

June 22, 1937.

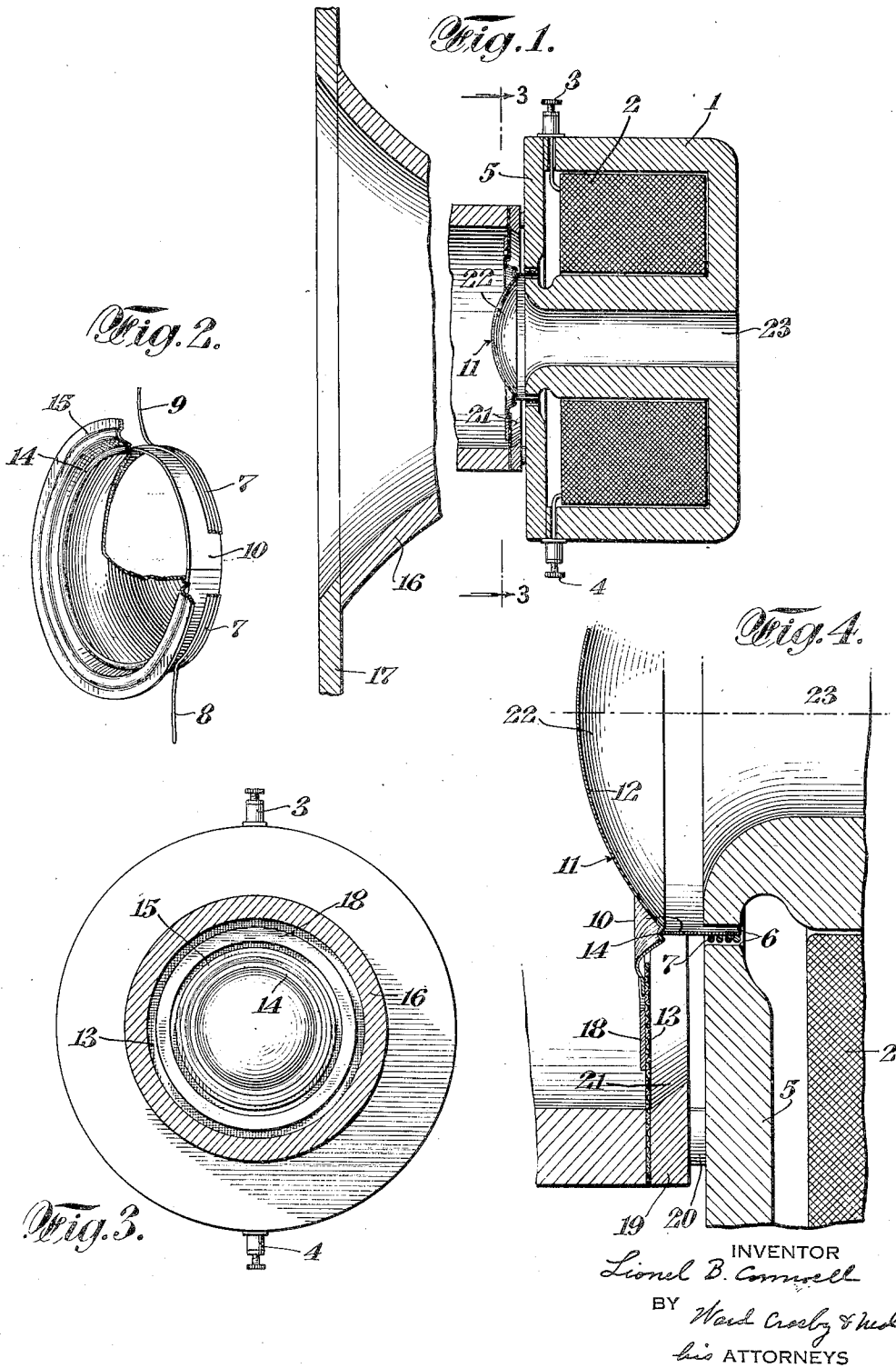
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2,084,944

