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ACOUSTIC DEVICE

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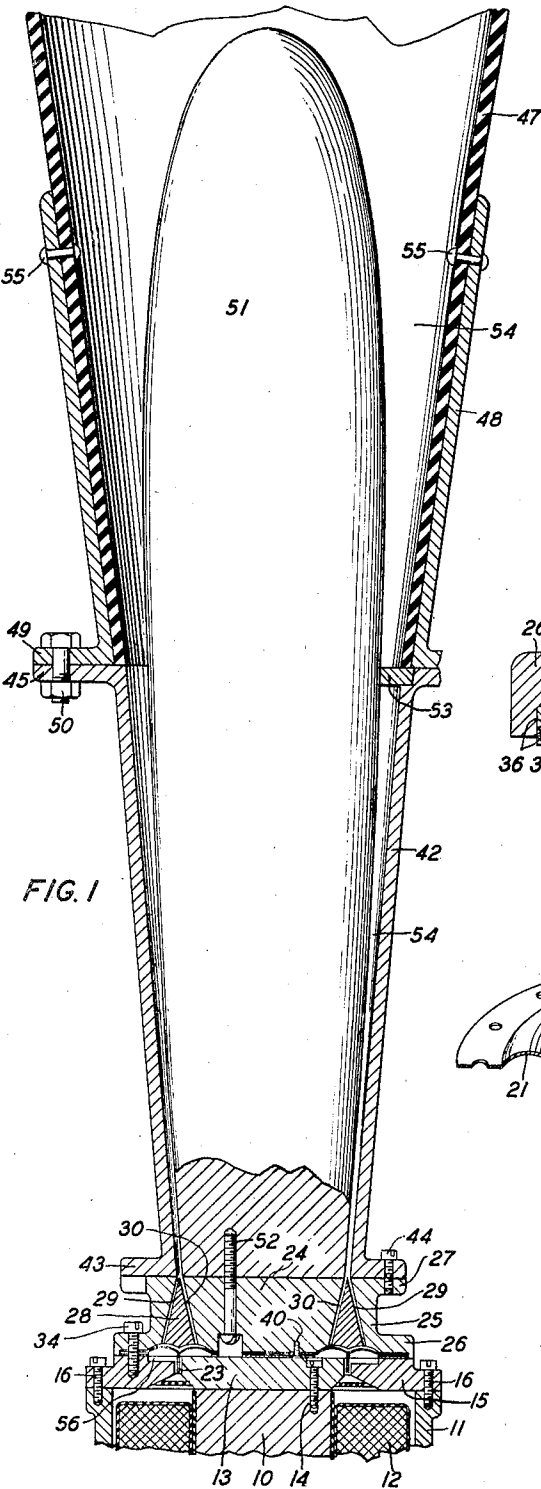


