

May 1, 1951

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2,551,556

ACOUSTIC DIAPHRAGM WITH PLURAL VOICE COIL SUPPORTS

Filed Sept. 12, 1945

3 Sheets-Sheet 1

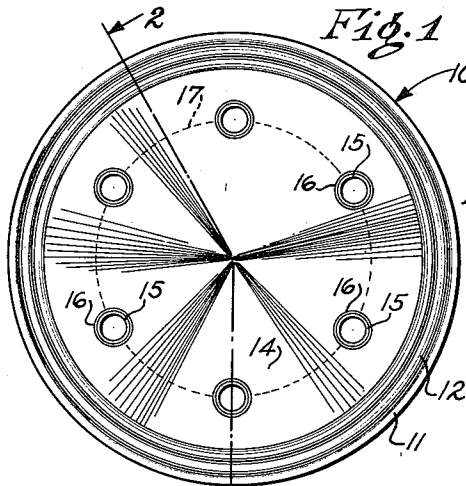
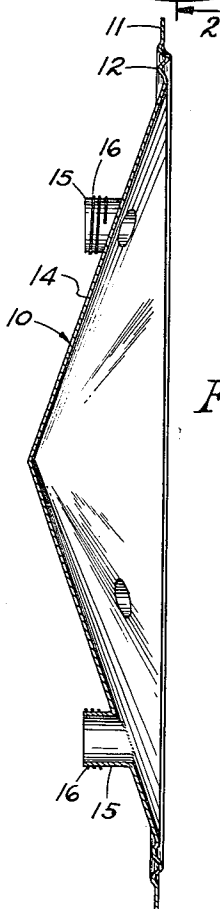


Fig. 2

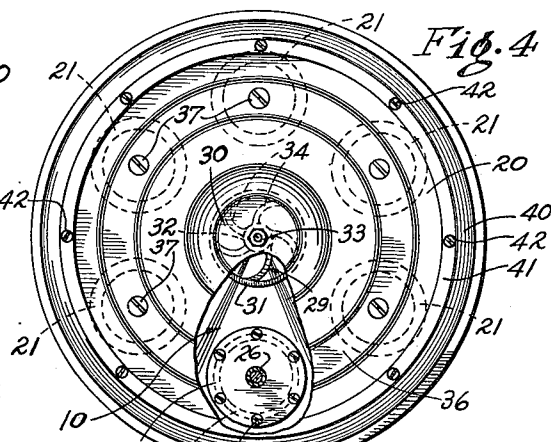
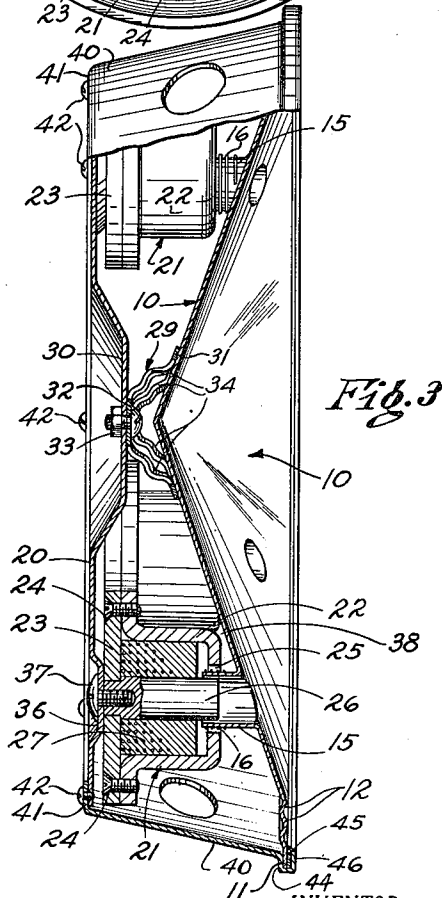


