, and voice-coil form thereby providing a rapid response to change in current in the voice coil and therefore good transient response in the reproduction of sound by movement of diaphragm 11 due to movement of voice-coil form 13.

The loudspeaker of FIG. 1 is easily and simply assembled and requires no large flux return structure. Moreover, there is no air gap which limits the radial thickness and therefore number of turns of the voice coil. It is thus readily apparent that this allows an increased number of ampere-turns of the voice coil and hence, establishment of a stronger magnetic field thereby. The length of the spacer 17 separating magnets 15 and 16 is determined by the size and quality of the magnets and the relative dimensions thereof.

Another embodiment, shown in FIG. 2, comprises a loudspeaker 30 having a frame member 31 supporting thereon a nonmagnet support member 32 which in turn supports a magnet assembly 33 having magnets 34 and 35 of generally cylindrical shape and spaced apart by a cylindrical shank member 36 of nonmagnetic material. This magnet and magnet-support assembly is mounted on base portion 37 of frame 31. Coaxially mounted about the axis of magnet assembly 33 is a cylindrical voice-coil form 38 of substantially the same length as magnet assembly 33. Wound about voice-coil form 38 is a voice coil comprising voice-coil sections 39 and 40. The voice-coil sections 39 and 40 are formed of equal numbers of turns and may be wound in either magnetic series aiding or series opposing relationship or connected in parallel as hereinafter explained.

Voice-coil form 38 is mounted on shank 36 of magnet assembly 33 and is movable longitudinally thereon, as hereinafter described. Mounted on voice-coil form 36 and carried thereby is a cone-type diaphragm 41 having a flange portion 42 at its inner edge securing the diaphragm to the voice-coil form 38. The outer edge or periphery 43 of diaphragm 41 is received between surface 44 of frame 41 and an annular mounted gasket or cushioning ring 46 in a conventional manner. Frame 41 further provides flanges 47 from mounting the frame on a suitable baffle, not shown, in a conventional manner. Diaphragm 42 further comprises a flexible compliance or surround portion 48. Compliance 48 may be made with a great degree of flexibility for reasons hereinafter explained.

In accordance with one aspect of the invention, the voice-coil form 38 is mounted on and freely movable along magnet assembly 33. As shown more clearly in FIGS. 3 and 4, extending radially inwardly from voice-coil form 38 are a plurality of angularly spaced ribs or support arms 49 having feet or tracks 50 thereon which are received in longitudinal grooves 51 defined in shank 36. This track and groove arrangement is provided to prevent any possible vibratory movement of voice-coil form 38, with respect to shank 36 and also to aid in centering the voice-coil form 38 with respect to the axis of magnet assembly. It will be noted that the speaker 30 utilizes no spider to support and center the voice-coil form with respect to the axis of the magnet assembly. The tracks 50 are preferably of a material having a very low coefficient of friction, such as polytetrafluoroethylene, to allow the voice-coil form to move freely on shank 36.

In an alternate form of construction in accordance with the invention (FIG. 5) the shank 36 of magnet assembly 33 may support the voice-coil form 38 thereon by means of a bushing or collar 38*a* carried by voice-coil form 38 which coaxially supports and spaces voice-coil form 38 from shank 36. In such a construction it is preferred that the bushing 31 be made of a material having a low coefficient of friction such as polytetrafluoroethylene. In the construction of FIG. 5, if it is deemed necessary, means may be provided for preventing any rotative or vibrational movement of voice-coil form 38, with respect to magnet assembly 33. Such means may comprise the provision of a slot 52 in an extending portion 53 of voice-coil form 38 which receives a pin 54 therein extending from nonmagnetic support member 32. It will be apparent that various means of supporting the voice-coil form of FIGS. 2 and 5 about and aligning it with respect to the axis of the magnet assemblies may be utilized. For example, the voice-coil form may be supported about the magnet assembly, as shown in FIG. 1 or slidably mounted thereon as exemplified in FIGS. 2 and 5.

The magnets 34 and 35 of magnet assembly 14 are of equal strength and otherwise identical. The magnets are oppositely poled in the same manner as illustrated in FIG. 1, with North N poles adjacent. Each of the magnets 33 and 34, as illustrated in FIG. 5, have an annular groove 55 provided therein which separates flux concentrating portions 56 and 57 which are symmetric with respect to groove 55 and provide flux concentrating surfaces 58 and 59 of equal area. It will be noted that each voice-coil section 39 and 40 is offset inwardly with respect to the groove 55 of an associated magnet. With this arrangement when the current through the voice-coil sections 39 and 40 or change of current therethrough is such that a magnetic field is established by each voice-coil section or the magnetic fields thereof vary, the interaction of the established magnetic fields and the magnets will be such that one voice-coil section will be pulled toward alignment with the center of the groove 55 of its associated magnet and the other voice-coil section will be pushed inwardly of the magnet assembly 33 away from its associated magnet. It will be seen that the distance L_1 between a point midway between flux concentrating surfaces 58 and 59 and a point one-half way along the length of a voice-coil section represents the excursion of the voice-coil sections 39 and 40 and hence the voice-coil form along the length of the magnet assembly.

