Sept. 29, 1942. H. E. HENRICH ET AL 2,297,218

LOUDSPEAKER

Filed April 22, 1938

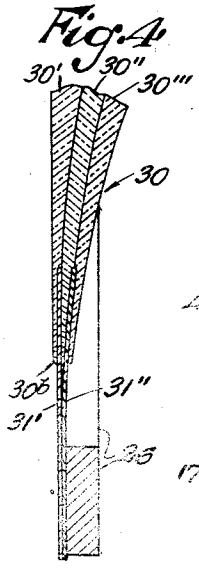

Fig. 4

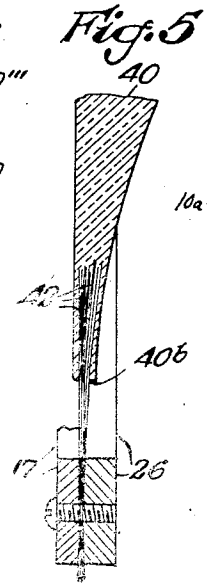

Fig. 5

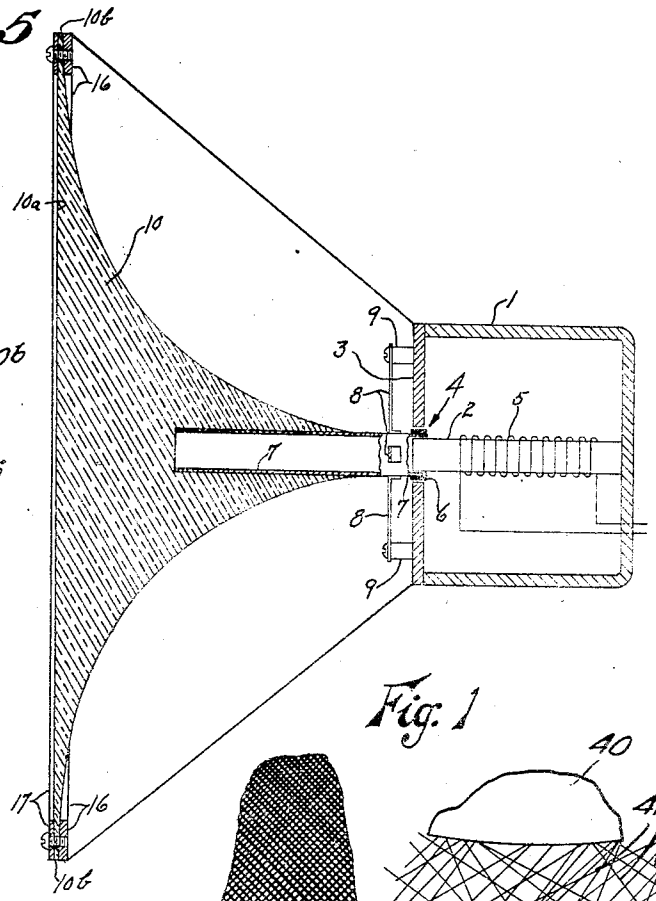

Fig. 1

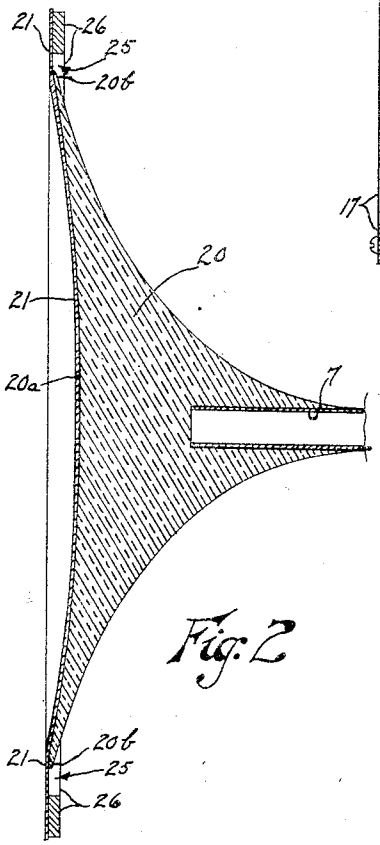

Fig. 2

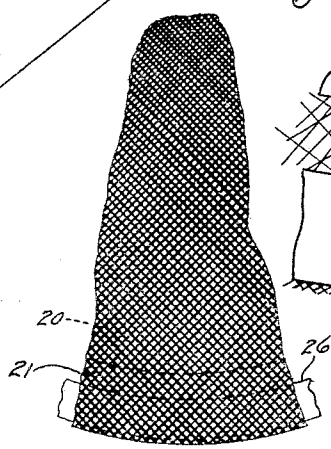

Fig. 3

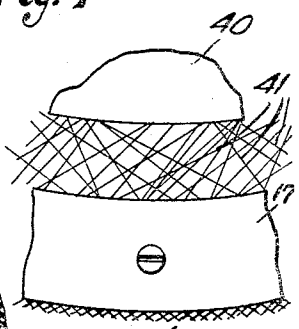

Fig. 6

INVENTORS:
HANS HENRICH
OSKAR VIERLING
BY Charles I. Cook
ATTORNEY.