Fig. 3

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3 Sheets-Sheet 2

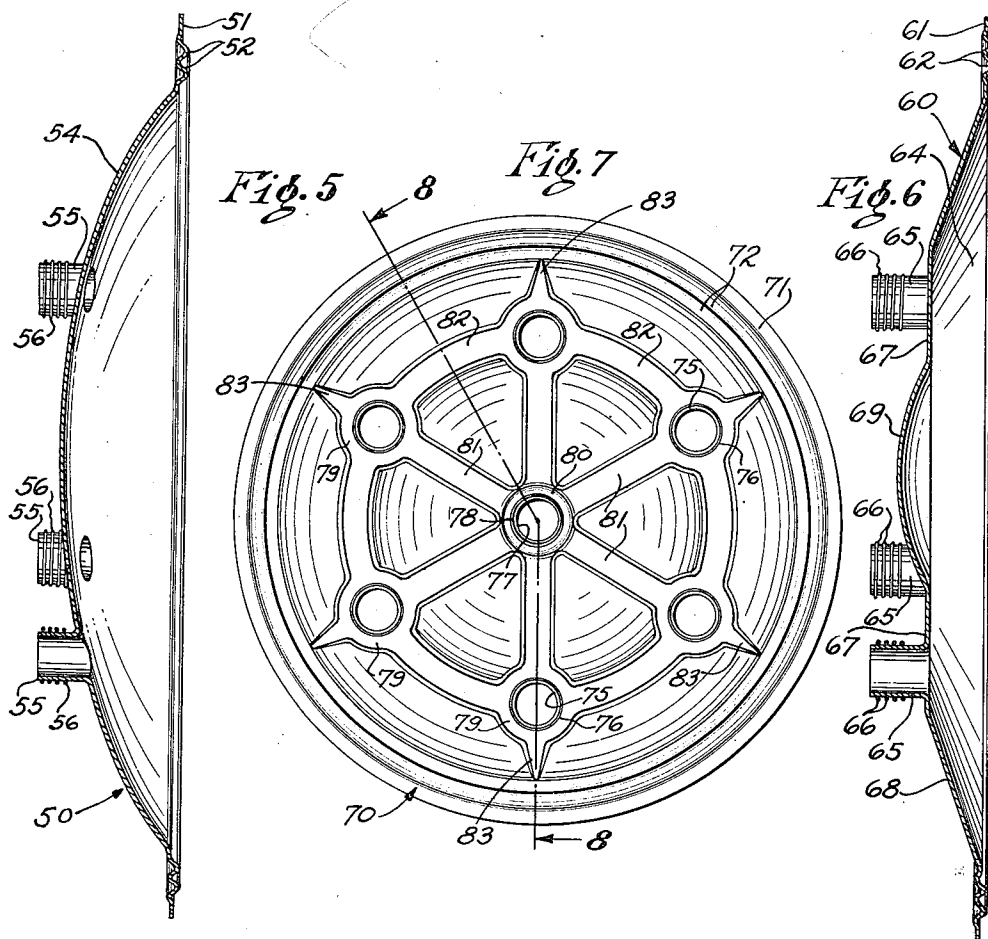
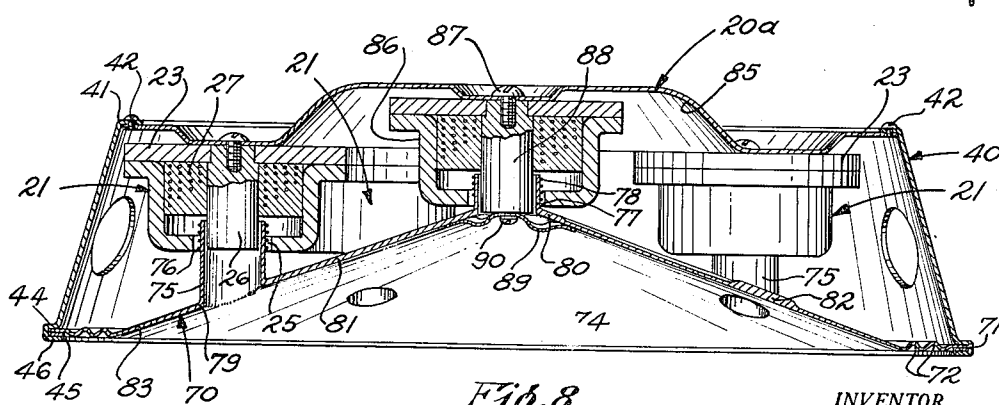


