Nov. 18, 1930. H. VOGT 1,782,278

VIBRATING CONDENSER

Filed Sept. 6, 1927 3 Sheets-Sheet 1

Fig. 1.

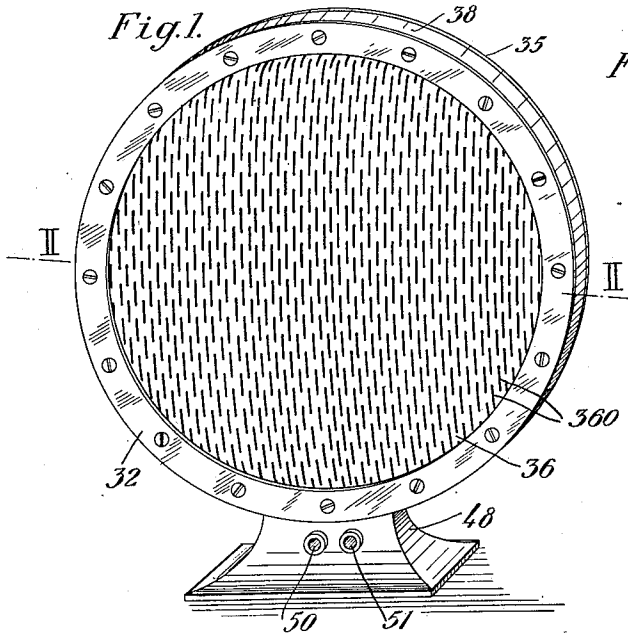


Fig. 2.

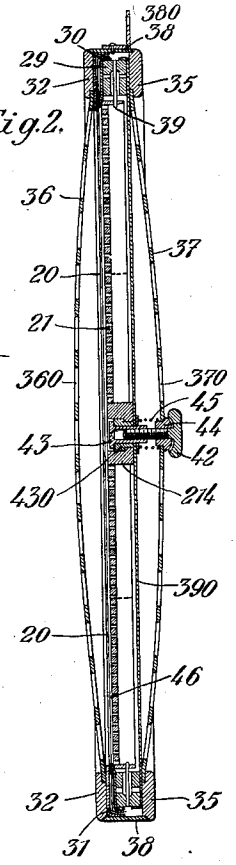


Fig. 5.

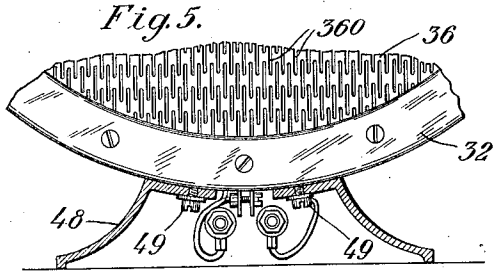


Fig. 6.

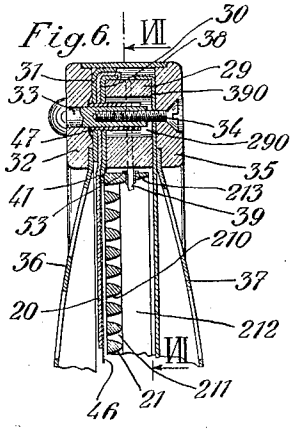
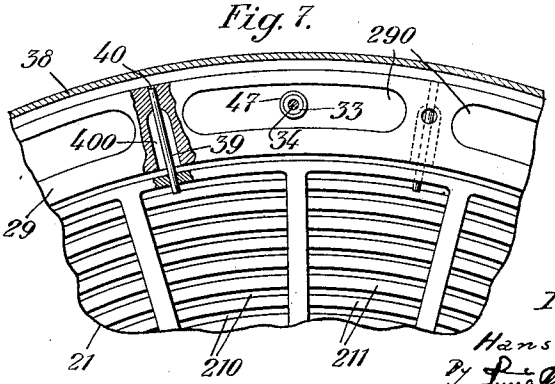


Fig. 7.



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Nov. 18, 1930. H. VOGT 1,782,278

VIBRATING CONDENSER

Filed Sept. 6, 1927 3 Sheets-Sheet 2

Fig. 3.

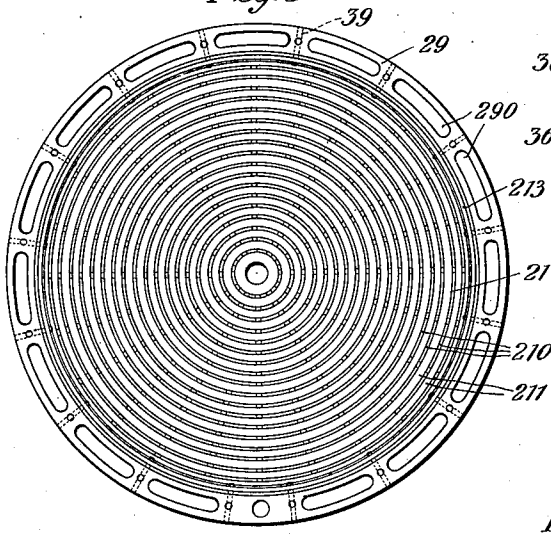


Fig. 8.

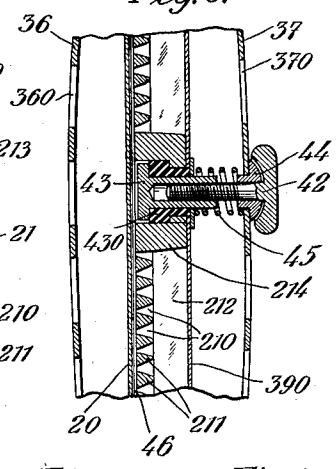


Fig. 9.