Patented Sept. 29, 1942

2,297,218

UNITED STATES PATENT OFFICE

2,297,218

LOUD-SPEAKER

Hans E. Henrich and Oskar Vierling, Berlin, Germany; vested in the Alien Property Custodian

Application April 22, 1938, Serial No. 203,632
In Germany April 24, 1937

15 Claims. (Cl. 181—32)

This invention relates to loudspeakers, and more particularly to the diaphragms an immediately associated components thereof. While the invention is not limited thereto, it has been particularly illustrated and described in connection with a loudspeaker of the electro-dynamic type.

A problem in the design of loudspeakers is the attainment of a satisfactory response over a large frequency range, from very low to very high frequencies, with a single loudspeaker. The electro-acoustic translating unit proper—e. g., the voice coil of the electro-dynamic speaker—can readily be made to respond over a wide frequency range, but it is difficult to make the diaphragm radiate properly over such a range. The diaphragm ordinarily has many modes of vibration; is unfavorably variable in its effective stiffness at the several frequencies; has (for example at the usual junction of the cone diaphragm and its peripheral attaching means) abrupt and appreciable discontinuities in its stiffness between the exciting region and the peripheral support, giving rise to reflections within the diaphragm with consequent formation of standing waves at certain frequencies and abrupt variations in response between neighboring frequencies; etc.

It is an object of this invention to provide a diaphragm for a loudspeaker in which some or all of these deficiencies are markedly reduced.

It is an object to provide a diaphragm which, while having proper stiffness characteristics, is unusually light.

It is an object to provide a diaphragm having a thickness tapered in an especially favorable manner from the exciting region to the peripheral support.

It is an object to provide a tapered diaphragm of a material permitting a large thickness at the exciting region without entailing excessive mass of the diaphragm.

It is an object to provide a proper peripheral supporting of the diaphragm while minimizing tendencies toward reflections and standing waves.

It is an object to provide a generally improved diaphragm for a wide-range loudspeaker.

It is an object to provide improved combinations of the diaphragm and its peripheral attaching means.

It is a general object to provide an improved wide-range loudspeaker.

Other and allied objects will more fully appear from the following description and the appended claims.

In the description reference is had to the accompanying drawing, of which:

Figure 1 is a vertical, central cross-sectional view of a loudspeaker of the electro-dynamic type wherein the invention has been embodied in a simple form;

Figure 2 is a partial similar view of a loudspeaker in which the invention has been embodied in a somewhat modified form;

Figure 3 is a fragmentary front elevational view of the diaphragm and peripheral attaching means of the loudspeaker of Figure 2;

Figure 4 is a fragmentary, enlarged view generally similar to a portion of Figure 1, but illustrating the embodiment of the invention in a further modified form;

Figure 5 is a fragmentary, enlarged view of the nature of Figure 4, but illustrating the embodiment of the invention in a still further modified form; and

Figure 6 is a fragmentary front elevational view of the loudspeaker of Figure 5.

Reference being had to Figure 1, there will be seen a conventional dynamic loudspeaker magnetic structure comprising the cup-shaped member or "pot" 1, the cylindrical core 2 extending forwardly from the closed end or rear of the pot 1 and co-axial therewith, and the front plate 3 closing the pot and centrally apertured to pass the core 2 with an annular gap 4, co-axial with 1 and 2, between it and the core. A field coil 5 is schematically shown surrounding the core 2 within the pot, it being understood that the excitation of the field coil by direct current will produce a field of high intensity across the gap 4. Within the gap 4 is located an annular voice coil 6; and it will be understood that when sound-representing electric oscillations are supplied thereto the voice coil 6, and the components with which it is secured and which are next described, will execute a sound-representing vibration in an axial direction.