Fig. 8

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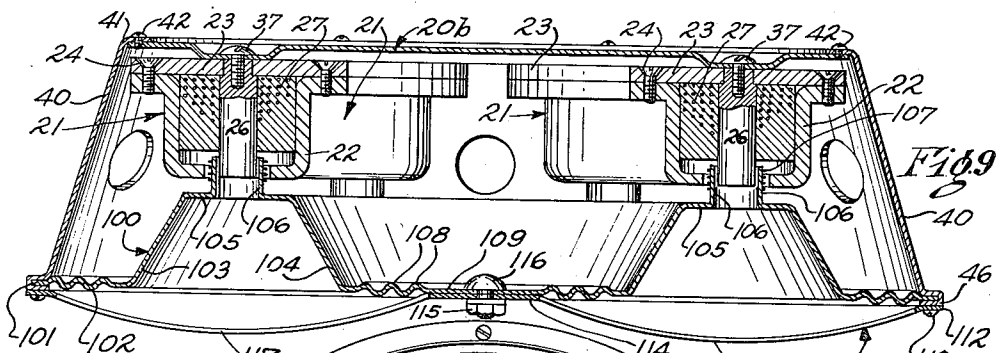
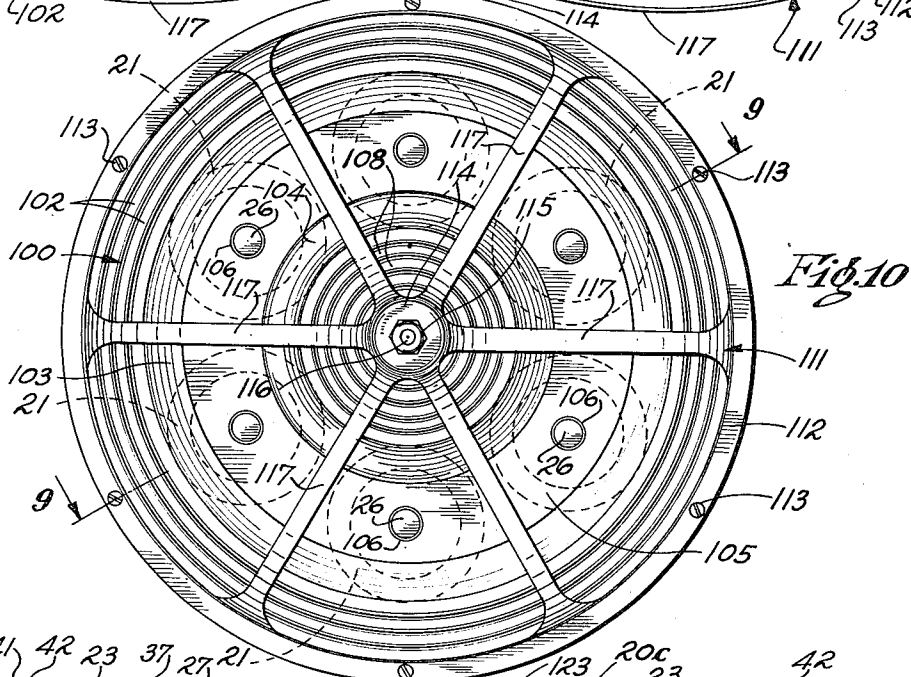
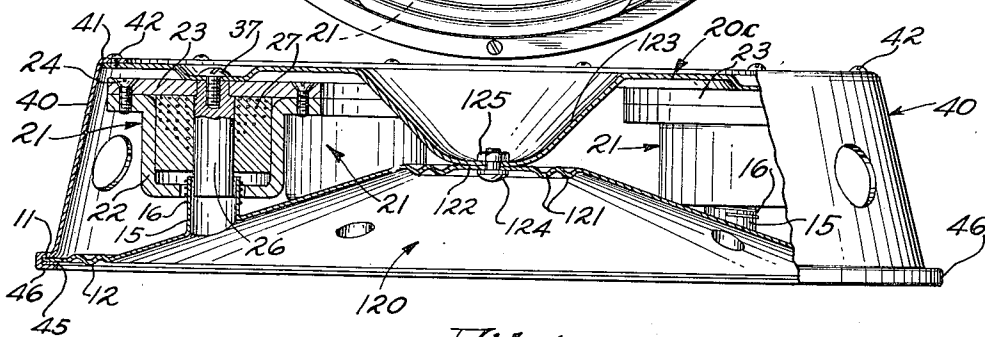
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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,551,556

ACOUSTIC DIAPHRAGM WITH PLURAL
VOICE COIL SUPPORTSJoseph B. Brennan, Bratenahl, Ohio, assignor to
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Application September 12, 1945, Serial No. 615,719

7 Claims. (Cl. 181—31)

1

This invention relates to acoustic diaphragms and loud speakers such as are employed in radio speakers, public address systems and the like.

A general object of the invention is the provision of an improved acoustic diaphragm and of a loud speaker embodying the same in which increased efficiency in the operation, and increased efficiency in the use of materials in constructing the apparatus are obtained. Other objects of the invention are the provision of an acoustic diaphragm and of a loud speaker embodying the same whereby increased fidelity of sound reproduction can be obtained as compared to present practices; the provision of an acoustic diaphragm and a loud speaker embodying the same whereby high efficiency and intensity of sound output can be obtained while maintaining fidelity of sound reproduction; the provision of an acoustic diaphragm and a loud speaker embodying the same whereby substantially the entire diaphragm is caused to vibrate in unison; the provision of an acoustic diaphragm arranged to have vibratory forces applied to it, as by voice coils, at a plurality of symmetrically spaced zones distributed about the axis of the diaphragm; the provision of a one-piece acoustic diaphragm embodying a plurality of voice coil supports formed integrally with the diaphragm; the provision of a diaphragm and loud speaker assembly in which the ratio of power input as compared to the mass of diaphragm may be high, whereby the diaphragm is constrained to vibrate in accordance with the electric currents supplied to the loud speaker with a high degree of fidelity; and the provision of a loud speaker embodying a diaphragm having a plurality of voice coils, and which can be manufactured economically and by simple manufacturing operations.