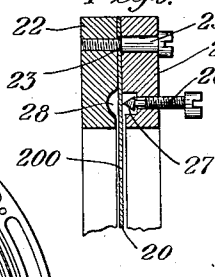


Fig. 10.

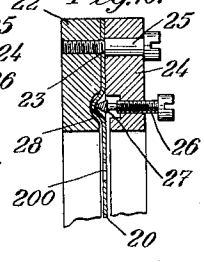


Fig. 4.

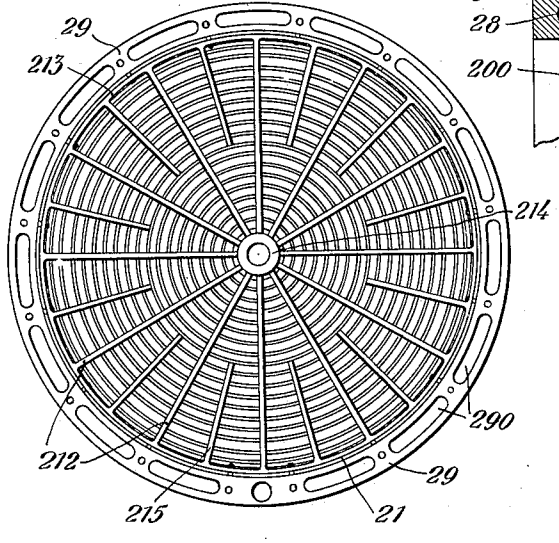
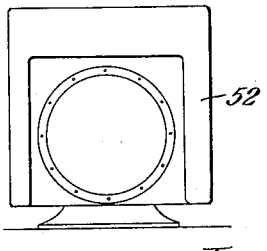


Fig. 11.



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Nov. 18, 1930. H. VOGT 1,782,278

VIBRATING CONDENSER

Filed Sept. 6, 1927 3 Sheets-Sheet 3

Fig. 12a.

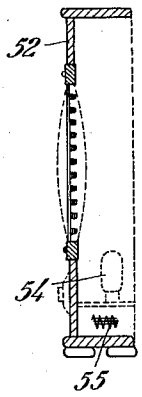


Fig. 12b.

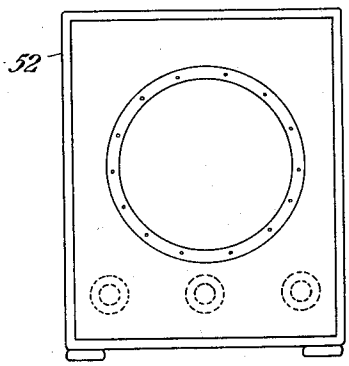


Fig. 6a.

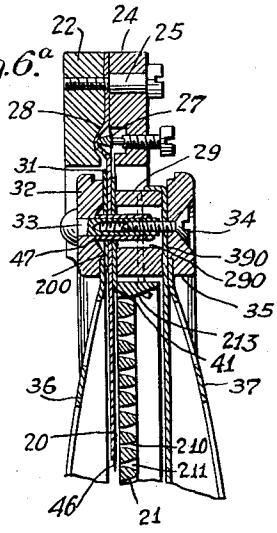
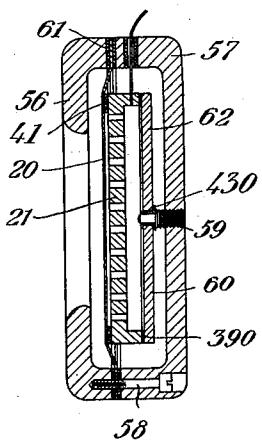


Fig. 13.



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Patented Nov. 18, 1930 1,782,278

UNITED STATES PATENT OFFICE

HANS VOGT, OF BERLIN-WILMERSDORF, GERMANY

VIBRATING CONDENSER

Application filed September 6, 1927, Serial No. 217,838, and in Germany April 28, 1926.

My invention relates to the production of sound waves in the air by way of electricity particularly for purposes of receiving and reproducing sounds or tones of the human voice and other natural sounds, music, tunes and any other tones or sounds perceptible to the human ear.

An object of my invention is to provide an apparatus or device for the production and reproduction of sound waves or sounds of the stated kind the intensity of which can be controlled at will. Another object of my invention resides in the particular construction and configuration of single parts or members of the said apparatus and the assemblage and interconnection thereof to constitute the apparatus as a unit. A chief feature of my invention, moreover, resides in the particular construction and arrangement of a metallic diaphragm adapted to be attached to a suitable frame or apparatus such as a telephone, a loud-speaker for radio reception, a grand or full-volume loud-speaker and the like, and to be caused to vibrate, according to the electrostatic principle, so as to impart its vibrations to the air for the production or reproduction of sounds of any desired intensity within a controllable range.

Apparatus of the kind as hitherto constructed and which are equipped with a diaphragm adapted to vibrate or oscillate in accordance with the electrostatic principle for the purpose of converting electricity to sound are objectionable for insufficient efficiency and, as far as my knowledge goes, this disadvantage is mainly due to the employment of unsuitable diaphragms, since the diaphragm is the most important member or constituent of an apparatus of this type.

