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FIG. 1.

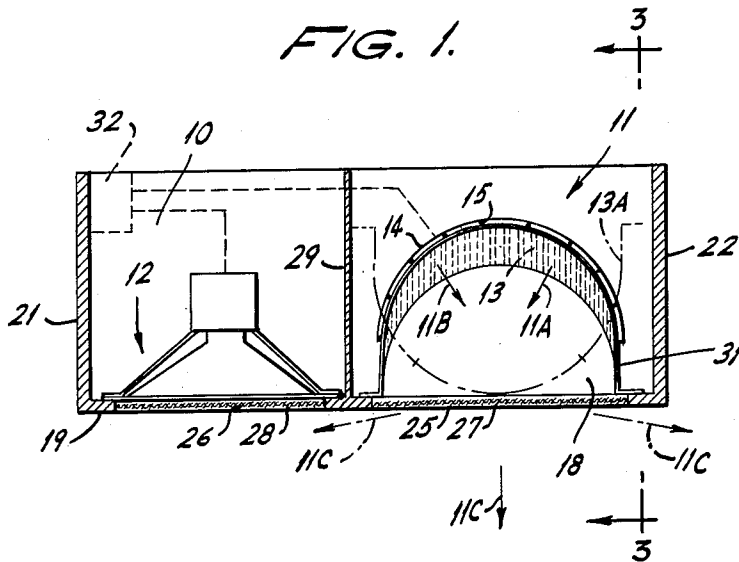


FIG. 2.

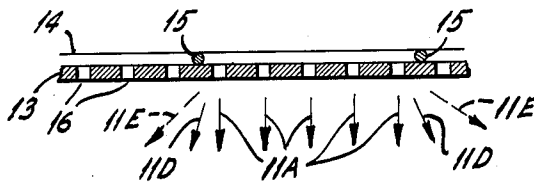
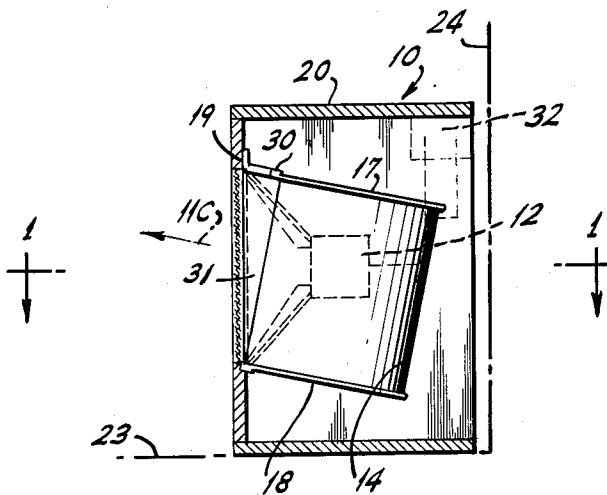


FIG. 3.



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1

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This invention relates to loud-speakers, particularly of the electrostatic kind, and has also to do with sound reproducing systems including such speakers.

Speakers of this general kind have been known for some time and have customarily been constructed with a membrane tensioned over a relatively rigid, foraminous plate, or clamped between a pair of such plates; and a well known and desirable construction has employed such a plate or plates of curved configuration. The plate curvature has generally been in form of a column or in form of a segment of a column, with a convex surface facing the listening area. Apparently this curved and forwardly convex form has been considered as being natural for the best propagation of sound from the membrane, since it is the membrane which generates the sound and since the desired pattern of sound propagation comprises curved wave fronts, progressing into and through the listening area with the convex sides of these curved fronts moving forwardly.

When closely studying the functioning of a speaker constructed and oriented in this way, particularly in the case of a speaker installed within a simple and desirable cabinet, having a straight and plain front panel, I found that improvement is possible, in several respects, by reversing the mounting of the speaker so that the speaker is forwardly concave and the sound reaches the listening area through the foraminous plate installed within the cabinet.

Accordingly, it is one of the objects and basic aspects of my invention to improve the speaker by such a reversal of the mounting thereof. A phenomenon which may be called "acoustical shadowing," and which formerly tended to limit the effectiveness of the speaker, has been eliminated by this arrangement.

It is a general object of this invention to combine an electrostatic speaker, of curved form and desirably of large area and volume, with a plain and compact cabinet for the same and to arrange these elements so as to employ them to best advantage.

It is a further object to eliminate the said acoustical shadowing and thereby to make improved use of the sound generating area of a curved electrostatic speaker mounted in a cabinet.

It is still another object to build a loud-speaker, particularly an electrostatic speaker, having relatively large, acoustically powerful, advantageously curved and widely diffusing membrane means within a relatively small functionally designed economical cabinet. A related object is to provide a system of sound reproducers, combining such an electrostatic element with a suitable dynamic speaker or the like, and by means of the effective use of sound generating area and volume of generated sound, provided by the electrostatic element, to enhance the fidelity of the entire acoustical system.