Further objects and advantages of my invention will become apparent from the following description of preferred forms thereof, reference being made to the accompanying drawings wherein Figure 1 is a rear elevation of a preferred form of acoustic diaphragm embodying my invention; Figure 2 is a section, on an enlarged scale, through the diaphragm of Figure 1 taken along the line 2—2 of Figure 1; Figure 3 is a generally similar sectional view showing a loud speaker embodying the diaphragm of Figures 1 and 2 with parts of the loud speaker housing broken away for convenience in illustration; Figure 4 is a rear elevation, on a reduced scale, of the loud speaker shown in Figure 3 with parts of the housing broken away for convenience in illustration; Figures 5 and 6 are sectional views

2

generally similar to Figure 2 but showing modified forms of diaphragms; Figure 7 is a rear elevational view of a still further modification of my diaphragm; Figure 8 is a sectional view illustrating a loud speaker embodying the diaphragm of Figure 7 and taken on the plane indicated by line 8—8 of Figure 7; Figure 9 is a transverse sectional view of a loud speaker embodying another modification of my invention; Figure 10 is a front view of the speaker shown in Figure 9 on a slightly reduced scale, the line 9—9 of Figure 10 indicating the section plane of Figure 9; and Figure 11 is a transverse sectional view taken along a line corresponding to the lines 2—2 of Figure 1 and 8—8 of Figure 7 and illustrating a loud speaker embodying a still further modification of my invention. Throughout the drawings the thicknesses of various portions of the diaphragm themselves are necessarily somewhat exaggerated.

Briefly my invention, in its preferred forms, contemplates an acoustic diaphragm having a body portion adapted to be vibrated to generate sound, said body having, instead of the usual single, centrally located voice coil support, a plurality of voice coil supports spaced about the body portion to distribute the vibratory forces applied thereto. The body portion may be hollow or flat, and may be of conical shape with the centers of the voice coil supports symmetrically disposed between the center of the diaphragm and the outer peripheral edge thereof. As will appear below, diaphragms of various shapes may be employed, and the voice coil supports may be located in various positions. The diaphragm, including the voice coil supports, is preferably of one-piece construction, integrally molded of felted fibrous material. The diaphragm may be supported at its outer edge in the usual manner and may also be centered at its central portion by a spider or other convenient means which may be either unitary with or separate from the body of the diaphragm. Each voice coil support is provided with a voice coil, and the diaphragm is intended for incorporation in a loud speaker structure in which a separate field structure is provided for each voice coil associated with the diaphragm.

In use, the several voice coils may be connected in parallel or series depending upon the electrical characteristics of the coils and the circuit with which the device is used, and thus the voice coils vibrate in response to the voice currents of the radio receiver, loud speaker or the like with which the device is employed. With

this arrangement, instead of attempting to vibrate the entire diaphragm from a single coil at the apex of the diaphragm as is the conventional practice, the diaphragm is vibrated by like forces applied at spaced points around the diaphragm with the result that the entire diaphragm vibrates in phase and much more nearly as a unit than is the case with a conventional diaphragm embodying only a single voice coil. Greater volume of sound output per unit of electrical input and higher fidelity of reproduction, can be obtained with such diaphragms than is possible with a conventional diaphragm of the same size.

Referring now to Figures 1 and 2 of the drawings, one preferred form of acoustic diaphragm embodying my invention is indicated in general at 10. This comprises a peripheral supporting flange 11 joined by the corrugated flexible portion 12 to the hollow conical body portion 14 of the diaphragm. The diaphragm is provided with a plurality of tubular necks 15 projecting therefrom which are adapted to support the usual voice coils 16. In the embodiment shown there are six tubular voice coil supporting necks 15, each with its associated voice coil 16. The voice coils may be mounted on the supports in any convenient manner, and may be provided with the usual lead wires (not shown). Alternatively, the construction disclosed in the Moynihan Patent No. 2,328,836 may be utilized and the necessity for lead wires eliminated.