Diaphragms as hitherto suggested for the purpose mainly consists of organic matter such as rubber, paper, celluloid, gold beater's skin, leather and the like overlaid with a conductive coating. Diaphragms of this kind, however, are objectionable for the reason that the efficiency thereof is highly affected or reduced by the rise and fall of temperature and by the moisture of the atmosphere, and further that the oxygen of the air exerts a detrimental action thereon so as to destroy or reduce the desirable good properties thereof.

For this reason, it is true, it has been suggested heretofore to use diaphragms made of a heavy metal such as iron or steel, but the high specific gravity of such metals has proved incompatible with the acoustic purposes of a diaphragm, the more so since it is impossible to reduce the thickness of an iron sheet, considering the comparatively great diameter of a diaphragm of up to 50 cm. and still more, to between 10 and 70, thousandths of a millimeter as required for transmitting the lowest sound frequencies at or with a relatively large amplitude.

Furthermore it has been proposed heretofore to employ thin mica discs or films, but although they will give better results, still they are not to be had in the trade and the high manufacturing cost and the fragility thereof are also a bar to any extensive use of the same. Besides that mica is, just as paper, rubber, celluloid and the like, objectionable for the so-called dielectrical residual or remanent charge effects, such residual charges remaining in the material and acting to disturb, in an entirely uncontrollable manner, the electric potential or tension conditions and consequently the vibratability of the diaphragm. Moreover, it was impossible heretofore to give a comparatively large freely vibrating diaphragm the required mechanical tension and to so mount the same with relation to the stationary, immovable grid-plate to be charged electrostatically, that the diaphragm will be capable of vibrating bodily or as a whole without performing natural vibrations or vibrations of its own, so as to obtain a clear reproduction of the deep or low tones.

For the purpose of preventing the resonances that is to say the occurrence of the said natural vibrations or self-vibrations of the diaphragm acting to falsify the reproduced sound or tone, it has been suggested heretofore to subdivide the diaphragm into a plurality of eccentric rings or sections or alternatively to provide means for supporting the diaphragm at the centre thereof or at certain points between the usual grid-plate

and the diaphragm. In this way, it is true, the fundamental oscillations of the diaphragm will be reduced, but irregular upper or harmonic oscillations frequently set up which impart a spluttering nasal or crackling character to the sounds reproduced by an electrostatic loud-speaker, and the efficiency thereof is greatly reduced due to the several supported points which will not partake in the oscillations or vibrations of the diaphragm.

In order to balance this reduction in or loss of efficiency to a certain degree, it has been suggested to use considerably high potentials or voltages such as 500 to 700 volts for operating the loud-speaker which obviously necessitates or involves correspondingly great variations in voltage. For this reason vibrating condensers for use as loud-speakers for broadcasting or radio telephone reception did not meet with success and did not come into fashion, the less so as, according to the present state of the art, it is impossible to accurately control and adjust the requisite gap or spacing between the diaphragm and the grid-plate over the whole of the surfaces thereof in order to be enabled to correctly adjust the parts to conform to the voltage and the variations thereof for the time being without thereby impairing the acoustic properties and reducing the electro-acoustic efficiency of the same.

According to my invention the problem of a vibrating or oscillating condenser adapted for use as a loud-speaker, headphone or microphone is solved and practically accomplished in a most perfect and efficient manner by employing for the purpose in view an extremely light and extremely elastic metallic diaphragm of high tensile strength and which is given, in case of a loud-speaker, a large size exceeding far beyond the dimensions customary in diaphragms of the kind. My invention further comprises means for periodically imparting to the said diaphragm, independently of outer influences, ample vibrations devoid of resonance at relatively low voltages and for adjusting the spacing or gap between the diaphragm and the grid-plate so as to thereby realize strict conformity with the prevailing voltage.

Other important features of my invention will be hereinafter specifically described and then pointed out in the claims. The inventive idea involved obviously is capable of expression in a variety of mechanical forms one of which, for the purpose of illustration, is shown in the accompanying drawings, but it is to be understood that said drawings are for the purpose of illustration only, and not for the purpose of defining the limits of the invention, reference being had to the claims for the purpose.

In the drawings forming a part of this specification I have shown a vibrating condenser for use as a loud-speaker and a modified construction thereof for use as a telephone or microphone, both embodying my invention, but I wish to have it understood that the shown constructions are not the only embodiments of which the invention is capable, that a wide range of equivalents may be employed for parts which I have illustrated and that the phraseology which I have adopted is for the purpose of description and not of limitation except where the sense absolutely requires it.

In the drawings:

Figure 1 is a perspective view of a vibrating or sounding condenser constructed in accordance with the present invention;

Figure 2 is a section taken on the line II—II in Figure 1 at a larger scale;

Figure 3 is a front view of the grid-plate of the condenser;

Figure 4 is a similar view;

Figure 5 is a fragmentary view similar to Figure 1 with a base body or pedestal shown in section;

Figure 6 is a sectional view of the circumferential parts or clamping rings of the condenser shown on a larger scale to clearly illustrate the manner in which the grid-plate and the diaphragm are clamped between the rings;

Figure 6^a is a sectional view showing the details of Figs. 6, 9 and 10 combined into a single form of the invention;

Figure 7 is a section taken on the line VII—VII of Figure 6;

Figure 8 is a vertical section showing the adjusting device for setting or controlling the sound intensity;

Figures 9 and 10 are sectional views of an auxiliary device for tensioning the diaphragm with the tensioning elements shown in two different positions;

Figure 11 is a front view of the condenser in a sounding box or casing shown on a reduced scale;

Figures 12^a and 12^b are a sectional view and a front view of a similar apparatus; and

Figure 13 is a sectional view of the modification for use as a telephone or microphone.

