June 12, 1934. W. L. WOOLF ET AL 1,962,374

ACOUSTIC DEVICE

Filed Sept. 24, 1929

Fig. 1.

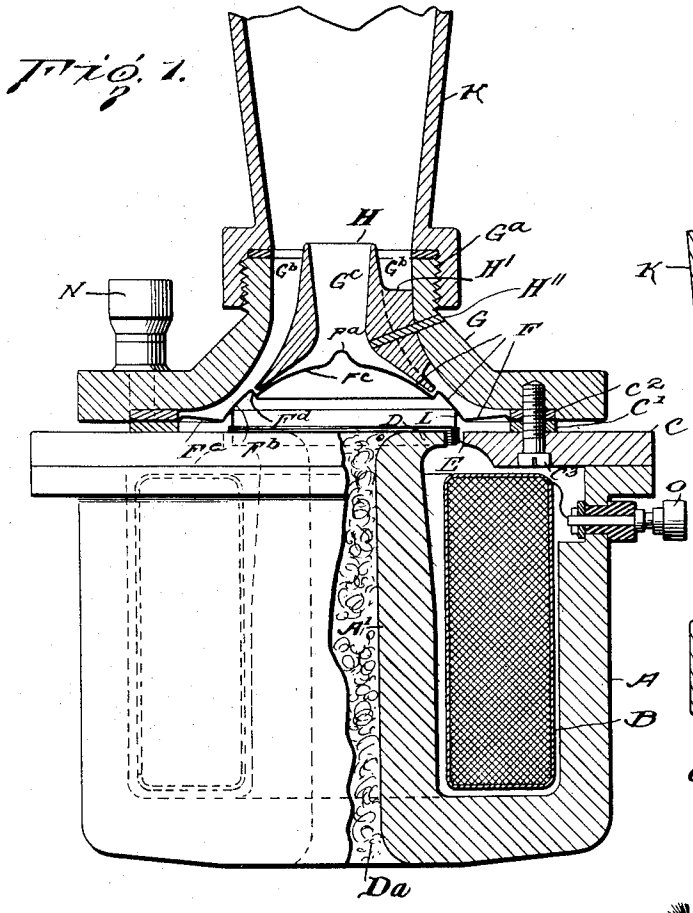


Fig. 2.

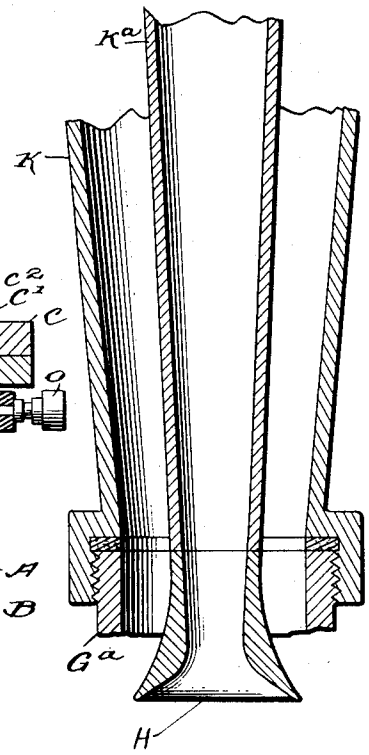


Fig. 4.

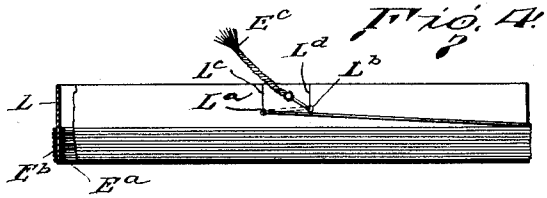


Fig. 3.

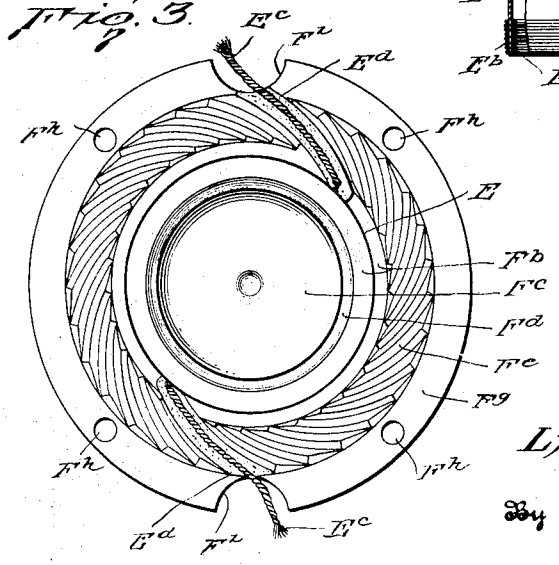
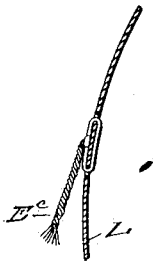


Fig. 5.