The voice coil supports are preferably spaced uniformly inwardly from the edge of the diaphragm and are also spaced uniformly in circumferential directions. Thus with a circular diaphragm as shown, the axes of the several voice coil supports 15 are parallel to each other and to the axis of the body portion and are evenly spaced around a circle which is concentric with the diaphragm itself. However, those skilled in the art will understand that different spacing arrangements may be employed to suit different purposes and that the axes of the voice coil supports need not lie on a circle, particularly in instances where the diaphragms are of elliptical, rectangular or other non-circular shape; in such cases the axes preferably lie on a line which is similar in shape to the periphery of the body portion, i. e., the juncture of the body portion with the flexible portion 12. Also, it is to be understood that a greater or lesser number of voice coil supports and voice coils may be employed, the number chosen depending upon the size of the diaphragm, the power output desired and other design considerations.

In the arrangement shown in Figures 1 and 2, the center lines of the axes of the voice coil supporting members 15 lie on a circle which divides the projected area of the conical diaphragm into two substantially equal parts. That circle is indicated in broken line in Figure 1 at 17, and the arrangement is such that the projected area of the body of the diaphragm within the circle 17 is substantially equal to the projected area of the body of the diaphragm between the circle 17 and the juncture of the body of the diaphragm within the corrugated portion 12. This is one method of distribution of the voice coil supporting members with respect to the body of the diaphragm which may be employed to obtain substantially equal vibratory effects throughout the diaphragm, i. e., to produce a diaphragm in which all parts of the diaphragm vibrate in approximately identical fashion at any given instant. Obviously, it is difficult, if not impossible, to determine the fre-

quency and amplitude of vibration of all parts of a diaphragm at a given instant, but it appears probable that the distribution of the voice coil supporting members as described above which results in a corresponding distribution of the vibratory forces applied to the diaphragm when it is installed in a loud speaker gives a much better approximation of this desired result than has been obtainable heretofore.

The diaphragm is preferably integrally formed of fibrous, felted material. The diaphragms may be made by depositing fibrous material from a suspension in liquid upon a perforate form in the usual manner, or may be produced by spraying fibrous material and a binder upon a form preferably in the manner described in my copending application, Serial No. 422,388, filed December 10, 1941, now Patent No. 2,408,038, issued September 24, 1946. Depending upon the characteristics desired, the felted material may be subject to further operations after it is initially deposited, or it may be used after merely drying. A preferred method of drying or curing is disclosed in my copending application Serial No. 615,720, now abandoned, filed of even date herewith. As examples of other treatments the deposited material may be subjected to a pressing operation, may be cured by heat, and/or may be impregnated with various stiffening and strengthening materials such as various lacquers, resins, binders and the like. The thickness of various portions of the diaphragm may be varied to provide different characteristics of flexibility; thus the edge portions of the diaphragm may be constructed as described in my Patent No. 2,302,178 in order to provide increased flexibility. If desired, and as described below, the body of the diaphragm may be provided with reinforcing portions of increased thickness and stiffness as described in my copending application Serial No. 422,388 aforesaid. It is believed that no detailed description of various materials for and methods of making the diaphragms is necessary for the purposes of the present disclosure inasmuch as appropriate materials and methods are known to those skilled in the art and/or are disclosed in my patent and applications aforesaid.

Diaphragms embodying my invention lend themselves readily to incorporation in loud speakers of simple and efficient design. An example of such a loud speaker embodying the diaphragm 10 of Figures 1 and 2 is illustrated in Figures 3 and 4. The device comprises a supporting frame embodying a supporting plate 20 to which a plurality of field structures, each indicated in general at 21, are secured; the field structures being spaced to correspond to the spacing of the voice coil supports 15 and coils 16. As shown particularly in Figure 3, each field structure comprises a hollow cup-shaped member 22 provided with an open end to which a plate 23 is secured, for example by screws 24, and with an aperture 25 at the end opposite the plate 23. A pole piece 26 is pressed into an opening in the plate 23 or otherwise suitably secured thereto and projects through the opening 25. The pole piece is accurately centered with respect to the opening 25, providing an annular air gap within which the voice coil 16 and support 15 are disposed.

In the form shown, the requisite magnetic field is set up by means of a coil 27 surrounding pole piece 26 and disposed within the member 22 in the usual manner, but those skilled in the art will understand that permanent magnet fields may be employed. The flow of voice currents

5

through the voice coil will cause the coil to vibrate in the magnetic field set up by the coil in accordance with the direction, frequency and amplitude of the voice currents as is well known. The field structures 21 are all preferably identical with each other, are energized in the same manner, and each coacts with its associated voice coil 16 in the same way. The voice coils are preferably identical and are connected in parallel or in series in the output circuit of the radio receiver, public address system or the like with which the speaker is used. Therefore, substantially identical forces are applied at any given instant to all of the voice coils associated with the diaphragm.