FIG. 1

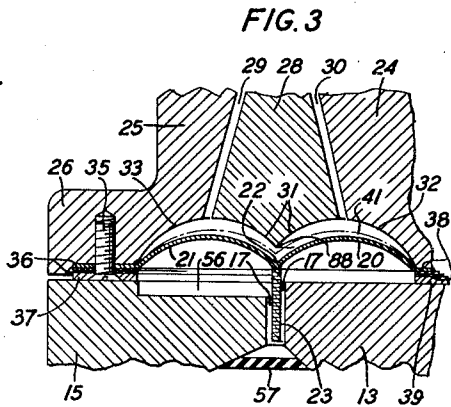


FIG. 3

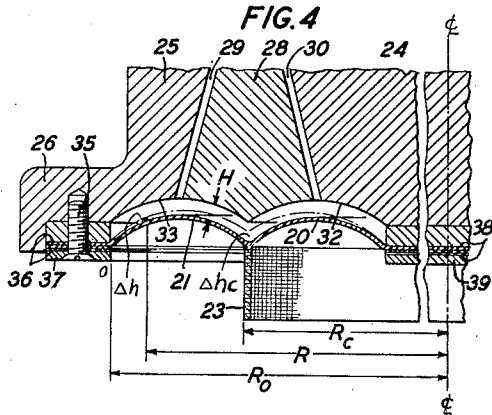


FIG. 4

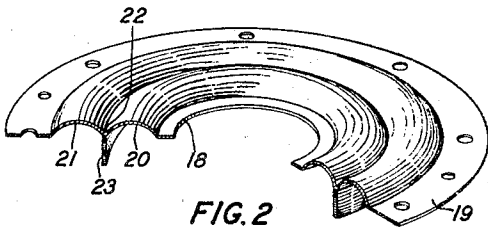


FIG. 2

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ACOUSTIC DEVICE

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18 Claims. (Cl. 181-27)

This invention relates to acoustic devices and more particularly to horn type loud-speakers having a moving coil actuated diaphragm.

One object of this invention is to transmit sound with high uniformity throughout a wide band of frequencies of importance in speech and music.

Another object of this invention is to increase the efficiency and sound power output of horn type loud-speakers.

In one illustrative embodiment of this invention, a loud-speaker comprises a magnet having concentric pole-pieces spaced to form an annular air-gap, an annular diaphragm mounted upon the magnet, an annular actuating coil coupled to the diaphragm and disposed in the air-gap, and a horn acoustically coupled to the diaphragm.

In accordance with one feature of this invention, the diaphragm comprises inner and outer flange portions and a radiating portion between the flange portions and composed of a pair of concentric annular dished sections or corrugations having a common edge to which the actuating coil may be connected. The inner and outer flange portions are securely held between clamping members which extend to the junctions of the flanges and the sections or corrugations so that these junctions define axes about which the annular sections or corrugations vibrate.

In accordance with another feature of this invention, a coupler member is provided between the diaphragm and the throat of the horn, the coupler member having a plurality of annular sound passageways therein extending from the radiating portion of the diaphragm and converging to a common annular orifice at the throat of the horn. The coupler member may include an annular outer portion overlying the outer portion of the outer annular section or corrugation of the diaphragm, a central generally circular member overlying the inner portion of the inner section or corrugation of the diaphragm, and an annular member or plug between the annular outer portion and the central member and overlying portions of the sections of the diaphragm adjacent the common edge. The several elements of the coupler member are spaced to provide two concentric annular sound passageways extending one from the center of each of the annular sections of the diaphragm and converging to a common annular orifice. This construction provides relatively short paths between the sound passageways and between all points on the radiating portion of the diaphragm so that sound energy originating at different points of the diaphragm arrives at the throat of the horn substantially

in phase and neutralization, particularly at the higher frequencies, is materially reduced or substantially prevented.

In accordance with a further feature of this invention, the surfaces of the various elements of the coupler member in juxtaposition to the corrugations or dished sections of the diaphragm are so shaped that the increment in pressure in the chamber between the diaphragm and the aforementioned surfaces of the coupler member, produced by vibrations of the diaphragm, is substantially constant throughout the chambers. More specifically, these surfaces are so shaped that the clearance between the dished sections or corrugations of the diaphragm and the surfaces increases in a predetermined way from zero at the junctions about which the annular sections or corrugations vibrate to a predetermined value at the common edge of the sections. By this construction undesired cross flow of air particles from one portion of the chamber to another portion is prevented and the loss of energy attendant upon such flow is eliminated.

In accordance with still another feature of this invention, the flow of air between the chambers bounded by the annular sections or corrugations of the diaphragm and the magnet, through the annular gap in which the actuating coil is disposed, is substantially prevented whereby the introduction of a resonance effect within the frequency range to be reproduced is prevented. To this end the portion of the magnet adjacent the outer annular section or corrugation of the diaphragm is recessed to such a degree that the increment of volume displaced by this section when the diaphragm vibrates divided by the total volume of the chamber of which this section is one wall is equal to the increment of volume displaced by the inner section divided by the total volume of the chamber between the inner section and the magnet structure.