ACOUSTIC DEVICE

Filed July 3, 1933

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

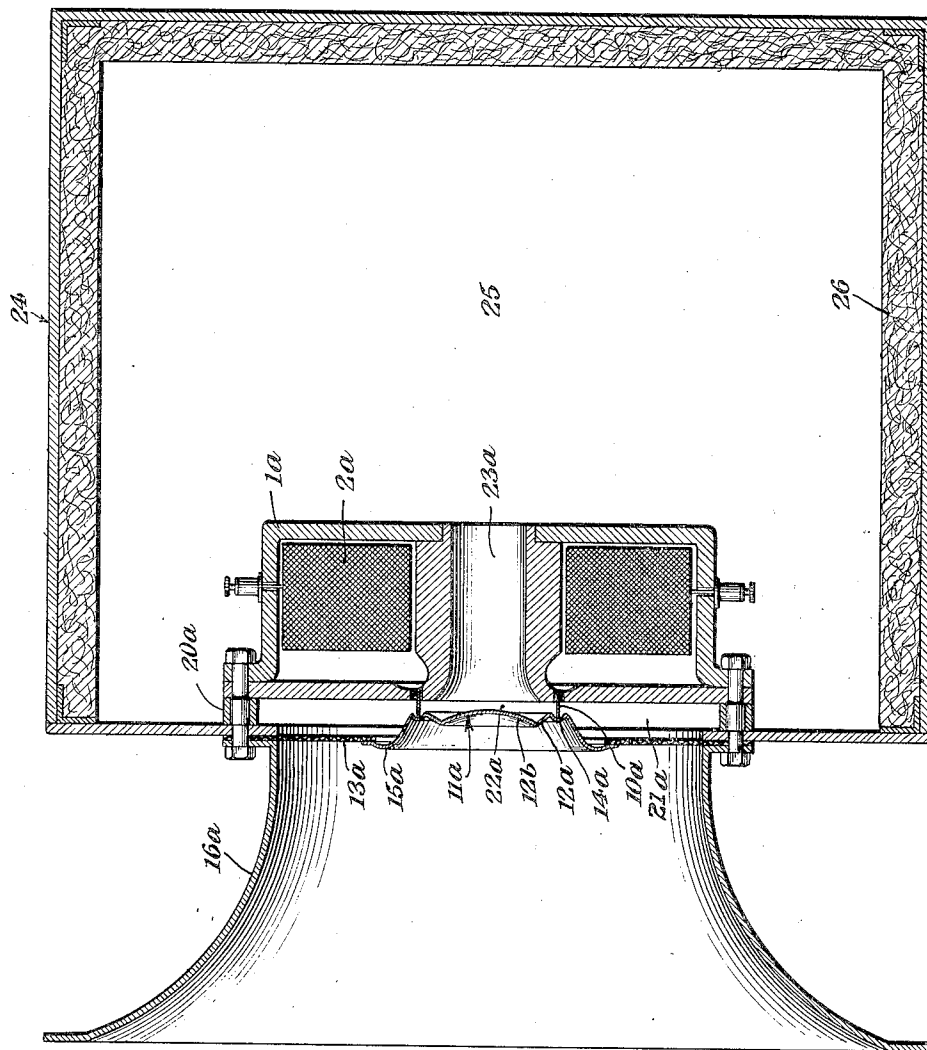


Fig. 5.

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ACOUSTIC DEVICE

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4 Claims. (Cl. 179—115.5)

This invention relates to acoustic devices such as are utilized in translating electrical impulses to sound vibrations or vice versa. The invention as exemplified in the embodiment herein disclosed takes the form of a sound reproducer or loud speaker, and the invention will be described with reference to such illustrative embodiment, which will permit those skilled in the art to understand the invention.

For the human ear useful audible vibrations cover a range of from 30 cycles per second minimum to approximately 16,000 cycles per second maximum; and the so-called middle range may be said to lie in the neighborhood of approximately 1,000 to 3,500 cycles. Therefore a good loud speaker will reproduce any frequencies within the above minimum-maximum limits, showing no partiality to any particular frequency but producing frequencies accurately in accordance with and with as much volume as the original sound. It should also be capable of reproducing transient sounds, such as sharp impact or plucking sounds.