The diaphragm may be centered with respect to the plate 20 by a spider 29 connected to the indented portion 30 of the plate and cemented into the outer surface of the diaphragm. As shown particularly in Figure 4, the spider may comprise a rim portion 31 secured to the diaphragm, a central hub portion 32 secured to the plate as by the bolt or screw 33 and a plurality of flexible spiral spokes 34.

The plate 20 supports the several field structures in proper relationship to coact with the coils of the diaphragm, the plate being provided with an annular indentation 36 and having holes therein corresponding to the position of the axes of the voice coils. Screws 37 threaded into the pole pieces 26 secure the respective field structures in the desired positions, the holes in the plate 20 preferably being somewhat larger than the shanks of the screws to permit of a limited amount of adjustment to enable the pole pieces and members 22 to be accurately centered with respect to the voice coils and supports. It will be noted that the voice coil supports 15 are of sufficient length so that the voice coils 16 are positioned within the air gap and at the same time there is sufficient clearance between the inner portion of the member 22 and the surface of the diaphragm as indicated at 38. The necessary length, of course, depends upon the diameter of the member 22 and the shape of the diaphragm.

In order to complete the frame structure for the loud speaker mechanism and to support the outer rim or flange 11 of the diaphragm, I preferably provide an annular member 40 having an inwardly extending flange 41 which is secured as by self-threading screws 42 to the outer surface of the plate 20. The openings in the flange 41 which receive the screws 42 may be made oversize to permit adjustments to compensate for inaccuracies in manufacture and to insure accurate mounting of the supporting flange 11 and of the entire diaphragm with respect to the several field structures. At its opposite end the member 40 is flanged outwardly as at 44, providing an annular surface to receive the supporting flange 11 of the diaphragm 10. The flange 11 may be secured in position by a clamping ring 45 which is held against the flange by the inwardly extending portion 46 of the axially extending flange 44, the portion 46 being crimped or spun into engagement with the ring 45 after the parts have been assembled and accurately adjusted to proper position.

Figure 5 illustrates a modified form of diaphragm embodying my invention wherein the diaphragm, indicated in general at 50, is provided with a supporting flange 51 and a corrugated portion 52. Here the body portion 54 of the diaphragm is curved rather than conical in section, for example, a parabolic shape may be employed.

6

The diaphragm is also modified slightly in that the voice coil supporting members 55 and voice coils 56 are disposed substantially midway between the center of the diaphragm and the outer peripheral edge of the body portion. This arrangement places the voice coil supports 55 on a flatter portion of the curve of the body of the diaphragm and makes it possible to employ shorter voice coil supports and still obtain the requisite clearance between the field structures and the diaphragms. Obviously the positioning of the voice coil supports described in connection with Figures 1 and 2 may also be employed in diaphragms of this type, or if desired the spacing shown in Figure 5 may be employed with conical diaphragms such as shown in Figures 1 and 2.

Figure 6 illustrates a further modification wherein the diaphragm indicated in general at 60 has a supporting flange 61 and a flexible corrugated portion 62 but in which the body 64 of the diaphragm is shaped so that the voice coil supports 65, carrying voice coils 66, are disposed on an annular flat surface 67 interposed between a conical portion 68 and a curved portion 69 of the body. This arrangement also makes possible the utilization of shorter voice coil supports without interference between the diaphragm and the several field structures. In this modification, the voice coil supports are again positioned about midway between the center of the diaphragm and the edge of the body portion where the body portion joins the corrugated portion. Here again, the spacing described in connection with Figures 1 and 2 may be employed. Instead of utilizing a curved central portion as shown, the central portion may be conical as shown in Figures 1 and 2. Also, if desired, a curved central portion such as the portion 69 of Figure 6 could be employed in conjunction with the diaphragm of Figures 1 and 2.

The diaphragms of Figures 5 and 6 may be incorporated in loud speakers of designs similar to that shown in Figures 3 and 4 except for the positioning of the several field structures which obviously must be spaced to correspond to the spacing of the voice coil supports. Also, it may be necessary to reduce the diameter of the field structures somewhat for the same size of diaphragm, for with the field structures disposed closer to the center of the diaphragm they are necessarily spaced closer to each other.