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UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

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17 Claims. (Cl. 181—31)

This invention relates to acoustic devices for the reproduction of sound.

An object of the invention is to devise a sound reproducer having high efficiency on frequencies over the complete audio band.

A further object of the invention is to devise an improved sound chamber for associating a vibrating diaphragm with a sound projector.

A further object of the invention is to devise an improved structure for a vibrating diaphragm and driving means therefor.

In accomplishing the objects of our invention, we have devised a sound reproducer employing a diaphragm in which sound vibrations at certain frequencies are reproduced principally by vibration of a limited portion of the vibrating diaphragm, and other frequencies are reproduced principally by vibration of the diaphragm as a whole. Separate sound chambers are provided for transmitting the vibrations from the different areas of the diaphragm.

In the structure which we have devised, the vibrating element comprises a novel diaphragm having a relatively stiff or rigid central portion and a flexible peripheral portion, the diaphragm being associated with a novel sound chamber structure leading to a horn or sound projector. In prior structures employing vibrating elements the driving connection has been made either to the center of the diaphragm or to the periphery of the stiffened central portion. The center drive emphasizes the high frequencies at the expense of the low, and the peripheral drive is objectionable in that the entire diaphragm, including the driving coil or connection, must vibrate to give the highest frequency desired. In our structure, the driving force is applied at a point or points within the periphery of the stiffened central portion, with the result that we secure the benefits of both methods of driving and obtain very high efficiency. In our invention, the entire diaphragm is vibrated substantially only on frequencies below a certain point, and frequencies above this point are reproduced principally by vibration of a portion of the diaphragm less than the whole, and more especially the stiffened portion of the diaphragm within and near the driving connections, the movements necessary to reproduce the high frequencies being too rapid to set the entire diaphragm into motion of sufficient amplitude to produce sound of satisfactory volume. Since there is a tendency for the high frequencies to be absorbed in a sound chamber of sufficient size to efficiently transmit low frequencies from the entire diaphragm, we provide an inner sound chamber for transmitting these high frequency vibrations into the mouth of the horn. Around the inner sound chamber we provide a second sound chamber concentric with the first which serves to conduct the vibrations originating from the peripheral edge of the stiffened portion and from the flexible periphery of the diaphragm to the mouth of the horn.

This invention is an improvement on our invention described and claimed in our prior application filed September 10, 1929, which discloses an electro-dynamic type loud speaker employing a vibrating diaphragm of the same general type as disclosed in this application, but wherein the domed part of the diaphragm projects into a sound chamber forming a single sound passage of increasing cross-sectional area leading from the periphery of the vibrating diaphragm to the tip of the domed central portion and into the mouth of the horn.

Our invention is illustrated in the accompanying drawing in which:

Figure 1 is a sectional view illustrating a loud speaker structure embodying the features of our invention;

Figure 2 is a fragmentary view illustrating a modification of the structure shown in Figure 1;

Figure 3 is a back view of the vibrating diaphragm assembly;

Figure 4 is an enlarged view of the driving coil with parts shown in section; and

Figure 5 is an enlarged fragmentary view illustrating the manner in which the ends of the driving coil are secured.

Referring to Figure 1, the loud speaker which we have devised is of the electrodynamic type and comprises a cylindrical casing or pot A of magnetic material, such for example, as steel, containing an annular magnetizing winding B, and having an annular pole piece C secured to the periphery of its open end. A hollow core member A' projects from the bottom of pot A and its upper end D forms a central pole piece within the annular pole piece C, leaving an annular air gap between the two pole pieces. A driving coil E mounted upon a circular diaphragm F is suspended in the annular air gap formed between the pole pieces C and D. The vibrating diaphragm F is clamped at its periphery between rings C1 and C2 by suitable clamping screws C3 passing through the pole piece C and through the rings C1 and C2 into a cap member or housing G surmounting the vibrating diaphragm F. Located within housing G is an annular member H arranged concentric with the domed