An object of the invention is to produce a device having the above desired characteristics.

Another object of the invention is to provide suitable damping or loading means without interfering with the desired operative characteristics of the device.

The class of sound reproducers to which this invention is directed is that known as the dynamic, or moving coil type, in which a "voice" coil wound on a coil support drives a diaphragm attached to the coil support.

The invention consists in the novel features, arrangements, construction and combination of parts embodied by way of example in the apparatus to be hereinafter described, as illustrating the present preferred form of the invention, and the invention will be more particularly pointed out in the appended claims.

A particular feature of the invention resides in the rigid attachment of a coil support, having a relatively high ratio of stiffness to weight, to a very light rigid area of the diaphragm. Thin sheet mica is ideally suited as a coil support and the rigid diaphragm area is conveniently provided by a groove in the diaphragm to which the edge of the sheet mica may be fastened by cement. By reason of this feature the very high frequencies are propagated only by the said rigid diaphragm area which vibrates in unison with the coil support without appreciable absorption or distortion of the vibrations. As the frequencies become lower the area of the diaphragm

under vibration spreads beyond the said rigid area.

Further and more specific objects, features and advantages will more clearly appear from the detailed description given below taken in connection with the accompanying drawings which form a part of this specification, and in which

Fig. 1 is a longitudinal sectional view,

Fig. 2 is a perspective view of a segment of the vibratile member and voice coil, with parts broken away more clearly to show the details,

Fig. 3 is a transverse sectional view taken at 3—3 of Fig. 1,

Fig. 4 is an enlarged fragmentary view of parts shown in Fig. 3, and

Fig. 5 is a sectional view of a modification.

In the embodiment of the invention herein illustrated I have shown a loud speaker of the electro-dynamic type, in which a magnetic field is provided by an electro-magnet, and a movable voice coil is utilized in an air gap in the field of said magnet, but it will be understood by those skilled in the art that certain features of the invention are not to be limited to these particular features.

Referring to the drawings, and more particularly to Fig. 1, a magnetic field means is provided as follows. A magnetic iron bowl provides an annular receptacle of suitable form for accommodating a field coil 2 which has terminals 3—4 for applying electrical potential, and a cover plate 5 is provided at what will be termed the upper wall to facilitate manufacture and assembly. In the upper wall an annular air gap 6 is provided for receiving a movable armature coil or voice coil 7 which is of small size and of light weight and preferably is made of fine aluminum wire, and is provided with highly flexible terminal lead-in wires 8—9 for attaching the coil in a pulsating or alternating electrical circuit whose pulsations or alternations vary according to the sound vibrations to be reproduced.

These pulsating or alternating currents set up magneto-motive forces in the coil 7 which are strongly reactive due to coil 7 lying in the flux of magnetic field above described. This produces certain physical forces in coil 7 which are utilized as a motive force for a suitable vibratile member adapted to move air in audible vibrations. It will therefore be appreciated that this coil must be not only of extremely light weight, but that its connection to the vibratile member must also be of extremely light weight so that it will have as little inertia as possible; and its connection must

be rigid so that there will be no absorption or distortion of its movements.

To this end the coil 7 is wound on and supported by a cylindrical member 10 which I have found to be ideally suitable when made of sheet mica. Such crystalline sheets can be reduced to a thinness of approximately .0015 inch and still be very stiff and substantially non-compressible. When a sheet of this order of thinness is formed into a cylinder the resulting cylinder may easily have a maximum wall thickness of substantially .0015 inch, and it is possible to have substantially all of the wall portion approximately .0015 inch thickness. This is made possible by abutting the edges of the cylindrically wound sheet and then holding the same in position by the surrounding coil which is preferably cemented in place. Although the sheet may have a thickness somewhat greater than .0015 inch, it should preferably be not greater than .004 inch. Mica is an eminently suitable material for the purpose because sheets of this crystalline substance, of the order of thinness mentioned above, have an extremely high ratio of stiffness of weight. Young's modulus of elasticity for this sheet mica is approximately 30×10^{-6} pounds per square inch, and yet its specific gravity is only about 2.9. The cylinder 10 is suitably attached, such as by cement, to a vibratile member, or diaphragm, designated in its entirety as 11, which will now be more particularly described since its particular construction constitutes an important feature of the invention.