In Figures 7 and 8 I have illustrated a diaphragm and loud speaker adapted for particularly heavy duty. As before, the diaphragm indicated generally at 70 is provided with a flange portion 71 and a flexible corrugated portion 72. The body 74 of the diaphragm is constructed as described in my copending application Serial No. 422,388 aforesaid with reinforcing areas to increase the strength and rigidity of the diaphragm. The diaphragm may be of conical form, and the voice coil supporting members 75 carrying voice coils 76 are preferably positioned as described in connection with Figures 1 and 2. Here, however, there is an additional voice coil support 77 carrying a voice coil 78 and disposed in the center of the diaphragm, and the diaphragm is reinforced by thickened annular portions 79 surrounding each voice coil support 75, a central thickened annular portion 80 surrounding the voice coil 77. Also, I may provide radial thickened reinforcing portions 81 extending between the central reinforcing portion 80 and the reinforcing portions 79, arcuate reinforcing portions

82 extending between the reinforcing portions 79, and/or radial reinforcements 83 extending outwardly from the annular reinforcements 79 to the juncture of the body portion 74 with the corrugated portion 72 of the diaphragm.

This arrangement produces an exceptionally rigid and powerful diaphragm which, however, may be made of reasonably light weight. The reinforcing portions insure that the entire diaphragm will vibrate substantially as a unit at all times even under high input of power. The thickness and the width of the reinforcing portions may be varied in accordance with requirements; however, I prefer that the reinforcing portions be at least several times as thick as the remainder of the diaphragm, and I preferably produce them by the method described in my aforesaid application Serial No. 422,388.

As shown in Figure 8, diaphragms of this type may be incorporated in loud speakers generally similar to the structures shown in Figures 3 and 4, and in Figure 8, the same reference characters that were used in Figures 3 and 4 have been applied to those parts which are identical with those previously described. However, the plate 20a of Figure 8 is provided with a recessed portion as at 85 in order to receive the additional field structure 86 required for the central voice coil 78. This structure may be identical with the field structures 21 heretofore described and may be secured to the plate 20a as by a screw 87 extending through an opening in the plate and into the pole piece 88 of the field structure. As before, there is preferably clearance between the opening in the plate 20a and the screw 87 to permit adjustment of the field structure with respect to the plate. In this type of device a conventional spider 89, secured to the interior of the diaphragm 70 and to the pole piece 88 as by a screw 90, may be employed.

Figures 9 and 10 illustrates a loud speaker embodying another form of diaphragm made according to my invention. Here the diaphragm 100 is provided with a supporting flange 101 and a flexible corrugated portion 102 corresponding to similar parts in the previously described modifications, but the body of the diaphragm is made up of two oppositely inclined frusto conical surfaces 103 and 104 connected by an annular surface 105 from which the voice coil supports 106 project; the supports being provided with the usual voice coils 107. In this modification the need for a separate central support or spider is eliminated, the diaphragm being provided with a central flexible corrugated portion 108 and a central plane portion 109 which is adapted to be secured to a suitable support. Thus the flexible corrugated portion 108, which is disposed within the locus of the several voice coil supports, permits the annular body of the diaphragm to vibrate freely yet insures proper alignment of the diaphragm with respect to the remaining structure of the loud speaker.

Diaphragms of this type may be employed with loud speaker structures generally similar to those heretofore described and the same reference characters used in the description of the previous modifications are applied to corresponding parts shown in Figures 9 and 10 of the drawings. In this form, however, the supporting plate 20b differs from the plate 20 heretofore described in that no provision need be made for supporting the central portion of the diaphragm therefrom. The central portion of the diaphragm is sup-

ported adjacent the front of the speaker inasmuch as the corrugated portion 108 and the central portion 109 lie in substantially the same plane as the edge or flange 101 and the corrugated portion 102. In order to support the central portion 109 I preferably employ a member such as the spoked member 111, the edge 112 of which is secured to the flange 46 as by screws 113 or any other suitable means; the central portion 114 being secured to the central portion 109 of the diaphragm as by a nut 115 and bolt 116 or any other convenient securing means. The central portion 114 is supported by spokes 117 which are preferably bowed outwardly, as shown, to eliminate any possibility of contact between vibrating portions of the diaphragm and the spokes.

Figure 11 illustrates another form of diaphragm and diaphragm and speaker assembly in which the need for a separate supporting spider in the central portion of the diaphragm is eliminated. In this modification the diaphragm and the speaker structure in general are substantially identical with the construction shown in Figures 1, 2 and 3, except for the central portion of the diaphragm and here again the same reference characters are employed to indicate parts which have not been substantially changed. However, in this modification the diaphragm itself, indicated in general at 120, instead of continuing on to the apex of the cone as in Figures 1, 2 and 3, is terminated short of the apex of the cone and has integrally formed with the body portion thereof a flexible corrugated portion 121 connecting the conical body of the diaphragm with the central plane portion 122. In the speaker the supporting plate 20c is formed with a depression 123 of greater depth than the depression 30 previously described and the central portion 122 of the diaphragm is secured to the center of the depression 123 by the bolt and nut 124—125 or by other convenient means. Otherwise, as noted above, the structure shown in this figure is substantially identical to that previously described in connection with Figures 1, 2 and 3.