According to a broad aspect of the invention I provide a transducer membrane area—desirably of the electrostatic type but possibly of other type—having an approximately semicylindrical and forwardly concave form. This new arrangement as applied to an electrostatic speaker has also been found to avoid a serious danger of electric shock and to minimize bothersome dust deposits, as will appear hereinafter.

Specific details of the invention are illustrated in the

2

drawing appended hereto, wherein FIGURE 1 is a diagrammatic, sectional plan view of apparatus incorporating this invention, the section being taken along line 1—1 in FIGURE 3. FIGURE 2 is an enlarged detail from FIGURE 1; and FIGURE 3 is a vertical section of the apparatus of FIGURE 1, the section being taken along line 3—3 in FIGURE 1.

As shown in FIGURE 1, the cabinet 10 has mounted therein an upright, semi-cylindrical, electrostatic speaker unit 11; and it may also contain a conventional, conical dynamic speaker unit 12.

The present electrostatic speaker 11 comprises a single semicylindrical plate 13, having a membrane 14 tensioned over spacers 15 which are disposed on or incorporated in the back surface of the plate. Suitable mechanical fasteners, not shown, interconnect edge portions of the semicylindrical plate and membrane; and the plate and membrane have electrical terminals, not shown, connecting them to output terminals of any suitable audio amplifier or equivalent device. Some of these features of speaker construction are disclosed in the copending application of Wilbur B. Reed and Henery E. Johnston, Serial No. 600,896, filed July 30, 1956, now Patent No. 2,863,953 entitled "Transducers," which is assigned to the assignee of this invention.

The plate 13, as best shown in FIGURE 2, is perforated by apertures 16, desirably distributed thereover in regular pattern. For instance, vertical rows of such apertures may extend between vertical spacers 15, with uniform spacing of apertures in each row and uniform spacing of rows between said spacers. It is usual to provide such apertures to relieve back pressure even in the event that only the sound emitted on the convex side of the membrane is used. In the present speaker, the sound to be heard in the listening area passes through the openings 16, and it is therefore particularly desirable to make the area and the arrangement of such openings acoustically efficient, by known expedients such as making the individual openings slightly wider than the plate is thick and arranging them so that their total area equals a proper percentage of the plate area covered by the membrane.

As best shown in FIGURE 3 the speaker 11 may have top and bottom plates 17, 18 secured edgewise to the curved edges of the perforated plate 13. These top and bottom plates hold the perforated plate 13 against the tension of the membrane 14; in addition they serve as mounting means whereby the speaker 11 may be mounted on the front panel 19 of the cabinet 10. The cabinet also has a top 20 and, as shown in FIGURE 1, a pair of side panels 21, 22. As shown in FIGURE 3 it may stand on a floor 23, in front of a wall 24.

The concave side of the speaker 11, facing forwardly, radiates sound forwardly through an opening 25 in the front panel 19, which opening may be approximately square and slightly larger than the front dimensions of the speaker. Similarly and in the same general direction, the dynamic speaker 12 radiates through an opening 26 (FIGURE 1). Acoustically transparent front members 27, 28, for instance of decorative fabric, may be placed across the openings 25, 26.

In operation, electrical signals are received by the electrostatic and dynamic speakers 11, 12, causing their respective membranes to vibrate and thereby to emit sound through the panel openings 25, 26. Sound is also emitted in the opposite directions, into the cabinet 10, and in order to minimize or eliminate all undesired interference and resonance between the two speakers 11, 12, within this cabinet, it may be desirable to provide a dividing baffle 29, or the like. It may also be desirable to mount a plate 30, FIGURE 3, between the forward top edge of the speaker 11 and the top edge of the opening 25, and

similarly to install side plates 31. The sound emitted into the cabinet is relatively largely lost from that listener's standpoint, since large parts of such sound are absorbed in cabinet 10.

An important feature of speaker performance has to do with the directions of sound emission, particularly with the directional pattern of the speaker at high frequency. This directional pattern of the present electrostatic speaker 11 is extremely broad, since the speaker, as shown in FIGURE 1, comprises individual radiators, emitting sound through the foraminous plate 13 in different, inward directions 11A, 11B; these inward directions, collectively, provide a broad pattern of sound emission, as appears at 11C—11C. In addition there may be some added diffusion or diffraction of sound, caused by the narrowness of the individual radiators regardless of their curvature and orientation, see FIGURE 2, where 11D indicates a typical angle of diffraction for relatively high sounds, while 11E indicates the corresponding angle for relatively lower sounds. At the same time the specially curved form, the orientation and the arrangement of the speaker, as shown, has the further effect of providing a relatively large sound generating area—much larger, for instance, than opening 25—and a correspondingly large potential of acoustical volume, within a relatively small cabinet 10.