central portion of the diaphragm F and concentric with the threaded outlet G*a*. This annular member may be formed separately from the housing G and supported therein by radial pins or other means, or it may be formed integral with the housing and supported by radial fins or partitions. One method of supporting the annular member H is illustrated in Figure 1, wherein three or more equally spaced radial fins H' formed integral with the member H are provided for centering the annular member with respect to the housing G, and a small pin H'' is passed through each fin H' to secure the annular member in proper position. Only one fin is shown in cross-section in Figure 1. The width of the fins is made as small as possible and only slightly exceeds the diameter of the pin H''.

The details of the diaphragm F are illustrated in Figures 1 and 3. The central portion of the diaphragm is domed or convex in shape and is provided with a pronounced tip or protrusion F*a* at its center. The domed part of the diaphragm comprises an annular section F*b* and a central circular section Fc connected together by an intermediate annular section F*d*. Surrounding the convex portion of the diaphragm is an annular section F*e* corrugated with curved corrugations in the manner shown in Figure 3. The corrugations are preferably arcuate in shape, whereby section F*e* is stiffened, and bending of the diaphragm takes place only at the outer and inner peripheries of the corrugated section. This structure avoids any ripples which would otherwise be produced in section F*e* if this area were not stiffened. The driving coil E is supported upon a cylinder of very thin insulating material indicated at L, which in turn is cemented at one end to the diaphragm F by suitable cement applied between the outside of the cylinder and the domed portion of the diaphragm. We prefer to make the cylinder L of such diameter that it will be attached to the diaphragm F on a circle at which the pressure exerted on the diaphragm within the circle during operation is equal to the pressure exerted on the diaphragm outside of the circle. In this manner the driving coil is attached at points at which there is mechanical balance, and there will be no tendency for the diaphragm to see-saw about the points of attachment. Outside of the corrugated section F*e* is a flat peripheral section F*g* by which the diaphragm is clamped between clamping rings C1 and C2. The flat peripheral section F*g* is provided with a number of holes F*h* for receiving clamping screws C3, and a pair of notches F*i* to facilitate bringing out the leads of the driving coil E to two insulated binding posts N (only one shown) mounted upon housing G (see Fig. 1). The diaphragm is preferably stamped by dies from a very thin sheet of light metal, such as duralumin.

Driving coil E is wound of fine copper wire and consists of two layers, one layer supported upon the inside of insulating cylinder L and the other layer supported on the outside of this cylinder. This arrangement is formed by first winding the inside layer directly upon a collapsible mandrel and then the insulating cylinder is placed over this layer and cemented to the turns thereof by any suitable cement. The winding is then continued upon the outside of the cylinder to form the second layer of the coil. The second layer may be secured to the cylinder by suitably coating the outside with cement before winding on the layer. The collapsible mandrel is then withdrawn, leaving the two layers of wire permanently cemented to the insulating cylinder L. In Figure 4, E*a* indicates the inside layer of the winding coil and E*b* indicates the outside layer. The cylinder L may be cut from cylindrical stock material of proper diameter and thickness of wall, or it may be formed by bending a thin sheet of parchment paper of proper thickness into cylindrical form with the ends abutting, or the cylinder may be formed by winding directly upon the first layer of the winding a number of superimposed turns or layers of very thin paper to give the required thickness of wall for the supporting cylinder, the turns being cemented together during the process of winding. The ends of the winding are preferably terminated on opposite sides of the coil, and each end is passed through two holes L*a* and L*b* formed in the supporting cylinder, as shown in Figure 5, to secure the ends of the winding against unraveling. Slits Lc and L*d* may be cut in the edge of the cylinder L leading to the holes L*a* and L*b*, respectively, to facilitate inserting the wire in the holes. If desired, the holes L*a* and L*b* may be omitted, and the ends of the winding suitably anchored by inserting the wire in the slits Lc and L*d*. Each end of winding is provided with flexible stranded terminal conductors indicated at Ec, these conductors being formed of a large number of fine strands of wire twisted together, making up a size of wire sufficient to carry the necessary current for operating the coil E. This provides a flexible connection to the coil on the diaphragm which will not break by reason of crystallization caused by violent vibrations of the diaphragm as would be the case if a solid wire were used for this purpose. The flexible lead conductors Ec lead away from the coil along the bottoms of two corrugations on opposite sides of the diaphragm, with thin pieces of insulating material E*d*, such as paper, inserted between the leads and the diaphragm. The strips of paper E*d* are cemented to the diaphragm and the leads Ec are cemented to the paper and to the diaphragm by a coating of suitable cement, which also serves to insulate the conductors.