Parts which are repeated in the several figures bear the same reference characters in each case.

20 denotes the metallic diaphragm. Best results, as regards a loud reproduction free from distortions, are obtained by manufacturing the diaphragm of a material which is light in weight and as hard as it can be. Respecting density or tensional strength steel obviously would be the very best material. Up to now, however, it has been impossible to roll steel down to a minimum thickness of 5 thousandths of a millimeter, so that steel cannot be employed with a view to ensure satisfactory results. Further light metals such as aluminium cannot be used, because

they do not possess the required tensional strength so that a film or thin sheet made thereof cannot be tensioned to the required degree and when tensioned will yield or expand.

After much study and research I have found that alloys of light metals consisting mainly of aluminium or magnesium alloyed with metals adapted to impart to the material the required properties of high tensile strength and unlimited rolling capability so that the material or alloy can be rolled, eventually before or after a suitable refining process, to form sheets or films of extreme thinness, say of 5 to 10 thousandths of a millimeter, with a tensile strength of 32 to 40 kg. per square millimeter, will give best results. As regards the refining operation I prefer to refine the alloy subsequently to the rolling operation by heating and suddenly cooling the sheets or films preferably while they are in a stretched or tensioned condition in order to remove all unevenness and irregularities in the material.

The vibratory mass of the diaphragm is to be kept as low as possible in consideration of the reproduction of the high tones and the necessity of preventing natural vibrations. In researches made to the end I found that electrostatic loud-speakers operated with the aid of voltages of 100 to 300 volts and consequently possessing a certain electrostatic field of limited strength, are not capable of uniformly reproducing or transmitting the practical acoustic range of 70 to 12000 Hertz except if the vibrating mass thereof does not exceed beyond a certain value. As the vibratory mass of a diaphragm depends upon or is defined, on the one hand, by the specific gravity of the material and, on the other hand, by the thickness thereof, both values are to be considered and the product resulting therefrom—with the thickness indicated in millimeters—is to be inserted into the calculation. I have found that the figure indicating said product must be of a value not greater than 0.25 in order to not prejudice and reduce the acoustic efficiency in a high degree.

Thus for example in case of a diaphragm made of a light metal alloy as above described, and having a specific gravity of 2.5 and a thickness of 40 thousandths of a millimeter, the said value will amount to 0.1. If it is desired to come to or obtain the same value in connection with a diaphragm made of steel, the latter ought to be of less thickness, proportionate to the difference in the specific gravity, that is a thickness of 13 thousandths of a millimeter.

I prefer to use alloys manufactured according to the modern development of the art, particularly an aluminium alloy containing magnesium or zinc and endowed with the properties of high tensile strength and unlimited rolling capability. The aluminium alloy universally known as duralumin and containing manganese and copper is of no avail for the reason that it cannot be rolled to the required degree of thinness. On the other hand an aluminium alloy such as magnalium consisting of pure aluminium (up to 99.5 percent) and magnesium (up to 3.5 percent) answers the purpose in a very satisfactory way. The thickness of the diaphragm may vary between 5 and 80 thousandths of a millimeter.

Referring to the drawings, 21 denotes the grid-plate made of a suitable metal or alloy by way of a casting operation or in any other suitable manner. I wish it to be understood, however, that also a grid-plate may be used, in accordance with my invention, which consists of any appropriate electrically insulating material capable of being cast or molded such as ebonite, vulcanite, porcelain, artificial stone and the like, but it goes without mentioning that in this eventuality the grid-plate must be given an electrically conducting coating at least on the side or surface adjacent to the diaphragm. The grid-plate 21 is provided with a greatest possible number of perforations 210 for the purpose of ensuring communication between the vibrating diaphragm 20 and the adjacent layer of air and reducing the air damping in the gap between the diaphragm and the grid-plate. As it would be very expensive to produce the perforations by means of a stamping, boring or cutting machine and for other reasons, I prefer to manufacture the plate inclusive of the perforations or apertures therein, according to the present invention, by a casting or pressing operation and a subsequent turning or grinding operation for smoothing the plain surface of the plate. The said casting or pressing operation involves the necessity of shaping the skeleton pieces or strips 211 bordering or confining the said perforations or apertures 210 in the form of a wedge so as to facilitate the removal of the casting from the mold.

When assembled to form a condenser as shown in Figure 1 the diaphragm 20 and the grid-plate 21 are mounted in parallelism and in close proximity to each other, as will be clearly seen in Figure 2. Prior to such assemblage the diaphragm 20 is to be subjected to a tensioning process by means of a suitable stretching device in order to impart to the same the required highest possible radial tension.

A device suitable for the purpose is shown in the Figures 9 and 10. The same comprises a strong metallic ring 22 with threaded bores for the reception of screws 25. The diaphragm 20 provided with corresponding marginal holes 23 is placed upon the ring 22 so as to have the holes 23 register with the bores of the ring 22, whereupon a second

metallic ring 24 of the same diameter and provided with corresponding bores is placed upon the diaphragm so that all of the bores and holes will be in axial alinement for the reception of the screws 25 which upon having been inserted and screwed up, as shown in Figures 9 and 10, will hold the diaphragm firmly enclosed between the jaw-like acting rings 22 and 24. The ring 22 is provided with an annular groove or recess 28 on its inner face and the ring 24 is provided with threaded bores for the reception of tensioning screws 26 located so as to register with the said groove 28, the inner ends or points of the screws 26 engaging in a circular groove provided on the inner face of the ring 24 and in which a metallic ring 27 is encased. By screwing up the screws 26 the ring 27 will be forced towards and against the diaphragm and by penetrating more and more into the annular groove 28, the ring 27 will cause the diaphragm 20 to gradually recede into the annular groove 28 whereby the diaphragm will be tensioned gradually and in proportion as the screws 26 are tightened up. The tightening of the screws 26 is continued until almost the limit of the tensile strength or resistance of the diaphragm is attained.