By virtue of the cylindrically curved arrangement, the propagation of the entire acoustic spectrum, even of relatively high frequencies, is free of substantial "beaming," in horizontal planes; but such "beaming" may occur in vertical planes, in the direction of arrow 11C, FIGURE 3. Fortunately, the vertical distribution is less of a problem, in the ordinary listening area, than is the horizontal distribution of the sound. The reversed, semicylindrical speaker 11 can properly radiate into all significant parts of rooms of the type and size indicated above. Desirably, the arrangement of the speaker 11 is slightly inclined, as shown in FIGURE 3; the sound may then effectively reach a large group of listeners, from a low cabinet 10. Also, reflection of sound will then create minimum danger of interference and standing waves.

Conventionally, as mentioned, an electrostatic speaker of more or less arcuate shape has been arranged with the convex side forward. A speaker so oriented, particularly a semicylindrical speaker mounted within the cabinet 10 with orientation opposite to that of the new speaker 11, is indicated by broken lines 13A in FIGURE 1. A unit so arranged, having the same size as the speaker 11 and being installed behind the same aperture 25, would be utilized only in small part, due to acoustical shadowing. Such shadowing would render all of that area virtually ineffectual which lies between the ends of the speaker 13A and the peripheral points, marked with short cross lines in the drawing, which lie on the radii of the arc-shaped speaker, intersecting the edges of the aperture 25. In other words, a given cabinet 10 provides broader distribution of sound and more efficient use of a given speaker membrane area when this area is forwardly concave than when it is forwardly convex.

The more efficient use of the speaker membrane area, provided by this mounting, has a further beneficial effect in that it facilitates electrostatic reproduction of relatively low frequencies. Other things being equal, electrostatic speakers of larger effective membrane area can effectively reproduce sound down to lower frequencies, thereby extending the advantages of this type of speaker to these frequencies. While this relation of membrane area to frequency range is well known, and while large, low frequency electrostatic speakers have previously been built, such speakers are believed to be improved by this invention in that they are disposed in relatively small cabinets and yet are utilized with relatively high effectiveness.

Summarizing, the principal advantages and features of the new speaker unit 10, 11, 12 can be listed as follows: extremely high fidelity as well as full, sonorous volume, even at middle frequencies, due to the use of electrostatic actuation down to a middle part of the frequency range; excellent breadth of directional pattern of the dynamic and electrostatic speakers even at high frequencies; and perfect facility and economy of uniting the electrostatic and dynamic speakers in an attractive cabinet design, by virtue of the favorable disposition of the large electrostatic membrane area.

In addition, the reversed arrangement of a single-ended speaker 11 has been found to provide advantages in entirely different connections, seemingly quite independent from the matters discussed up to this point.

For instance, from the standpoint of safety incident to inspection and maintenance operations, it is a distinct advantage that the membrane 14, not the plate 13 is exposed in the rear of the cabinet. The plate 13 often carries dangerous electrical potentials, such as a typical biasing potential of 300 volts. Heretofore, the user was exposed to severe shock if he inadvertently contacted the exposed plate of a speaker, arranged as at 13A, FIGURE 1. In the new unit, even the inadvertent user is protected from such danger, access to the plate 13 being prevented by the fabric 27 in front of the cabinet. In the back of said cabinet only the membrane 14 is exposed; and the conductive layer of that membrane cannot only be grounded but can also be covered by an insulating varnish or the like.

A final advantage of the new speaker arrangement is that certain troubles, caused by dust, can be avoided. The dust precipitated on the speaker tends to accumulate in certain parts of the cavities between members 13, 14, 15, through the apertures 16, due to the collective effect of the inward-outward, diffusive-directive air currents resulting from the operation of the speaker; and such accumulation of dust is very damaging. It tends to impair and to break down the dielectric values of the narrow air space, provided for the vibration of the membrane. In this respect the new speaker 11 is much improved. Dust can no longer freely enter any exposed plate apertures, from the open rear of the cabinet, the plate 13 being covered by the membrane 14; and in front, at least some protection against the entrance of dust is provided by the usual fabric materials 27.

While the foregoing description has been limited to a relatively simple arrangement, comprising a single, electrostatic, single ended speaker 11, in a single cabinet 10, it will be realized by persons skilled in the art that numerous modifications are possible, within the scope of my invention as defined by the following claims.

I claim:

1. In a loud-speaker, a cabinet having an apertured front portion; and vibratory membrane means, disposed behind and adjacent said apertured front portion, arranged in upright, approximately semicylindrical form and having its concave side facing said front portion.

2. Apparatus as described in claim 1 wherein the membrane means consists of a single electrostatic speaker membrane.

3. Apparatus as described in claim 2, including at least one rigid, curved, perforated plate on which the membrane is tensioned while being slightly spaced therefrom.

4. In a sound reproducer for a listening area, perforated, electrically conductive plate means having a concave side and a convex side, means supporting the plate means with the concave side presented toward said area; a thin membrane tensioned on said convex side and slightly spaced therefrom for electrostatic vibration, and an upright panel between said area and said plate and membrane, adjacent the front edges of said plate, said panel having at least one large aperture

in front of said plate whereby said panel provides a baffle between said area and the plate means and membrane.
5. Apparatus as described in claim 4 wherein the arcuate plate has an upright axis, at least slightly inclined from a vertical position.

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5

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