The vibratile member 11 comprises in general two pieces or parts, a circular inner plunger part 12 and an outer concentric ring part 13 (Figs. 1, 3 and 5). The inner plunger part is made of a light and rigid material which may be molded or pressed of plastic materials into the desired shape. I have found that aluminum of a thickness of .002 inch also gives satisfactory results. The inner part has a central area stiffened by the particular formation of its wall or shell, which is preferably arched in a convex or in a concavo-convex shape as in Fig. 5, or dome shaped as in Figs. 3 and 4, and in the present embodiment the dome or arch follows the arc of a perfect circle. At the outer edge or base of the dome is a rigid annular region such as the inverted groove 14, which may be either angular or arched as in Fig. 5, which is the region to which the cylinder 10, carrying the voice coil, is attached. From the groove 14 a skirt 15 extends upwardly and outwardly along a curved path and then extends outwardly forming an arched portion in a substantially flat marginal flange. The skirt 15 extends upwardly and outwardly along a curved path in order to obtain as much rigidity as possible which permits but a minimum of circular vibrating nodes to take place, while if the skirt 15 extends upwards and outward in a straight line forming the usual cone shape a thicker material is necessary in order to retain the required rigidity which being heavier introduces inertia problems, etc. It is obvious that the curved shape is the most desired if best results are to be expected. It follows that since the marginal flange of skirt 15 is the only area of the plunger part 12 which is not arched or curved, it is the most flexible area of part 12. The outer ring 13 is integrally attached to the flat marginal flange of skirt 15 as by cement. The ring 13 and the marginal flange of skirt 15 thus constitute an annular marginal area integral with the diaphragm. The area of ring 13 should be at least 50% of the area of the plunger part 12, and is preferably

equal to or greater than the area of said rigid plunger.

From the foregoing it will be understood that the movements or vibrations of the voice coil 7 are transmitted without alteration through the substantially non-compressible cylindrical member 10 to the highly stiffened region 14; with the normally to be expected result that the inner part 12 would thereby be given a substantially uniform movement. I have found, however, that at the highest frequencies the whole area of the part 12 does not vibrate in such manner as to produce sound; but instead, only the region 14 is in sound producing motion, the central or dome shaped area and the outer skirt 15 remaining practically stationary. Under this condition the stiff coil support 10 and the stiff diaphragm portion 14 rigidly cemented thereto vibrate in unison without absorption or distortion of the vibrations. But when the frequency becomes lower the area in vibration extends in both directions from the extremely rigid region 14, and more and more of the central area and of the skirt are brought into vibration. This is of great inherent benefit because the active vibrating area necessary for a constant amplitude on the human ear is substantially inversely proportional to the frequency in cycles per second. However, in view of these characteristics I have found that it is essential that the diameter of the complete inner part 12 be kept very small, otherwise the middle range of frequencies (1,000 to 3,500 cycles per second approximately) would be vibrated at much greater amplitude than the frequencies above 3,500 cycles per second. I have found, for example, that in the present preferred form of the invention, the over-all diameter of the inner part 12 should be not greater than 5 inches. The given active area does not remain the same at a given frequency, but varies also with the change of volume at said given frequency. For this reason also it is desirable to keep the diameter of the inner part 12 relatively small so that the middle range of frequencies may be reproduced at an amplitude that is in proper relation to the higher frequencies.

From the foregoing it will be understood that in the reproduction of frequencies from approximately 1,000 cycles per second downward, the part 12 functions as a plunger moving back and forth uniformly, and herein the physical factors of mass and tension are to be more especially considered.