The magnet voice coil arrangement of FIG. 5 would be such that the voice-coil sections 39 and 40 may be magnetic series aiding relationship or in parallel aiding relationship with the magnets 34 and 35 in opposed relationship. It will be apparent that the direction of winding of one of the voice-coil sections or the mode of connection thereof and the direction of poling of one of the magnets may be reversed and the same operative relationship obtained. The rule should be followed that if the magnets 34 and 35 are oppositely poled, the voice-coil sections should be reversely poled or connected, or vice versa, to obtain an operative push-pull relationship therebetween.

The flux concentrating surfaces 58 and 59 and the groove 55 of each magnet are so dimensioned that magnetic flux emanates predominantly from one of the surfaces 58 or 59 and returns to the other as indicated by the dashed line B. The groove 55 is dimensioned sufficiently deep that the path of lowest magnetic reluctance external of the magnets is between the flux concentrating surfaces 58 and 59. It will be apparent that each of the magnets 34 and 35, could be replaced with a pair of serially aiding poled disk-type magnets having a magnetic spacer therebetween of smaller diameter to provide a magnetically equivalent structure to that illustrated.

It will be noted that the voice-coil form 38, besides having movement imparted thereto by interaction of the magnets and the magnetic fields established by the voice coil, will have a component of movement imparted thereto by the motor action of the fields of the magnets cutting the turns of the voice-coil sections and the current through the voice-coil sections.

Where a loudspeaker embodying the invention may have a long excursion of the voice-coil form which might

not be accurately followed by the conventional diaphragm structure illustrated in FIGS. 1 and 2, the invention also provides a new and improved diaphragm construction.

FIG. 6 illustrates a loudspeaker, generally similar to that of FIG. 2, having a voice-coil form **38** and magnet assembly **33**, as previously described in conjunction with FIGS. 1 and 2. In FIG. 6, the voice-coil form **38** supports thereon a cone diaphragm assembly **60** which comprises a pair of cone diaphragm members **61** and **62** of conventional diaphragm material, each having their inner peripheral mounting flanges **63** and **64**, respectively, secured to voice-coil form **38** at spaced-apart points along the length thereof. The outer peripheries of diaphragm cones **61** and **62** are joined together to form the rigid self-supporting diaphragm assembly **60**. As illustrated, cone **62** is lapped over the outer edge **63** of cone **61**. This construction could be reversed with cone **61** lapped over the outer edge of cone **62** or alternately the ends of both cones **61** and **62** may be joined together by a substantially U-shaped cap member **65** (FIG. 7). Joining of the outer peripheries of the cones **61** and **62** either to each other or with a cap member **65** may be accomplished with a suitable adhesive. A flexible spider **66** may be provided between shoulder **67** of frame **68** and voice-coil form **38** to position the voice-coil form in a rest position when the voice-coil is not energized.

The diaphragm construction of FIG. 6 provides a rigid, self-supporting diaphragm which requires no external support at its outer periphery and therefore no supporting compliance or surround is required. The spider **66** may be utilized as the sole support of voice-coil form **38** about magnet assembly **33** in the same manner as illustrated in FIG. 1 or the spider may be eliminated and the voice-coil form supported solely on the magnet assembly. The self-supporting diaphragm assembly **60** requires no supporting compliance at the outer periphery thereof. Therefore, the outer periphery has no restraint thereon and may move the same distance as the voice-coil form **38**, thus reducing the distortion of the sound reproduced by the loudspeaker.

The push-pull movement exerted on the voice-coil forms of the disclosed speakers, eliminates the necessity of rim compliances or voice-coil supporting spiders exerting a restoring force on the voice-coil form and may, where used (FIGS. 1 and 2), be extremely flexible so as not to unduly limit movement of the voice-coil form or diaphragm.

It is to be understood that the various features of construction illustrated in the embodiments of the invention disclosed may be used interchangeably. For example, the voice-coil form **13** of FIG. 1 might be mounted on magnet assembly **14** in the manner taught in FIGS. 2 and 4. Also the diaphragm assembly **60** of FIG. 6 might be used with the voice coil form-magnet assembly arrangement of FIG. 1. The magnet assemblies illustrated may be secured together with a single bolt **19** as illustrated in FIG. 1 or with a plurality of studs **69**, as shown in FIG. 3. Moreover, the magnets **14** and **15** (FIG. 1) may be formed as magnets **34** and **35** of FIG. 5.

The voice-coil sections **39** and **40** which are of equal turns (FIGS. 2 and 5) may be connected either in series or parallel. Also, the voice-coil sections, dependent on the poling of the magnets **34** and **35** may be connected so that the magnetic fields are either in the same direction or opposite directions as previously described.