A ring 29 connected with the grid-plate 21 and the outer diameter of which is smaller than the inner diameter of the compound ring 22 and 24, is provided or coated with a perforated insulating ring 30 and the tensioning device with the diaphragm 20 therein is placed upon and over the grid-plate 21 and the outer ring 29 connected therewith, so that the peripheral portion of the diaphragm will rest upon the insulating ring 30. The said peripheral portion of the diaphragm possesses perforations 200 corresponding to similar perforations of the insulating ring 30 and the two parts are fitted and united in a manner that the perforations thereof accurately coincide or register. A second insulating ring 31 is then placed on top of the diaphragm. This ring 31 is also provided with perforations exactly corresponding to the perforations of the diaphragm and the ring 30 and the parts are assembled in a manner that all of the perforations thereof accurately coincide or register.

The thus assembled parts are sandwiched, as a unit, between two clamping rings 32 and 35 as will be readily understood on inspection of Figure 6. The rings 32 and 35 are each provided or integral with perforated protective discs 36 and 37, respectively, and they are further provided with holes or perforations exactly corresponding to the perforations of the several parts enclosed between the rings 32 and 35 and discs 36 and 37, an insulating sheet of oil-paper 390 having been previously inserted between the ring 29 and the clamping ring 35 for the purpose of insulation and prevention of dust particles from entering the efficient gap between the diaphragm 20 and the grid-plate 21. The means for ensuring a rigid interconnection of the grid-plate and the clamping rings 32 and 35 with the several intermediate rings and sheets in duly assembled position, comprise elongated perforations 290 in the ring 29 and screw-bolts 33 passing through the registering perforations of the rings 29, 30 and 31, the diaphragm, the oil-paper sheet 390 and the elongated perforations 290 of ring 29. The bolts 33 are screwed up into threaded bores of the counter-ring 35.

As shown in Figure 6 the bolts 33 may be of tubular form with internal thread for engagement with screws 34 fitting in bores of the counter-ring 35 and engaging in the bolts 33 projecting into the elongated perforations 290 so that the assemblage and rigid interconnection of the parts can be readily accomplished by means of a screw-driver as will be clearly understood on inspection of Figure 6. In order to prevent metallic contact between the screws 33 and the diaphragm 20 a protective sleeve 47 of insulating material is fitted on each screw.

In order to remove the tensioning device from the structure the diaphragm may be cut out in the annular gap between the rings 32, 35 and the clamping rings 22, 24 of the tensioning device or the screws 26 and 25 of the latter may be unscrewed so that the marginal portion of the diaphragm will freely project beyond the outer periphery of the rings 32 and 35 after the removal of the disengaged rings 22 and 24, and may be trimmed off as desired. At any rate the thus assembled and interconnected parts constitute a structure which may be handled as a unit and subjected to any appropriate finishing treatment.

The protective discs 36 and 37 provided with perforations 360 and 370, respectively, of any desired size, number and configuration, are coated on the inside with a coloured textile fabric pervious to sound such as silk-tissue, fixed to the inner surfaces of the discs by means of any suitable agglutinant. A shallow annular recess provided in the outer peripheral surface of the structure or rings 32 and 35 serves for the insertion of a metallic ring or closed band 38 which will conceal the inturned edges of the diaphragm and the insulating rings and form at the same time an æsthetic closure. If it is desired to mount the structure in wooden plates, the band 38 may be provided with say three small angle-pieces 380 each having one or several holes for screws or the like.

The grid-plate 21 is not rigidly connected with the intermediate ring 29 supporting the diaphragm 20, but a number of resilient radial steel pins 39 are fitted in radial bores 40 of the ring 29 so as to engage with the in-

wardly projecting ends in holes provided for the purpose in the rim 213 of the grid-plate 21. These pins 39 prevent the somewhat elastic grid-plate 21 from getting uneven due to stresses setting up in the ring system 29, 32 and 35 during the mounting operations. Further the pins 39 will act to force the grid-plate the ground or polished surface of which projects a little beyond the corresponding surfaces of the ring 29, say for about half a millimeter so as to be situated correspondingly nearer to the plane of the adjacent ring 32 than the ring 29, firmly towards and against the tensioned diaphragm so that disturbances caused by wearing, ageing and similar effects due or inherent to the nature of the material, will be compensated and the diaphragm caused to always maintain its original tension. I find it advisable to insulate the grid-plate with relation to the ring 29 in order to thereby minimize the useless capacity, and to this end I insert bushings or short sleeves of insulating material into the radial holes provided in the rim 213 of the plate 21 for the reception of the pins 39.

By joining the parts 32, 30, 20, 31, 29, 390 and 35 by means of the screws 33 and 34 to form the system or structure described, the capacity surface is bent out towards the rearside and away from the diaphragm owing to the elasticity of the pins 39. The tension of the diaphragm thus produced, therefore, depends upon the resiliency of the yielding pins 39. In order to afford the pins the possibility of yielding under the stress, the bores 40 of the ring 29 are enlarged at their inner ends and the enlargements 400, see Figure 7, afford the pins greater freedom and space for lateral movements.