The lower the frequency, the greater is the amount of air that must be displaced to make the sound equal in amplitude to that at the high frequencies. As heretofore stated, the plunger part 12 is small and in order to displace the required amount of air it is joined to a suitable horn such as 16, the opening of which in the present embodiment joins to the horn opening in a cabinet or container 17, such as might be used in housing the complete loud speaker. The expanding column of air within the horn 16 allows the plunger to get a grip on the air at low frequencies. For the plunger properly to follow the physical motion of the electrical pulsations at the low frequencies, it must be so mounted as to be perfectly free to move back and forth the necessary distance and velocity required by the amplitude of the electrical impulses necessary for the average room volume of home radio for which the particular speaker herein illustrated is designed. Because of the extreme lightness of the plunger 12 herein described, it has

an extremely low moment of inertia and low momentum, making it more responsive to the transient impulses such as the plucking of strings, impact sound, drums, etc.

5 With such requirements it is desirable to produce an extremely flexible and light mounting or support for the plunger part 12, and further, such mounting should be resonant at frequencies in the neighborhood of 50 cycles (and not substantially greater than the order of 200 cycles), the point of resonance being quite broad. 10 In addition to this, it is desirable that this mounting act as a part of the vibratile member, which may be termed a plunger diaphragm of which the ring 13 is a part. The ring augments the displacement area of the vibratile member at the lower frequencies. The ring 13, heretofore described, is designed to perform these functions; it should be substantially air-impervious, 20 otherwise the air upon being displaced would circulate from one side of the diaphragm to the other.

To describe materials suitable for the construction of the ring 13 the following are given as examples of satisfactory rings with which I have 25 experimented. In the course of my experiments, I have found that chamois in its commercial state is ideally suited for this purpose. I have further found that light weight cotton, one side of which is napped and which is treated as follows is quite satisfactory. The napped condition helps to prevent the ring from resonating at any frequency other than extremely low frequencies. 30 On the smooth side of the cotton cloth there is applied a suitable filler or coating such as a very thin application of rubber which may take the form of latex in solution. It will be appreciated that other materials may be found satisfactory, the chief characteristics desirable being that the material should be air-impervious, flexible, and non-resonating except as it may be made to resonate within a certain range of low frequencies in accordance with the desire of the designer. 40 The range of frequencies within which the material is resonant may be selected by stretching it to the desired degree, since by such stretching its tightness or looseness becomes a factor in the mass and tension formula. It will be understood that by character such material is non-responsive at any frequencies unless stretched and mounted and arranged for the purpose in such a manner as is herein more fully pointed out, as for example where it is involved in joint action with the inner plunger part 12 at very 50 low frequencies only.

At very low frequencies the ring 13 is herein utilized in the displacement of the air, for as mentioned heretofore an increasing quantity of air must be displaced as the frequencies decrease. 60 To assist in making the ring 13 more effective in the air displacement at low frequencies, a flat relatively rigid ring 18 may be attached, as by cementing, at the central portion of the ring 13 (Fig. 4). This stiffening annular member 18 65 may be made of any thin, light and relatively stiff material, such for example as cardboard. It will be understood that adjacent to the inner and outer edges of the stiffening ring 18 the unstiffened portions of the ring 13 remain flexible.

70 The entire plunger diaphragm or vibratile member 11 heretofore described is supported in such a manner as by being cemented to the ring 19 which holds the same in place and which in turn is suitably secured, such as by screws or 75

bolts, to the plate 5. In this manner the voice coil 7 is held within the air gap 6 without rubbing against the faces of the annular air gap and is free to vibrate or oscillate back and forth in accordance with the electrical pulsations flowing through it. 5

Such a construction provides a combination of a dome (or arched) and a flat diaphragm which is ideally adapted for the greatest efficiency in operation. The inner plunger part 12 10 drives the air at the middle and high frequencies (the active sound producing area varying inversely as the frequency) and the entire diaphragm including the plunger part 12 and flexible ring 13 with its stiffening member 18 drive 15 the air at low frequencies.