While the invention has been described and illustrated in several forms thereof for purposes of disclosure, other embodiments of the invention as well as modifications to the disclosed embodiments of the invention may occur to those skilled in the art which do not depart from the spirit and scope of the invention. Accordingly, it is intended to cover in the appended claims all embodiments and modifications of the invention which do not depart from the spirit and scope of the invention.

What is claimed is:

1. A dynamic speaker comprising a frame, a magnet assembly supported from said frame, said magnet assembly comprising axially aligned spaced apart, magnetically isolated magnets, a cylindrical voice coil form supported coaxially about said magnet assembly and axially movable with respect thereto, a substantially cylindrical voice coil on said form, said voice coil being operatively positioned on said voice coil form such that current in said coil sets up a magnetic field oppositely directed with respect to one of said magnets and similarly directed with respect to the other of said magnets, and a diaphragm mounted on said voice coil form.

2. The speaker of claim **1** wherein said voice coil comprises two equal coil sections and the center point along the length of each section is normally disposed axially inwardly of the axial center of an associated magnet.

3. The speaker of claim **1** wherein each of said magnets has annular axially spaced-apart flux concentrating surfaces.

4. A dynamic speaker comprising a frame, a magnet assembly supported from said frame, said magnet assembly comprising axially aligned spaced apart, magnetically isolated magnets, a generally cylindrical voice coil form supported coaxially about said magnet assembly and axially movable with respect thereto, a voice coil on said form, said voice coil being normally centrally disposed between said magnets and operatively positioned on said voice coil form such that current in said coil sets up a magnetic field oppositely directed with respect to one of said magnets and similarly directed with respect to the other of said magnets, and a diaphragm mounted on said voice coil form.

5. A dynamic speaker comprising a frame, a magnet assembly mounted on said frame, said magnet assembly being generally cylindrical in shape and comprising axially aligned, spaced apart magnets, a nonmagnetic spacer between said magnets, a voice coil form slidably mounted on said spacer coaxial with said magnets, a voice coil on said form, said voice coil being operatively positioned on said voice coil form such that current in said coil sets up a magnetic field oppositely directed with respect to one of said magnets and similarly directed with respect to the other of said magnets.

6. The speaker of claim **5** including a diaphragm mounted on said voice coil form, said diaphragm comprising a pair of conical members having their inner peripheries spaced apart along the length of said voice coil form and means joining together their outer peripheries, said outer peripheries being otherwise free of restraint.

7. A dynamic speaker comprising a frame, a magnet assembly supported from said frame, said magnet assembly comprising axially aligned spaced apart, magnetically isolated magnets, a cylindrical voice coil form supported coaxially about said magnet assembly and axially movable with respect thereto, a voice coil, said voice coil comprising two spaced-apart sections of equal turns, each voice coil section being spaced axially inwardly of one of said magnets on said voice coil form, said magnets and said voice coil sections being arranged such that current through one of said sections establishes a magnetic field in opposite direction to an associated one of said magnets and current through the other of said sections establishes a magnetic field in a like direction to the other of said magnets.

8. The speaker of claim **7** wherein said voice coil sections are connected in series and similarly wound and connected to establish similarly directed magnetic fields and said magnets are arranged with similar poles facing.

9. The speaker of claim **7** wherein said voice coil sections are connected in parallel.

10. The speaker of claim **7** wherein said voice coil form is mounted on and movable on said magnet assembly.

11. The speaker of claim 7 wherein said voice coil sections are connected in series and connected to establish oppositely directed magnetic fields and said magnets are arranged with dissimilar poles facing.

12. In a dynamic speaker comprising a frame, a magnet assembly mounted on said frame, a cylindrical voice coil form having a voice coil thereon positioned in operative relationship with said magnet assembly: a diaphragm assembly comprising first and second conical diaphragms having their inner peripheries mounted on said form in spaced apart relationship and means joining together the outer peripheries of said conical diaphragms, said outer peripheries otherwise being free of restraint.

13. In a dynamic speaker comprising a frame, magnetic means mounted on said frame, a cylindrical voice coil form having a voice coil thereon positioned in operative relationship with the magnetic means and resilient means for positioning said voice coil form with respect to the magnetic means: a diaphragm assembly comprising first and second conical diaphragms having their inner peripheries mounted on said form in spaced-apart relationship, the outer peripheries of said diaphragms being joined together and otherwise free of restraint.

14. A dynamic speaker comprising a frame, a magnet assembly supported from said frame, said magnet assembly comprising generally cylindrical permanent magnets coaxially aligned and axially spaced apart, the facing poles of said magnets being of similar polarity, a cylindrical voice coil form supported coaxially about said magnet assembly and axially movable with respect thereto, a substantially cylindrical voice coil on said form, said voice coil being operatively positioned on said voice coil form such that current in said coil sets up a magnetic field oppositely directed with respect to one of said magnets and similarly directed with respect to the other of said magnets.

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