The invention and the features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is an elevational view, partly in cross-section, of a loud-speaker illustrative of one embodiment of this invention, a portion only of the horn therefor being shown;

Fig. 2 is a perspective view, partly in cross-section, of the diaphragm and actuating coil therefor in the loud-speaker shown in Fig. 1;

Fig. 3 is an enlarged detail view in cross-section illustrating the movement of the diaphragm in the loud-speaker shown in Fig. 1; and

Fig. 4 is a detail view similar to Fig. 3 of a device wherein the surfaces of the coupler member are equally spaced from the portions of the diaphragm in juxtaposition thereto.

Referring now to the drawing, the loud-speaker shown therein comprises a magnet having a central pole 10 and an outer pole 11, the inner pole being encompassed by a suitable field coil 12. A circular pole-piece 13 is secured to the inner pole by a plurality of screws 14, only one of which is shown, and is encircled by an annular pole-piece 15 secured to the outer pole 11 by screws 16, the pole-pieces 13 and 15 being spaced to form a narrow annular gap 17.

A diaphragm overlies the pole-pieces 13 and 15 and includes annular inner and outer flanges or edge portions 18 and 19 respectively and a radiating portion including concentric annular dished sections or corrugations 20 and 21, which may be of substantially equal width, having a common annular edge or ridge 22. The diaphragm may be actuated by an annular coil 23 which is suitably secured, as by cementing, to the common edge 22 and is disposed in the annular gap 17. Preferably the diaphragm is made of thin lightweight material, so that its mass is small and but a small amount of the energy for vibrating the diaphragm is expended in overcoming the inertia of the diaphragm. For example, the diaphragm may be made in one piece of duralumin 1 mil in thickness. The annular dished portions may be relatively narrow, for example each one-half inch in width.

A coupler member, which may be a single piece metallic casting, overlies the diaphragm and comprises a central generally circular portion 24, an annular outer portion 25 having a pair of flanges 26 and 27, and an annular plug 28 which may be secured to the portion 24 and annular portion 25 by narrow integral webs, not shown. The annular plug 28 tapers away from the diaphragm and together with the central portion 24 and outer portion 25 forms a pair of annular passageways 29 and 30 extending from approximately the middle of the annular sections 20 and 21 of the diaphragm and converging to an annular orifice at the upper surface of the coupler member. The passageways 29 and 30 may be of uniform width or they may be of varying width so that the area thereof increases exponentially away from the diaphragm.

As shown clearly in Fig. 3, the surfaces 31, 32, and 33 of the plug 28 and those of the central portion 24 and the outer portion 25, respectively, are of the same form as the portions of the sections 20 and 21 of the diaphragm in juxtaposition thereto. That is, they are of such configuration that there would be an accurate fit between these surfaces and the sections 20 and 21 of the diaphragm if the edge 22 were displaced upwardly until it contacted with the ridge or edge 38 on the plug 28 thereadjacent.

The diaphragm and coupler construction and arrangement, it will be apparent, provide relatively short paths between the diaphragm ends of the passageways 29 and 30 and all parts of the sections 20 and 21 of the diaphragm. Hence, sound waves originating at all portions of the section 21 will arrive at the passageway 29 substantially in phase, and sound waves originating at all portions of the section 20 will arrive at the passageway 30 substantially in phase, and the sound waves from both sections traversing their respective paths will reach the orifice defined by the junction of the passageways 29 and 30, sub-

stantially in phase. As a result, neutralization and distortion is effectively prevented.

In the assembly of the loud-speaker, the diaphragm may be mounted on the coupler member and the unitary structure thus formed secured upon the outer pole-piece 15 by a plurality of screws 34 which pass through the flange 26. For example, the flange or outer edge portion 19 of the diaphragm may be secured to the flange 26 by screws 35, one of which is shown in Fig. 3, together with suitable washers 36, such as paper rings, and a metallic clamping ring 37. The clamping ring 37 and the lower surface of the flange 26 engage the entire flange or edge portion 19. Similarly, the flange or inner edge portion 18 of the diaphragm may be clamped against the central portion 24, together with suitable washers, such as paper rings 38, by a circular metallic plate 39, which is secured to the central portion 24 as by screws 40, one of which is shown in Fig. 1. As indicated clearly in Fig. 3, the clamping plate 39 and the central portion 24 engage and hold the flange or inner edge portion 18 of the diaphragm.