In view of the extreme lightness of the inner plunger part 12 and of the voice coil and its attaching cylinder 10, any damping or loading influence its response very materially, especially at low frequencies. Such damping is provided for, without interfering with the efficiency of operation of the device, in the following manner. The vibratile member supporting ring 19 is spaced 20 away from the plate 5 by spacing members 20 which are preferably held in place by the screws or bolts serving to attach the supporting ring 19. In this manner I provide for venting the chamber which will be designated as 21 and which is bounded on the upper side by the skirt 15 and the flexible ring 13, whose inner limit is defined by the wall of the cylindrical member 10, and whose lower wall is defined by the plate 5. The air from the chamber 21 is thereby permitted to escape through the vents provided by the spacers 25 20, and these vents have a predetermined area in cross section which will be defined more particularly hereinafter. It will also be noted that a chamber 22 lies beneath the central dome of the inner member 12 and the outer margin of such chamber is defined by the inner wall of the cylinder 10. The said chamber 22 communicates with the atmosphere, through the hole or bore 30 23 which is provided through the iron bowl 1. The following conditions and proportions with respect to the chambers and their respective venting means and the air pressure in the horn 16 during the operation of the device will now be particularly pointed out in order that this feature of the invention may be better understood and appreciated. 50

The cross section areas of the venting means between the spacers 20 and the cross section areas of the bore 23 are such as to bring about the predetermined degree of damping with respect to the operating pressure in the horn 16 55 as applied over the face of the plunger diaphragm 11, i. e. the extent of damping to a greater or less degree is provided by predetermining the cross sectional areas to a greater or less degree. On the other hand, if the operating pressures in the chambers 21 and 22 are substantially different, this will result in causing a flow of air around the lower end of the cylinder 10 within the air gap 6, thereby resulting in 65 the production of extraneous sounds causing distortion of the sounds to be reproduced and otherwise presenting undesirable characteristics in operation. Accordingly, the respective cross sectional areas of the vent through the bore 23 to the chamber 22 and between the spacers 20 to the chamber 21 are so proportioned, with respect to the areas within the said chambers, as to produce substantially equal pressures of operation 70 75

within the chambers 21 and 22. In this way an effective damping means is provided to any predetermined degree while at the same time there is avoided the movement of air around the lower end of the voice coil from the air gap 6.

Referring to Fig. 5, I have shown a modification which illustrates certain variations and other features of the invention, but which in many respects is similar to the device illustrated in Fig. 1. Similar parts of the device illustrated in Fig. 5 will be given corresponding numerals designating similar parts in Fig. 1, with a letter suffix added.

The vibratile member 11a at its central area first rises outwardly from the annular region 14a as at 12a and then turns inward forming a concave center 12b; thereby providing a central area having a concavo-convex configuration. This form of structure permits the use of a larger diameter voice coil cylinder 16a while still retaining the required degree of stiffness. It is also noted that the skirt portion 15a extends further upward and outward than in the embodiment illustrated in Fig. 1; also that the flexible ring 13a is given a larger radius. I have found that such construction permits using a shorter horn 16a when combined with a special form of baffling which will be more particularly described hereinafter which is still capable of producing the lower notes.

A substantially air-tight enclosure 24 constructed at the rear of the diaphragm acts as an infinite baffle which prevents the air waves which emanate from the areas 21a and 22a from circulating around to the other side (front side) of the diaphragm, regardless of frequency. Without this enclosure the ordinary type of flat baffle would be needed which has to be prohibitively large, if the low frequencies are to be made audible. If the directive baffle were used it would be necessary to lengthen the horn 16a to such a length as to make it impossible for use in the average home. The radius of the flat baffle would have to be equal to, or greater than, one fourth of the wave length of the lowest frequency to be reproduced.

With this new infinite baffle construction, described above, any frequency to which the diaphragm can respond will be radiated without loss through circulation of the wave from one side of the diaphragm around to the other side.

The area circumscribed by the sides of the enclosure 24 is bound to be resonant to some frequency; and the frequency at which it is resonant depends upon the dimension of the cavity 25 within the enclosure 24.