The voice coil 6 may be wound and secured around the extremity of a light, thin-walled and non-metallic cylinder 7; this cylinder is supported, coaxially with the gap 4, for vibratory axial movement. A front support for the cylinder is provided through the intermediary of the diaphragm, as will hereinafter appear. A rear support for the cylinder may be provided just a little forward of the voice coil 6; it may comprise three or more light, flexible fingers 8 having first extremities secured to the cylinder 7 and extending preferably radially therefrom, and having second extremities secured to front plate 3 as through spacing pillars 9. The fingers 8, taken together, may be considered a "spider" for the support of

cylinder 7; their radial extension from the cylinder is preferred, however, as it avoids the torsional forces that tend to appear at large vibrational amplitudes with other forms of supporting spiders.

Around the forward extremity of the cylinder 7 may be placed and secured the diaphragm 10. Since the diaphragm according to a preferred embodiment of the invention is of very appreciable thickness in the exciting or central region, the cylinder 7 may extend from the rear into the diaphragm for a considerable distance, insuring a particularly firm union of the diaphragm and cylinder. It will be apparent in the structure so described that the voice coil 6, and cylinder 7 rigidly coupling it to the diaphragm 10, are the immediate exciting means for the diaphragm; but it will be understood that in its broader aspects the invention is not limited to this particular form of exciting means, nor to the electrodynamic operation thereof, these having been chosen for illustrative and explanatory purposes.

According to the preferred embodiment of the invention the diaphragm 10 has a thickness which tapers from the exciting region to the diaphragm periphery. Preferably the diaphragm is in the form of a solid conoid—i. e., a solid body having the approximate though not necessarily the exact shape of a cone—coaxial with the cylinder 7, rearwardly convergent to be excited in its apical region, and having its base 10*a* facing forwardly. In Figure 1 the diaphragm has been illustrated as a solid conoid whose altitude (or thickness measured parallel to the axis) tapers or decreases, with increasing distance from the axis, in a smooth concave curve. While the curvature of the thickness may be according to any of a variety of mathematical laws, an exponential curvature has proven peculiarly effective in providing proper relative stiffness characteristics, and uniformity of response, at the various frequencies throughout a particularly wide range. While the exponential curvature may be reckoned from either the axis or the surface of the cylinder 7 or from therebetween, a reckoning approximately from the cylinder surface has been assumed in Figure 1.

It is desirable that the thickness of the diaphragm in the exciting region (or maximum altitude of the conoid) be relatively large—for example, a major fraction of the radius or even of the diameter of the front of the diaphragm (or base of the conoid). This not merely facilitates the firm union of the diaphragm with the cylinder 7 or its equivalent as abovementioned, but in general provides a firm central diaphragm portion, permits the greatest ease and accuracy in the tapering of the thickness, and takes fullest advantage of the tapered formation. Such a central thickness can be satisfactorily employed, however, only if the diaphragm material be of unusually small specific gravity, or weight per cubic foot.

According to the invention the diaphragm is formed of a very light, aeriferous material, preferably very completely honeycombed with minute interstices or air cells (the terms "aeriferous" and "air cell" being intended to be broadly construed to relate to gases as well as to air); a preferred material may be likened to very fine foam "frozen" into permanent condition. A natural material of the light, aeriferous character is the pith of certain plants, typically the pith of the elder. Artificial material of similar physical nature is preferably employed, however—such, by way of non-limitative example, as might be successfully used for heat insulation purposes. Particularly in the artificial materials, the air cells may be substantially uniform and uniformly dispersed, and the materials may be considered homogeneous.

The base substance of the diaphragm material may be for example a uriatic-formaldehyde condensation product, an artificial resin, a phenolic plastic, a cellulose or latex derivative, a caesin-gelatin product, or the like; such a substance may be processed mechanically or chemically to produce minute air cells therethrough—a typical chemical processing for the purpose comprising the production and dispersion of a gas through the substance in process, as by the interaction of certain materials being mixed into the substance.

These aeriferous materials may have a weight per cubic foot of the order of less than 10 pounds, and typical ones a weight per cubic foot of less than 3 pounds—e. g., of 2½ pounds or even less. A particular artificial material whose characteristics have been found good for the instant purpose may be mentioned, wholly non-limitatively, as the caesin-gelatin product commercialized for other purposes under the trade name of "Cellglue"; this has a weight per cubic foot of the order of 2½ pounds.

It may be pointed out that, over and above their lightness, these homogeneous, aeriferous materials, with their cellular structure, are inherently characterized by appreciable internal damping; this by itself, and independently of other features of the invention, appears beneficially to reduce the effective transmission of waves through, and the reflection thereof at the periphery of, the diaphragm.