It will be seen that by winding the driving coil as a continuous winding in the manner just described with two layers, one supported upon the inside and the other upon the outside of a supporting cylinder, the two ends of the coil terminate at the same end of the coil, which greatly facilitates bringing out the terminal conductors to suitable binding posts. We prefer to wind the coil so that the ends of the winding terminate adjacent the end of the cylinder by which it is attached to the diaphragm, although it is clear that the ends may be brought out at the free end of the cylinder, if desired.

As illustrated in Figure 1, the central circular section Fc of the domed portion of the diaphragm is set back or depressed with respect to the annular section F*b* by a distance substantially equal to the width of the annular section F*d*. The arrangement is such that the annular section F*d* substantially encircles the lower peripheral edge of the annular member H, and the outer surface of the annular member H is substantially a continuation of the surface of the domed section F*b*. By providing the depressed central section Fc in the domed part of the diaphragm, for cooperation with the annular member H, the diaphragm is effectively divided into an annular peripheral section outside of the section F*d* and a circular central section within section F*d*, the two sections being substantially independent acoustically. The clearance between the lower

edge of member H and the annular section Fd is made as small as possible without causing interference with the free vibration of the diaphragm. The inner contour of housing G and the outer contour of the annular member H, and of sections Fb and Fe of the diaphragm, are shaped to provide an annular sound passage Gb of gradually increasing cross-section area for the transmission of sound vibrations originating from the corrugated peripheral section Fe and the domed section Fb of the diaphragm. The inner contour of annular member H is shaped with respect to the outer contour of the domed section Fc and the tip Fa of the diaphragm to provide a second sound passage Gc of gradually increasing cross-sectional area for sound vibrations produced by the central section of the domed part of the diaphragm. The two sound passages are preferably formed to provide an exponential increase in area from the beginning points of the passages to their outlets, however, it is not essential that this exact relation be obtained. The central tip Fa on the diaphragm serves to eliminate the small air pocket which would otherwise be formed in the passage Gc at the center of the diaphragm. Such air pockets have been found to absorb the energy of the high frequency notes and substantially impair the transmission in the upper range of the audible scale. The tip Fa serves to produce a gradual change in direction of the sound waves as they are concentrated from the annular section of the sound passage to the circular section. It will be seen that annular member H forms an auxiliary sound chamber within housing G providing a separate sound passage leading from the periphery of a central area of the domed part of the diaphragm to the mouth of the outlet passage of housing G. Cap G and member H are preferably die cast from "white metal", which presents a very smooth and slick surface for the sound passages and materially increases the efficiency of transmission of the high frequency notes. Sound passage Gc is designed for the efficient transmission of high frequencies, whereas passage Gb is designed for the efficient transmission of low frequencies, both passages, however, serving to transmit all frequencies to a limited extent. In effect, sound passage Gc constitutes a short air column which emphasizes or brings out the high frequencies.

The space within the hollow pole piece D may be filled with loose fibrous material Da, such as wool, to absorb the sound waves in the rear of the diaphragm, and prevent acoustic resonance effects in this space. As an alternative, the pole piece D may be made solid, or filled with solid material, and the enclosed space between the convexed portion of the diaphragm and the pole piece D may be designed to produce the same pressure against the underside of the diaphragm as exists on the upper side during operation. This space is substantially closed, except for the small annular air gap existing between the coil E and the pole piece D. This equalization of pressures produces equal loading on each side of the diaphragm and is materially effective in eliminating distortion which would otherwise occur.

A sound projector K is secured to the mouth of housing outlet Ga for receiving sound vibrations from the annular passage Gb and from the circular passage Gc, and for projecting the sound in the desired direction. An alternative structure is illustrated in Figure 2 in which the sound passage Gc is provided with a separate horn Ka supported within the horn K. The horn Ka may be longer or shorter than horn K, or it may be omitted entirely as in Figure 1, in which case horn K serves as a projector for both sound passages.