The grid-plate 21 is shaped to form a disc provided with concentric segmental slits 210 with similarly shaped intermediate solid webs, stays or strips 211 forming a skeleton disc with the aid of interconnecting radial ribs 212 on the rear face of the plate. The ribs 212 extend from the rim or periphery 213 of the plate radially towards and to the hub 214 thereof and shorter reinforcing ribs 215 are provided between adjacent ribs 212 to ensure perfect rigidity of the segemental stays or strips 211 having the largest diameter.

The grid-plate 21 is constructed to allow of being bent out to the amount of a few thousandths of a millimeter. For the purpose of adjusting the grid-plate to the correct distance, that is, spacing the same with relation to the diaphragm, as required by and for a certain potential or voltage, there is provided in the hub of the grid-plate an adjusting device for bending the latter out to the minimum amount required for the purpose, so that the plate and the diaphragm will be in exact parallelism throughout, that is to say, the width of the gap between the central zones of the plate and the diaphragm will be accurately the same as that between the peripheral zones thereof, where the insulating ring 41 determines the clearance. The said adjusting device comprises a set-screw 42 engaging in a threaded bushing or nut 43 fixed in the hub of the grid-plate by means of a sleeve 430 of insulating material. The set-screw 42 is supported in a bearing 44 provided in the centre of the bulged out and consequently duly stayed protective disc 37, a spring 45 coiled about the screw and the outer end of the bushing 43, acting to normally hold the disc 37 a certain distance apart or spaced from the grid-plate, so that the screw 42 cannot get loose. By properly setting the screw 42 the grid-plate can be adjusted and spaced to assume or occupy the best possible position with relation to the diaphragm for ensuring a highest possible strength or loudness of sound at a given or predetermined tension. This position lies a little before the unstable point of the diaphragm.

Inserted between the grid-plate and the diaphragm is a suitable insulating layer in the form of an elastic sheet or film 46 which may be of collodion, silk-paper or the like. I prefer, however, to employ instead a sheet or film made of a material which possesses insulating properties and at the same time is electrically conductive in a slight degree and I succeed in making sheets or films possessing the above characteristics by mixing a suitable insulating material with a substance or substances adapted and acting to reduce the insulating property of the material. In this way I prevent the insulating sheet or film from retaining any residual or remanent charges since they will flow off into the diaphragm the very moment they set up. This is of great importance as regards the desirability of obtaining a loud-speaking condenser of never failing efficiency. Further an insulating sheet or film of the stated kind will prevent immediate contact between the diaphragm and the grid-plate and consequently short-circuiting, furthermore the same will prevent the vibrating diaphragm from striking immediately and hard against the grid-plate which otherwise, particularly if a hard insulating layer or sheet would be used, will impart to the sound a disagreeable spluttering nasal and whizzing timbre. Best results will be obtained by using a sheet or film of utmost thinness not exceeding 15 thousandths of a millimeter and free from dielectric hysteresis as above indicated.

Obviously the sheet or film 46 may be entirely dispensed with particularly if the apparatus is to be operated immediately with high frequency such as when used for controlling high frequency transmitters and connected for the purpose immediately with the antenna without the interpolation of amplifiers, rectifiers and the like. Heating will never occur

in such a case since high frequency losses cannot happen on account of lack of any solid dielectric. Apparatus of the kind as hitherto suggested cannot be utilized for similar purposes for the reason that, setting aside any other difficulties, they are not constructed and arranged so as to stand the enormously high wattless high frequency current of about 10 to 30 amperes.

The electrostatic condenser herein described may be connected with a pedestal 48 by means of screws 49, as shown in Figure 5, and the pedestal preferably also serves for the accommodation of the choking coils, condensers, resistances and similar fittings required for the completion and operation of the apparatus. Two sleeves or sockets 50 and 51 are provided in the front face of the pedestal for connection by means of a two-pin plug.

Sounds are emitted by the described loud-speaking condenser unrestrainedly from both sides thereof. In some cases particularly in case of a small apparatus wherein the diameter of the efficient surfaces does not exceed thirty centimeters, I provide a sound-strengthening screen such as a casing or box made of wood, sheet-metal or the like, open on opposite sides, as shown in Figures 11, 12^a and 12^b. The enclosure surrounding the loud-speaker laterally and on top to form a broad resonance body 52 prevents slow sound frequencies from being equalized too rapidly and causes them to take their way into the open space. For this reason a loud-speaker of the described type is particularly well adapted for use in constructional connection with broadcasting or radio apparatus, phonographs and the like. For surrounding wooden structures or casings which, however, must be open at the rear, will assist in greatly improving the efficiency of the loud-speaker as regards the upper or lower frequencies, and serve at the same time for the accommodation of the required electrical parts or fittings 54 and 55, as shown in Figure 12^a.

A diaphragm 20 of the described type but of correspondingly reduced dimensions and extreme thinness may just as well be employed in connection with a headphone, which will be much superior to the usual magnetic receivers, as regards understanding, since the same is free of resonances and adapted to transmit or reproduce consonants of the order of 4000 to 10000 Hertz in a more reliable manner than magnetic telephones. In constructional respects the dimensions of the single parts constituting the apparatus must be correspondingly reduced and simplified.