When the diaphragm is actuated in accordance with the currents in the coil 23, the annular sections or corrugations 20 and 21 vibrate about the edges thereof adjacent to the clamped portions. Line 41 in Fig. 3 indicates the position of the diaphragm for one instantaneous value of current. Because of the relatively small dimensions and of the dishing of the sections or corrugations 20 and 21, these sections will vibrate in the manner described throughout a very wide band of frequencies.

The loud-speaker unit described hereinabove may be used advantageously in conjunction with a horn including a truncated conical throat section 42 having a flange 43 seated upon the flange 27 of the coupler member and secured thereto by screws 44, and having another flange 45. The horn may include also a flaring bell section 47, for example of composition board fibre, coupled to the throat section 42 by a truncated metallic collar 48 having a flange 49 seated upon the flange 45 and secured thereto as by bolts 50. The bell section 47 may be secured to the collar 48 as by rivets 55. Disposed within the horn and coaxial with the sections 42 and 47 is an elongated member 51, which may be, for example, an aluminum casting. The member 51 may be secured to the part 24, as by screws 52, only one of which is shown, and may be held in position within the horn by a plurality of spacing fingers 53, only one of which is shown, clamped between the horn sections 42 and 47. Preferably the member 51 is so dimensioned that the annular sound passageway 54 increases exponentially in area away from the coupler member. As shown in Fig. 1, the inlet of the passageway 54 is coincident with the passageways 29 and 30 at their points of convergence at the upper surface of the coupler member.

It will be appreciated, of course, that the several considerations pointed out hereinabove should be properly correlated in order to produce a loud-speaker suitable for a particular purpose. That is to say, the entire structure should be designed so that it will be capable of delivering a desired power at some reasonable amplitude of motion of the diaphragm and of the actuating element, such as the driving coil 23 therefor. For example, the depth of the chamber between the diaphragm sections 20 and 21 and the portions of the coupler member thereadjacent should be

large in comparison with the amplitude of diaphragm displacement required to deliver the maximum power at the lowest frequency to be reproduced and the actuating element, such as the coil 23, must be able to radiate the electrical power dissipated in it and to develop the required mechanical force to drive the diaphragm to the required amplitude. Also the various masses, stiffnesses and loads involved should have the magnitudes requisite to give the desired efficiency throughout the range of frequencies to be reproduced.

One of the factors affecting the efficiency of a device of the general type to which this invention pertains is the energy loss occurring in the chambers below the diaphragm. This loss will be understood from the following consideration with reference to Fig. 4. In this figure, in which conditions are exaggerated for purposes of explanation, the surfaces 32 and 33 and those of the plug 28 are all equally and uniformly spaced from sections 20 and 21 of the diaphragm. In such a construction when the edge 22 is given a displacement upward of Δh_c the corresponding displacement at some point on section 21 of radius R is Δh such that

$$\frac{\Delta h}{\Delta h_c} = \frac{R_0 - R}{R_0 - R_c} \quad (1)$$

and the volume of air displaced by that part of section 21 between limiting values of R corresponding to R_1 and R_2 is

$$\begin{aligned} \int dv &= \int 2\pi R \delta R \Delta h \\ &= \int 2\pi \Delta h_c \frac{R_0 - R}{R_0 - R_c} R \delta R \end{aligned} \quad (2)$$

$$v = \frac{2\pi \Delta h_c R^2}{(R_0 - R_c)} (R_0 - R) \Big|_{R_1}^{R_2} \quad (3)$$