Operation of the invention is as follows: The magnetizing winding B is energized with direct current from any suitable source connected to the two coil terminals O (only one shown). The driving coil E is energized from a source of varying electric current which is to be reproduced in o sound vibrations. As is well understood by those skilled in the art, the interaction between the magnetic field set up by current flowing in the driving coil E and the magnetic field induced across the annular gap between poles C and D causes the diaphragm to vibrate in accordance with variations of the electric current supplied to the driving coil. For certain frequencies, the entire diaphragm, including the corrugated section and the entire domed portion, is effective in producing sound vibrations. Accordingly sound waves of certain frequencies, principally the lower frequencies, emanate from both sound passages Gb and Gc. For other frequencies, the domed stiffened portion of the diaphragm within and near the driving connection is principally effective in producing sound vibrations. Since sound passage Gc is designed for the efficient transmission of the high frequency vibrations this passage is most effective in transmitting the high frequency vibrations produced. The auxiliary sound chamber formed by annular member H serves to prevent cross-vibrations or interference at the center of the diaphragm due to the concentration of the sound waves at this point from the surrounding peripheral area of the diaphragm. The tip Fa on the diaphragm serves to prevent cross-vibrations within the auxiliary sound chamber.

From the foregoing description, it will be seen that we have devised a loud speaker employing a vibrating diaphragm in which the diaphragm is divided into concentric areas, and separate sound passages are provided for the different areas, each portion of diaphragm and each sound chamber possessing characteristics different from the other and so designed that the combination of all gives a very efficient response over practically the entire spectrum of audible frequencies.

While we have shown coil E attached to the domed section Fb, it is clear that it may be attached to annular section Fd or to the peripheral edge of the domed section Fc. It is also clear that the domed portion of the diaphragm comprising sections Fb and Fc may be formed as one continuous domed surface without section Fd, but we prefer the construction illustrated in the drawing.

It is apparent that many other changes in detailed construction may be made without departing from our invention in its broadest aspect. It will also be understood by those skilled in the art that the operation of our device is reversible, and it may be used as a transmitter for converting sound vibrations into electric current variations.

We claim:

1. A sound reproducer comprising a housing provided with an outlet passage, a diaphragm mounted in said housing, means cooperating with the vibrating portion of said diaphragm for forming acoustically independent areas thereon, and means within said housing for forming separate sound passages leading from said independent

areas of said diaphragm to the mouth of said outlet passage.

2. A sound reproducer comprising a housing provided with an outlet passage, a diaphragm mounted in said housing, said housing having a plurality of concentric sound passages formed therein leading from different areas of said diaphragm to the mouth of said outlet passage, and means for rendering the different areas of the vibrating diaphragm acoustically independent of each other.

3. A sound reproducer comprising a housing, a diaphragm mounted therein, and a sound projector secured thereto, said housing being provided with separate sound passages leading to the mouth of said projector from different concentric areas of said diaphragm, and means for rendering the different concentric areas of the vibrating diaphragm acoustically independent of each other.

4. A sound reproducer comprising a housing, a diaphragm mounted therein, and a sound projector secured thereto, said housing being provided with a plurality of separate concentric sound passages leading to the mouth of said projector from different areas of said diaphragm, and an acoustic barrier arranged between the different areas of said diaphragm to render said areas acoustically independent of each other.

5. In a sound reproducer, a vibrating diaphragm comprising a domed central portion surrounded by a flat peripheral portion, and driving connections for said diaphragm secured to said domed portion on the concave side thereof at points lying on a circle intermediate the center and the peripheral edge of said domed portion, and a sound chamber arranged on the convex side of said diaphragm and extending over an area encompassed by said driving connections.

6. A sound reproducer comprising a sound chamber provided with an outlet passage, a diaphragm mounted in said sound chamber, the wall of said sound chamber cooperating with said diaphragm to form a sound passage of increasing area leading from the periphery of said diaphragm to the mouth of said outlet passage, an auxiliary sound chamber mounted within said first mentioned sound chamber and cooperating with the surface of said diaphragm to form a sound passage of increasing area leading from points intermediate the center and the periphery of the diaphragm towards the center of the diaphragm and to the mouth of the outlet opening.

7. A sound reproducer comprising a sound chamber provided with an outlet passage, a diaphragm mounted in said sound chamber, the wall of said sound chamber cooperating with said diaphragm to form a sound passage of increasing cross-sectional area leading from the periphery of said diaphragm to the mouth of said outlet passage, an auxiliary sound chamber mounted within said first mentioned sound chamber, and forming a separate sound passage leading from the periphery of a central area of said diaphragm to the mouth of said outlet passage.