In general, the diaphragm may be cut, machined or otherwise formed from the material already prepared; or the material may—in its original preparation, for example—be directly molded into the desired diaphragm form. While many of the preferred materials may be moisture- (as well as fire-) resistant, it may frequently be desirable to lacquer or otherwise seal the surface of the prepared diaphragm.

Attention now being directed to the supporting of the diaphragm at its periphery, it will be seen that in Figure 1 the periphery 10*b* of the diaphragm is directly secured to the stationary support—i. e., to a supporting ring 16 secure with respect to the pot 1, to which ring the diaphragm periphery may be clamped as by a clamping ring 17. The rate of curvature at which the thickness of the diaphragm is reduced is made great enough to result in a very thin periphery 10*b*; the resulting flexibility at and near the periphery may be relied on to permit the proper piston-like movement of the central portion. To approximate the effect of an extremely thin periphery, while actually employing the minimum thickness necessary for sufficient mechanical ruggedness, it is helpful locally to soften the diaphragm at and adjacent the periphery, for example by treatment of this region, during or after the formation of the diaphragm, with suitable plasticizing agents.

In Figures 2 and 3 there is illustrated a modified form of the invention. Herein the diaphragm, designated as 20, is similarly excited to the diaphragm 10 of Figure 1, and may be of the same material. It again has the exponentially tapering thickness, but its base or front surface 20*a* by way of example has been shown as dished or slightly concave, which formation is frequently helpful acoustically for the minimization of tendencies toward rectification at very high fre-

quencies. Like that of the diaphragm 10, the periphery 20b of the diaphragm 20 is reduced to a very small thickness, but it is not in itself used as an attaching means. Instead there is secured on or formed in the front surface 20a of the diaphragm a flexible web or mesh 21, this being continued outwardly beyond the diaphragm periphery; this web may for example be a pre-formed web, as of strong thread fibres. This web is used as the attaching means, being glued to the supporting ring 26; this ring may be similar to ring 16 of Figure 1, excepting that it is of slightly larger diameter than the diaphragm periphery, the web 21 crossing the annular gap 25 therebetween and being active in that gap to provide the requisite flexibility. Figure 3 illustrates in elevation a fragment of the combined diaphragm 20 and web 21.

The structure of Figure 1 completely obviates discontinuities in stiffness of the movable system from the exciting region to the peripheral support; and while the structure of Figures 2–3 involves such a discontinuity, the magnitude thereof may be minimized by running the diaphragm 20 to a particularly small peripheral thickness—this being especially practicable in view of the reinforcement which the web 21 provides.

A slight modification of the structure of Figures 2 and 3 is fragmentarily illustrated in Figure 4. Herein the again-tapered diaphragm, designated as 30, is formed of a plurality of laminations 30', 30'', 30''' secured together; each may for example have an exponentially tapering thickness, so that their combination as diaphragm 30 likewise has such a thickness. A plurality of webs 31', 31'' are secured between the laminations; while the webs may extend any desired distance toward the center of the diaphragm, they have been illustrated as extending only a short distance inwardly from the very periphery 30b. The several webs extend outwardly as does the web 21 of Figure 2, and are together secured to the ring 26, which may be arranged as in Figure 2, as by gluing.

While pre-formed webs, attached to already-formed diaphragms or diaphragm laminations, have been shown in Figures 2–3 and 4, the invention also contemplates the use of a web formed in the diaphragm during the formation of the latter; in this case it is not necessary that the web be pre-formed. This has been illustrated in Figures 5 and 6, in connection with the diaphragm 40, which in configuration and disposition may for example be similar to diaphragm 20 of Figure 2. In the diaphragm 40 there are mixed with the diaphragm material a plurality of strands 42 of fibrous material; while these may extend any desired extent toward the center of the diaphragm, it is necessary only that they be mixed in adjacent the diaphragm periphery 40b. Many of these strands are caused to extend beyond the periphery 40b, and these extending strands are used as the peripheral attaching means for the diaphragm. Preferably the arrangement of the strands inside and outside the diaphragm is largely non-radial and criss-cross, so that the extending strands have the general formation of a web 41; they may be secured to the ring 26 in any convenient manner, for example by a clamping ring 17 as in Figure 1. In view of the integral formation of diaphragm 40 and web 41, the diaphragm peripheral thickness may be run down to approximately the mere thickness of the web 41, practically eliminating altogether any discontinuity in stiffness. Any residual discontinuity, however, with this or any of the other webs above described, may be still further reduced by treating the extending web appropriately, as with suitable varnishes, lacquers or the like, to alter its stiffness.