The volume of the air change between the limits of R_1 and R_2 is

$$V = \pi H R^2 \Big|_{R_1}^{R_2} \quad (4)$$

so that

$$\frac{v}{V}$$

varies with the value of R which means that in such a construction the increment of pressure resulting when the diaphragm is displaced is not constant throughout the whole air chamber and hence some of the air particles displaced flow to the annular passages 29 and 30 and some from one portion of the chamber of high pressure to another of lower pressure. The latter represents wasted energy and is of course undesirable. To avoid this, the construction in accordance with this invention disclosed is so designed that the depth H of the chamber varies from zero at the outer edges of sections 20 and 21 to H_c at the common edge 22 in such a way that

$$\frac{H}{H_c} = \frac{R_0 - R}{R_0 - R_c} \quad (5)$$

and the total volume between limits of R_1 and R_2 is

$$V = \frac{2\pi H_c}{R_0 - R_c} R^2 (R_0 - R) \Big|_{R_1}^{R_2} \quad (6)$$

Hence,

$$\frac{v}{V}$$

is constant for this construction and there will be no wasted energy.

It will be understood, of course, that the effect

described above in connection with Fig. 4 is not peculiar to the diaphragm and chamber described but is common to all cases where the amplitude of displacement relative to the air chamber depth varies throughout the diaphragm.

Inasmuch as section 21 of the diaphragm is larger in actual and in effective area than section 20, motion of the diaphragm will cause intercourse of air particles from the cavity between section 21 and the outer pole-piece 15 to the cavity between section 20 and the inner pole-piece 13, the path of intercourse being around the driving coil 23 in the annular gap 17 unless corrective measures are provided. Such intercourse is apt to result in a resonance effect within the frequency range to be reproduced and cause a variation in efficiency. The solution here is similar to that of the air chambers discussed in relation to Fig. 4 but as a practical measure may be approximated by recessing that part of the outer pole-piece 15 juxtaposed to section 21 of the diaphragm below the level of that part of the inner pole-piece 13 juxtaposed to section 20, the amount of the recessing being such that the increment of volume displaced by section 20 divided by the total volume between section 20 and the inner pole-piece 13 is equal to the increment of volume displaced by section 21 divided by the total volume between section 21 and the outer pole-piece 15. Alternatively, of course, the portion of the inner pole-piece 13 below section 20 of the diaphragm may be raised above the level of the outer pole-piece 15.

In order to control the effect of the chambers below the diaphragm sections 20 and 21 more effectively, the annular gap 17 may be wholly or partially sealed at its inner end by an annular member 57 of a relatively incompressible material such as wax, hard rubber or the like.

Although a specific embodiment of this invention has been shown and described, it will be understood, of course, that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. An acoustic device comprising an annular diaphragm including a pair of dished annular sections having a common edge, and actuating means connected to said edge.

2. An acoustic device comprising a diaphragm including inner and outer flange portions and an intermediate portion having a pair of annular corrugations joined to said flange portions, actuating means coupled to the center of said intermediate portion, and means clamping all of said flange portions whereby said corrugations vibrate about their lines of junction with said flange portions as axes.

3. An acoustic device comprising an annular diaphragm including inner and outer edge portions and an intermediate portion joined to said edge portions and having a ridge thereon, supporting means engaging all of said inner and outer edge portions, and actuating means connected to said ridge.

4. An acoustic device comprising an annular diaphragm consisting of inner and outer flanges and an intermediate portion consisting of a pair of dished annular sections of equal width and having a common edge, actuating means coupled to said common edge, and clamping means engaging said flanges, said clamping means extending to the boundaries of said intermediate portion.

5. An acoustic device comprising an annular diaphragm, means for actuating said diaphragm, and means forming a plurality of annular sound passageways in communication with said diaphragm.

6. An acoustic device comprising a diaphragm the radiating portion of which includes a plurality of coaxial corrugations, means for actuating said diaphragm, and means including a plug member overlying said corrugations, forming a plurality of annular sound passageways in communication with said radiating portion.

7. An acoustic device comprising a diaphragm including a plurality of coaxial annular dished sections, means for actuating said diaphragm, and means adjacent said diaphragm forming a plurality of sound passageways, each of said passageways extending from adjacent one of said dished sections.