In the modifications of Figures 9, 10 and 11 the necessity for separate central supporting spiders is eliminated thus obviating the troubles which frequently occur with such devices and cutting down the cost of the assembling operations while improving the accuracy of the support of the diaphragm itself. The diaphragms of Figures 9 and 10 are particularly adapted to large installations of high output while the diaphragm shown in Figure 11 is of high efficiency and provides an economical assembly. Those skilled in the art will appreciate that the same principle of utilizing an integrally formed flexible portion adjacent the center of the diaphragm may be used with diaphragms of various different shapes and with arrangements of voice coils different from those illustrated herein.

From the foregoing description of preferred forms of my invention, it will be evident that I have provided diaphragms and loud speakers embodying the same giving advantageous results particularly in the fidelity of sound reproduction. The distribution of the forces throughout the diaphragms makes possible the application of more energy to the diaphragms without requiring that the weight of the diaphragms be increased in proportion. Thus more power can be applied to a diaphragm of a given size and weight constructed in accordance with my invention than can be utilized successfully by a conventional diaphragm of the same size and

weight. The application of the forces by a plurality of voice coils spaced around the diaphragm is also advantageous in that the use of a plurality of smaller voice coils makes more efficient utilization of the metal necessary in constructing the fields and the voice coils than is possible in a single voice coil construction designed to have the same power output. The reason for this is that design considerations require the single voice coil and field structure to be of much larger diameter than the several smaller field and voice coil structures used in loud speakers embodying my invention, and the smaller structures obviously make more advantageous use of the metal in the coils and in the field because more ampere turns can be obtained with the same quantity of wire in small coils than can be obtained in coils of larger diameter.

Because of the distribution of the vibratory forces imposed by the voice coils, diaphragms made according to my invention vibrate substantially uniformly throughout. Because of this more nearly uniform vibration, my diaphragms are more efficient size for size as sound reproducing devices than the conventional diaphragms in which the force is applied only at the apex of the diaphragm, the increase in efficiency being particularly marked in the larger sizes. Furthermore, with diaphragms embodying my invention, sufficient input of power can be employed to render the natural periods or frequencies of vibration of the diaphragms inconsequential, and accordingly the diaphragms will vibrate more nearly in conformity to the voice currents flowing in the voice coils than has been possible with diaphragms of conventional type. The diaphragms are accurately supported in the speakers by flexible supporting portions at the periphery and also centrally, i. e., in the region within the locus of the voice coil supports. My loudspeakers are compact and efficient and of relatively simple construction.

It is to be understood that various changes may be made in the preferred forms of my invention disclosed herein without departing from the teachings of my invention. For example, the size, shape and contour of the diaphragms may be changed as may the number and spacing of the voice coil supports. The design of the field structures may be varied. The invention is useful in speakers of the permanent magnet type as well as in the dynamic type disclosed herein. Various other changes may be made within the precepts of the invention. It is therefore to be understood that my patent is not limited to the preferred forms described herein.

I claim:

1. A one-piece, seamless acoustic diaphragm comprising a peripheral supporting flange, a hollow body portion, a flexible portion connecting said body portion and said supporting flange, and a plurality of hollow cylindrical voice coil sup-

ports extending from the exterior of said body portion with their axes spaced from each other and parallel to the axis of the body portion, said diaphragm and said voice coil supports being integrally formed of felted fibrous material.

2. An acoustic diaphragm comprising a hollow body portion, and a plurality of hollow cylindrical voice coil supports joined to and extending from the exterior of said hollow body portion with their axes spaced from each other and parallel to the axis of the body portion.

3. An acoustic diaphragm according to claim 2, wherein the voice coil supports are disposed at substantially equal distances from the periphery of the body portion of the diaphragm.

4. An acoustic diaphragm according to claim 2, wherein the voice coil supports are disposed at substantially equal distances from the periphery of the body portion, and wherein a line connecting the axes of the voice coil supports and following a curve similar in shape to the periphery of the body portion will divide the projected area of the body portion into two substantially equal parts.

5. An acoustic diaphragm according to claim 2, and having a plurality of voice coil supports spaced from the axis of the body portion and an additional voice coil support having its axis aligned with the axis of the body portion.

6. An acoustic diaphragm according to claim 2, and having reinforcing portions adjacent the junctures of at least some of the voice coil supports with the diaphragm, said reinforcing portions being thicker than the adjacent portions of the diaphragm.

7. An acoustic diaphragm according to claim 2, wherein the body portion is substantially conical in shape and is provided with a plurality of voice coil supports with their axes circumferentially spaced about a circle concentric with said body portion.

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