8. A sound reproducer comprising a housing forming a sound chamber provided with an outlet passage, a diaphragm mounted in said chamber comprising a flexible peripheral portion and a relatively stiff domed central portion projecting into said housing, an auxiliary sound chamber mounted in said housing and forming a sound passage leading from the central area of said stiffened portion to the mouth of said outlet passage.

9. A sound reproducer comprising a sound chamber provided with an outlet passage, a diaphragm mounted in said chamber, an auxiliary sound chamber mounted within said first mentioned sound chamber over a central area of said diaphragm, the inner surface of said first sound chamber cooperating with the peripheral area of said diaphragm, and the external surface of said auxiliary sound chamber to form a sound passage of increasing cross-sectional area leading from the periphery of said diaphragm to the mouth of said outlet passage, and the inner surface of said auxiliary sound chamber cooperating with the central area of said diaphragm to form a separate sound passage of increasing area leading from the periphery of said central area to the mouth of said outlet passage.

10. A sound reproducer comprising a housing forming a sound chamber provided with an outlet passage, a diaphragm mounted in said chamber comprising a flexible peripheral portion and a relatively stiff domed central portion projecting into said housing, an auxiliary sound chamber mounted in said housing and forming a sound passage leading from the periphery of a central area of said stiffened portion to the mouth of said outlet passage, and driving means for said diaphragm secured to said domed portion at points substantially surrounding the central area covered by said auxiliary sound chamber.

11. A sound reproducer comprising a housing forming a sound chamber provided with an outlet passage, a diaphragm mounted in said chamber comprising a flexible peripheral portion and a domed central portion projecting into said housing, an auxiliary sound chamber mounted within said housing over a central area of said domed portion, said elements cooperating to form an annular sound passage of increasing area leading from the flexible periphery of said diaphragm to the mouth of said outlet passage, and the auxiliary sound chamber cooperating with the central area of said diaphragm to form a separate sound passage of increasing area leading from the periphery of said central area towards the center thereof and to the mouth of said outlet passage.

12. A sound reproducer comprising a housing forming a sound chamber provided with an outlet passage, a diaphragm mounted in said chamber comprising a flexible peripheral portion and a relatively stiff domed central portion projecting into said housing, said domed portion comprising an annular section and a depressed central section, an auxiliary sound chamber mounted in said housing over said central section and forming a separate sound passage leading from said central section to the mouth of said outlet passage.

13. A sound reproducer comprising a housing forming a sound chamber provided with an outlet passage, a diaphragm mounted in said chamber comprising a flexible peripheral portion and a relatively stiff domed central portion projecting into said housing, said domed portion comprising an annular section and a depressed central section, an auxiliary sound chamber mounted in said housing and cooperating with said depressed central section to form a sound passage of increasing cross-sectional area leading from the periphery of said central section to the mouth of said outlet passage.

14. A sound reproducer comprising a housing forming a sound chamber provided with an outlet passage, a circular diaphragm mounted in said chamber comprising a flexible peripheral portion and a relatively stiff domed central portion projecting into said housing, said domed central portion comprising an annular section and a depressed circular central section, an annular member mounted over said depressed central section and forming a sound passage leading from the periphery of said domed central section to the mouth of said outlet passage, the internal wall of said housing and the external wall of said annular member cooperating with the flexible peripheral portion and the annular domed section of the diaphragm to form an annular sound passage of increasing cross-sectional area leading from the periphery of said flexible portion to the mouth of said outlet passage.

15. An acoustic diaphragm comprising a domed central portion surrounded by a flat peripheral portion, said domed central portion comprising an annular section and a circular central section within said annular section, said circular section being domed in the same direction as said annular section but depressed below the dome outline of said annular section.

16. An acoustic diaphragm comprising a domed central portion surrounded by a flat corrugated peripheral portion, said domed portion comprising an annular peripheral section, a circular central section, and an intermediate annular section, said circular section being domed in the same direction as said annular section but depressed below the dome outline of said annular section.

17. A sound reproducer comprising a housing provided with an outlet passage, a diaphragm mounted in said housing, means cooperating with said diaphragm for forming a plurality of acoustically independent sound chambers associated with different areas of the vibrating portion of said diaphragm, said independent sound chambers being provided with individual sound passages leading to said outlet passage.

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