8. An acoustic device comprising an annular diaphragm including a plurality of coaxial annular dished sections of substantially equal width, means for actuating said diaphragm, and means forming a plurality of annular sound passageways, one for each of said sections, each of said passageways extending from substantially the center of the corresponding section.

9. An acoustic device comprising an annular diaphragm including inner and outer edge portions and an intermediate portion comprising a pair of annular corrugations having a common annular edge, actuating means connected to said annular edge, clamping means engaging all of said edge portions, a horn coupled to said diaphragm, a member within said horn and overlying the inner of said corrugations, and an annular plug overlying portions of said corrugations adjacent said common edge.

10. An acoustic device comprising a diaphragm having a pair of annular corrugations, means for actuating said diaphragm, and means including an annular plug member overlying said corrugations forming a pair of annular sound passageways in communication with said corrugations and converging away from said diaphragm to an annular orifice.

11. An acoustic device comprising an annular diaphragm having a radiating portion composed of a pair of coaxial annular corrugations, means for actuating said diaphragm, a pair of spaced members each overlying a portion of one of said corrugations, and an annular plug member between and spaced from said spaced members and overlying other portions of said corrugations.

12. An acoustic device comprising an annular diaphragm the radiating portion of which is composed of a pair of dished annular sections of equal width and having a common edge, means for actuating said diaphragm, an annular plug member overlying equal portions of said sections adjacent said common edge, said plug member tapering away from said sections, and a pair of members each overlying a portion of one of said sections and forming a pair of annular sound passageways with said plug member, said passageways converging away from said sections.

13. An acoustic device comprising an annular diaphragm including inner and outer flange portions and an intermediate portion consisting of a pair of annular corrugations having a common edge, means for actuating said diaphragm

coupled to said common edge, means including an annular member clamping all of said outer flange portion, means including a member within said annular member clamping all of said inner flange portion, and an annular plug member between said annular member and said first plug member and forming therewith a pair of annular sound passageways each extending from one of said annular corrugations.

14. An acoustic device comprising an annular diaphragm including inner and outer flanges, and an intermediate portion having a pair of coaxial annular sections of equal width joined at one end, actuating means connected to said edge, a coupler member overlying said diaphragm including a central member engaging all of said inner flange and having a portion overlying the inner of said sections, an annular portion engaging all of said outer flange and overlying the outer of said sections, and an annular plug member overlying the portions of said sections adjacent said edge, said annular and plug members being spaced to form a pair of annular sound passageways each extending from the center of one of said sections, said sound passageways converging to form an annular orifice, and a horn having an annular sound passageway coupled to said orifice.

15. An acoustic device comprising an annular diaphragm, means for actuating said diaphragm, and means adjacent the radiating surface of said diaphragm forming a sound chamber therewith, the depth of said chamber increasing from substantially zero at the edges of the radiating portion of said diaphragm to a maximum at the center of said portion.

16. An acoustic device comprising a diaphragm including a radiating portion composed of a pair of coaxial annular corrugations having a common edge, means for actuating said diaphragm coupled to said common edge, a coupler member overlying said diaphragm and forming a chamber with said corrugations, the depth of said chamber increasing from substantially zero at the edges of said radiating portion to a maximum at said common edge.

17. An acoustic device comprising an annular diaphragm including inner and outer flanges and a radiating portion composed of a pair of annular dished sections joined to said flanges, said sections being of equal width and having a common edge, clamping means extending to the other edges of said sections, actuating means coupled to said common edge, and a coupler member overlying said sections, the surfaces of said coupler member in juxtaposition to said sections being of the same configuration as said sections and being spaced therefrom to form a sound chamber the depth of which increases from substantially zero at said other edges to a maximum at said common edge.

18. An acoustic device comprising a diaphragm the radiating portion of which includes a pair of coaxial corrugations, and a pair of members disposed one below each of said corrugations and forming chambers therewith, the surfaces of said members in juxtaposition to said corrugations being displaced so that the chamber below the outer of said corrugations is of greater depth than the chamber below the inner of said corrugations.

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