In Figure 13 I have shown a structure, thus reduced and simplified which is adapted for use as a headphone or as a microphone. The diaphragm 20 is clamped between the front ring 56 and the rear plate or casing 57 by means of screws 58, rings of insulating material being inserted between the clamping and clamped faces. The grid-plate 21 is spaced a distance apart from the diaphragm by means of an insulating ring 41, and insulated against the casing 57 by means of an insulating ring 390 and an insulating sleeve or bushing 430 on the adjusting screw 59 abutting against an elastic plate 62 attached to the insulating ring 390 on the annular flange of the grid-plate. By screwing down the screw 59 the diaphragm 20 will be given the required final tension. A wire 61 is provided for conductive connection with the grid-plate. A construction such as shown in Figure 13 is highly sensitive and entirely independent of frequencies and can be manufactured in a simple manner at comparatively low cost, so that the same will be highly adapted for use in telephony in lieu of the customary magnetic telephone, viewing the improved efficiency particularly as regards understanding.

Loud-speakers of moderate and of maximum size, however, require diaphragms of a diameter between 20 and 60 cm. in order that the low tones reproduced thereby might be of sufficient loudness. If it is desired to further increase the loudness and the quality of sound I suggest to unite several loud-speakers of the described type in parallel connection and to impart to the single loud-speakers different or varying acoustic properties by varying the weights of the several diaphragms and by differently adjusting the spacing of the diaphragm and the grid-plate in each individual apparatus.

As regards the arrangement of the diaphragm in the apparatus I again emphasize the necessity of tensioning the same to the utmost possible degree within the ring 29 in order to obtain best results which cannot be realized except when the distance or gap between the diaphragm and the grid-plate is a minimum and perfectly uniform. Further the construction and arrangement of the parts must be such that the same will be independent of variations in temperature, that is to say, the normally prevailing variations of temperature must not exercise any appreciable influence on the tension of the diaphragm.

According to the present invention I realize this requirement by making both the diaphragm 20 and the supporting ring 29 of metals possessing the very same specific coefficient of expansion and by providing a resilient support.

A further important feature of my invention resides in the provision of means for compensating those diametrical differences or variations which depend upon or are brought about by the different rate at which any outer temperature is received and as-

sumed and which, therefore, depend upon the volume of the material to be heated. To this end I provide on either side of the diaphragm a standing layer of air enclosed between the diaphragm and the protective discs 36 and 37, with the result that in case of fall of temperature the diaphragm cannot cool down and contract more rapidly than the supporting ring 29.

Furthermore, in reducing my invention to practice, it is of great importance to subdivide or perforate in a suitable manner the grid-plate 21 co-operating with the diaphragm 20. I have found that the perforations or openings of the grid-plate 21 must bear a certain ratio in respect to the metallic skeleton thereof in order to reduce the air damping in the gap between the diaphragm and the plate and in the said perforations thereof to an adequate degree with relation to the emission of sounds and the suppression of the natural vibrations. It is, however, advisable to not go too far in this regard, that is to say, to not provide more or larger perforations than absolutely necessary for the purpose aimed at, since otherwise the material would not possess any air damping and would be able to fully develop its natural vibrations so as to disturb thereby the uniform reproduction of or over the whole of the sound range.

By increasing or maintaining within adequate limits the total area of the metallic skeleton or strips defining and framing the perforations of the grid-plate 21 I correspondingly enlarge the active electric surface thereof and, at the same time, I increase thereby the air damping and besides that I thereby remove any natural or own vibrations of the diaphragm 20 which, as regards its mass, is trifling. As in natural vibrations the maximum amplitudes predominantly occur in the central zone of a disc-shaped body, I enlarge the central rings or segmental webs 211 more or less in an adequate manner and I thereby ensure a damping effect gradually increasing towards the centre of the grid-plate. Enlarged central rings 211 are not illustrated in the drawings as the idea is readily conceivable without illustration.

In order to adapt the arrangement so as to conform to the stresses prevailing at a time, within narrow limits, that is to say, to be able to change or vary the spacing, I provide as hereinbefore described a grid-plate surface which is bent out or permits of being bent out. The latter modification affords the great advantage of ensuring thereby the like spacing at all points which is essential in respect of the required parallel movability and the free vibratability of the diaphragm.

It has been suggested heretofore, to control and regulate the spacing by adjusting the diaphragm with relation to the grid-plate by means of a set-screw provided in the centre of the same. But in this way it is impossible to have the diaphragm vibrate fully and freely inasmuch as the outer or peripheral zones thereof only will vibrate and the central zone will remain immovable so that a clear reproduction of the slow sound frequencies having large amplitudes cannot be brought about in a satisfactory manner.

As hereinbefore stated, I prefer to manufacture the grid-plate by way of a pressing, casting, centrifugal casting or similar process whereby stresses in the material which are objectionable in respect to the required capability of the grid-plate of bending in a thoroughly uniform manner, are avoided. The requisite perforations or apertures 210 are preferably given the shape of a truncated wedge or cone, taken or viewed in section, and the solid segmental strips or webs 211 forming the skeleton are similarly shaped, but inversely of course, or in other words, they have a wider base on the one side and a narrower top on the other side of the grid-plate. It also goes without saying, that the grid-plate must be supported in the apparatus in a manner that disturbing factors or momenta cannot accede from outside to exert any deranging action on the evenness of the efficient surface. For even local variations of a few thousandths of a millimeter would reduce the distance between the diaphragm and the grid-plate 21 to an appreciable degree at the affected point or place and the diaphragm, therefore, would be excessively energized at such a place or places and caused to vibrate unsymmetrically in the upper tones.