This natural law I put to use by making an infinite baffle box of predetermined cavity dimensions, the resonance of which is caused to be at some frequency that may happen to require reinforcement for proper diaphragm radiation.

The amplitude of the resonant point I control to the desired degree by the sound absorbing material 26. This material consists of any of the well known sound absorbent materials such as ozite material, cotton batting, etc., or the enclosure 24 may be made of a sound absorbing material such as celotex. Once the complete speaker is finished, it may be located in cabinets, etc., all of varying shapes and sizes without said cabinet influencing its tone fidelity.

While I have referred herein to certain portions of the vibratile member as vibrating at low frequencies only, it will be appreciated by those skilled in the art that this refers to such vibra-

tions which will be appreciably audible to the human ear. It is of course understood that if sufficient power be supplied to the voice coil, forced vibrations (600 to 800 cycles per second) may be made to occur in the regions which I have referred to as being vibratable at low frequencies only; but the vibrations resulting from such abnormally increased power input at high frequencies are not usefully audible to the human ear, and therefore such vibrations need not be considered in connection with the practical operation of the device in the manner herein described.

Having thus described my invention with particularity with reference to its preferred form, it will be obvious to those skilled in the art, after understanding my invention, that other changes and modifications may be made therein without departing from the spirit and scope of my invention, and I aim in the appended claims to cover such changes and modifications as are within the scope of the invention.

What I claim is:

1. In an acoustic device, the combination of actuating means therefor having an upper portion adjacent to which a vibratile member is mounted and a central bore communicating with the atmosphere, said vibratile member comprising a central plunger and an outer ring, voice coil means attached to the under side of said vibratile member intermediate said plunger and ring extending downwardly therefrom and serving to define the contiguous limits of chambers beneath said plunger and ring and respectively interior and exterior of said coil means, said interior chamber venting through said central bore and said exterior chamber being provided with a lower wall adjacent the upper portion of said actuating means and with venting means, said central bore and said venting means being of predetermined areas proportional with respect to the spaces within said interior and exterior chambers, respectively, to maintain substantially the same operating pressure in said interior and exterior chambers.

2. In an acoustic device, the combination of an actuating means therefor having an upper portion adjacent to which a vibratile member is mounted and a central bore, enclosure means extending around said actuating means and sufficiently air-tight to prevent any material leakage of air when under such pressures as are produced by a body producing audible vibrations, said central bore being in communication with an area confined within said enclosure means, said vibratile member comprising a central plunger part and an outer part, voice coil means attached to the under side of said vibratile member intermediate said plunger part and outer part and extending downwardly therefrom and serving to define the contiguous limits of chambers beneath said plunger and outer parts and respectively interior and exterior said coil means, said interior chamber being in communication with said confined area by means of said central bore and said central bore being of predetermined cross sectional area proportioned according to the desired damping to be effected within said interior chamber.

3. In an acoustic device, a plunger diaphragm having fastened to the back thereof a cylinder on which is wound a voice coil, the portion of said diaphragm between the walls of said cylinder being generally responsive to medium and high audible frequencies and the outer portion

of said diaphragm beyond said cylinder being generally responsive only to low audible frequencies, a substantially air-tight enclosure enclosing the space behind said diaphragm, means, 5 including the outside of said cylinder, and the back of said outer diaphragm portion, defining an air chamber, means including the inside of said cylinder and the back of the diaphragm portion between said cylinder walls, defining a 10 second air chamber, and air communicating means between each of said chambers and said enclosure.

having fastened to the back thereof a cylinder on which is wound a voice coil, said cylinder and coil being positioned within a narrow annular area between the pole faces of a magnet, an air chamber back of said diaphragm within 5 said cylinder, an air chamber back of said diaphragm outside of said cylinder, and means for venting each of said air chambers to a common air space, said venting means being proportioned to maintain the air pressures in said 10 chambers substantially uniform to prevent substantial flow of air past said coil cylinder.

4. In an acoustic device, a plunger diaphragm

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