With loudspeakers constructed in accordance with the invention and properly baffled in well understood manner, extremely favorable results have been obtained over such wide frequency ranges as 30 to 10,000 cycles. Reflections and standing waves are greatly minimized or substantially eliminated; vibration of the bulk of the diaphragm as a unit is very closely approximated; and practically the entire diaphragm mass is effective to establish a very low frequency of resonance of the vibratory system.

While the invention has been described in terms of specific embodiments thereof, it will be understood that no unnecessary limitations are intended merely by virtue of details of those embodiments or the various particular groupings of features therein. Likewise it will be understood that while the various attaching means shown and described are the preferred ones, diaphragms according to the invention may be beneficially employed with other attaching means, and no limitations in this respect are intended except as expressed. In many of the appended claims it is sought to express the scope of the invention broadly, subject, however, to such proper limitations as the state of the art may impose.

The following is claimed:

1. In a loudspeaker having an annular air gap adapted for magnetic energization, and a voice coil disposed within said gap: the combination of a hollow cylinder extending axially into said gap and carrying said voice coil and supported for axial vibratory movement, and a solid diaphragm secured on said cylinder, said cylinder penetrating into said diaphragm for a substantial distance.

2. In a loudspeaker: a diaphragm having a portion adapted for connection with vibratory exciting means and having in the vibratory direction a thickness which is reduced exponentially with increasing distance, normal to said direction, from said portion.

3. In a loudspeaker: a diaphragm having a rear portion adapted for connection with vibratory exciting means, having a concave forward face, and having in the vibratory direction a thickness which is reduced exponentially with increasing distance, normal to said direction, from said portion.

4. In a loudspeaker: a vibratile diaphragm system at least substantially wholly composed of a solid conoidal diaphragm having a thin periphery and having an apical portion adapted for connection with vibratory exciting means, of thickness which is at least a major portion of the diaphragm radius.

5. In a loudspeaker: a solid diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering approximately exponentially in thickness from said portion to a thin periphery and being formed of a light, highly aeriferous material.

6. In a loudspeaker: a solid diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering approximately exponentially in thickness from said portion to a thin periphery

and being formed of a honeycombed aeriferous material.

7. In a loudspeaker: a solid diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering approximately exponentially in thickness from said portion to a thin periphery and being formed of a homogeneous, highly aeriferous material.

8. In a loudspeaker: a solid diaphragm of approximately exponentially tapering thickness, adapted for connection with vibratory exciting means and formed of a homogeneous, light and highly aeriferous material.

9. In a loudspeaker: a solid diaphragm of approximately exponentially tapering thickness adapted for connection with vibratory exciting means and formed of a homogeneous, highly aeriferous material characterized by appreciable internal damping.

10. In a loudspeaker including a peripheral diaphragm support: a solid diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering in thickness from said portion to a thin periphery and being formed of a light, highly aeriferous material, and said material being locally softened in the region adjacent said periphery and being peripherally secured to said support.

11. In a loudspeaker including a peripheral diaphragm support: the combination of a solid, laminated diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering in thickness from said portion to a thin periphery and being formed of a light, highly aeriferous material; and fibrous web means secured between the laminations of said diaphragm and flexibly attaching said diaphragm periphery to said support.

12. In a loudspeaker including a peripheral diaphragm support: the combination of a solid diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering in thickness from said portion to a thin periphery and being formed of a light, highly aeriferous material; and fibrous web means intimately imbedded in said diaphragm material adjacent said diaphragm periphery, extending outwardly from said periphery, and flexibly attaching said diaphragm periphery to said support.

13. In a loudspeaker including a peripheral diaphragm support: the combination of a solid diaphragm having a portion of substantial thickness adapted for connection with vibratory exciting means, said diaphragm tapering in thickness from said portion to a thin periphery and being formed of a light, highly aeriferous material; and a plurality of fibrous strands intimately imbedded in said diaphragm material adjacent said diaphragm periphery, extending outwardly therefrom, and flexibly attaching said diaphragm periphery to said support.

14. In a loudspeaker including a peripheral diaphragm support: the combination of a solid, tapered diaphragm centrally adapted for connection with vibratory exciting means; and fibrous web means intimately imbedded in the material of said diaphragm adjacent the diaphragm periphery only, extending outwardly from said periphery, and flexibly attaching said periphery to said support.

15. In a loudspeaker including a peripheral diaphragm support: the combination of a solid, tapered diaphragm centrally adapted for connection with vibratory exciting means; and a plurality of fibrous strands intimately imbedded in the material of said diaphragm adjacent the periphery of said diaphragm, extending outwardly from said periphery, and flexibly attaching said periphery to said support.

OSKAR VIERLING.
HANS E. HENRICH.