My invention is also applicable in the construction of microphones. In such a case, however, the constituent parts of the device must be conformingly simplified and reduced, respecting the dimensions thereof, as shown in Figure 13, and a somewhat greater air damping must be provided therein. If these requirements are complied with a microphone or ear-telephone of the kind will possess great independence of frequency and will be of highly satisfactory efficiency.

I have not attempted to explain all of the minute details of the constructions and apparatus in which my invention is capable of being expressed, for it will be understood by those to whom this specification is addressed, that any parts not shown will be of conventional form and size and constructed and arranged in accordance with the tenets of electro-physics and machine construction.

I deem it also unnecessary to reiterate the operation of a loud-speaker or similar apparatus constructed according to my invention, for the operation of the essential parts has

been described in detail. Nor does it seem necessary to burden this specification with an exposition of the many advantages which the invention possesses, for they will be apparent to those skilled in the art to which this invention pertains.

What I claim is:—

1. An electrostatic telephone comprising a rigid plate having a plurality of apertures and composed, at least partially, of a suitable metal, and a vibratile diaphragm mounted in spaced relationship and substantially parallel to the said rigid plate, the said diaphragm consisting of a light metal alloy preferably aluminium alloyed with not more than 3.5 per cent of magnesium and having a tensile strength of more than 20 kg. per square millimeter and the said diaphragm further having a thickness of approximately .010 to .070 millimeters and a diameter of more than 20 centimeters and being wholly supported peripherally and maintained highly tensioned in radial direction.

2. An electrostatic telephone comprising a rigid plate having a plurality of apertures and composed of an insulating material superficially coated with a metallic layer, and a vibratile diaphragm disposed in spaced relation and substantially parallel to the said rigid plate, the said diaphragm consisting of a foil of light metal of minimum thickness of .010 to .070 millimeters, and of high tensile strength of at least 20 kg. per square millimeter and being wholly supported peripherally and maintained highly tensioned in radial directions.

3. An electrostatic telephone comprising a plurality of concentric rings interconnected by radial webs or ribs and forming a rigid plate, and a diaphragm mounted in substantially parallel relation to the said plate, the said diaphragm consisting of a foil of light metal of a minimum thickness and of high tensile strength, and which while being wholly supported peripherally is maintained highly tensioned in radial direction.

4. An electrostatic telephone comprising a rigid perforated plate, a supporting ring peripherally attached to said plate by means of a plurality of resilient pins symmetrically distributed over the periphery of the said ring and extending substantially in radial direction, and a diaphragm adapted to freely vibrate over the entire surface, the said diaphragm consisting of a light metal foil of minimum thickness and high tensile strength peripherally connected to the said supporting ring in order to be maintained in highly tensioned condition and in substantially parallel spaced relationship to the said rigid plate, and an insulating layer provided between the said supporting ring and the said metallic diaphragm.

5. In combination with an electrostatic telephone comprising a rigid plate and a radially tensioned vibratile diaphragm disposed in spaced and parallel relationship to the said plate, a stretching device adapted to impart to the said diaphragm the required high tension prior to effecting the junction thereof with the said rigid plate by means of a common supporting ring, the said stretching device comprising a pair of clamping rings of preferably rectangular cross-section and of an inner diameter somewhat greater than the outer diameter of the said ring supporting the rigid plate and the diaphragm, the said clamping rings being adapted to support and hold the diaphragm between them by means of clamping screws adapted to pass through the said rings and the diaphragm interposed therebetween, annular grooves being provided in the adjacent inner surfaces of the said clamping rings for the reception of a ring of preferably triangular cross-section, while in one of the said two clamping rings a plurality of axially extending compression screws are symmetrically distributed over the periphery thereof and adapted to be forced, when tightened, against the said ring of preferably triangular cross-section and to thereby impart a high degree of radial tension to the diaphragm fixed between the said two clamping rings.

6. In combination with an electrostatic telephone comprising a rigid plate, a radially tensioned vibratory diaphragm mounted in spaced and parallel relationship to the said plate, and a ring adapted to support both the said plate and the diaphragm, a method of fixing the diaphragm in tensioned condition to the said supporting ring, which comprises in imparting to the said diaphragm a radial tension preferably with the aid of a stretching device, placing the said stretching device with the diaphragm kept therein in tensioned condition over or onto the said supporting ring and the rigid plate disposed therein, and fixing the diaphragm to the rigid plate with the aid of a clamping ring insulated, with relation to the metallic diaphragm, by means of an insulating layer, and screws guided in insulating bushings and adapted to pass through the clamping ring; the diaphragm, the supporting ring and a second clamping ring co-operating with the former, whereupon the edge portions of the diaphragm projecting are severed beyond the periphery of the supporting ring.

7. An electrostatic telephone comprising a perforated, rigid plate composed, at least partially, of metal and a vibratory diaphragm disposed in spaced and substantially parallel relationship to the said plate and consisting of a light metal foil of a minimum thickness and high tensional strength, a supporting ring adapted to interconnect the said diaphragm while in tensioned condition with the said rigid plate, and an insulating layer interposed between the latter and the dia-

phragm and possessing a slight electrical conductivity.

8. An electrostatic telephone comprising a rigid plate and a vibratory diaphragm electrically insulated with relation to the said plate and both supported by a common ring, the said plate consisting of a plurality of concentric rings interconnected by long and short webs or ribs, a central hub and a threaded axial bore for the reception of screws supported by a bushing rigidly connected, by means of a supporting member, with the common supporting ring of the said rigid plate and the diaphragm, the said screws being adapted to slightly bend out, when turned or tightened from the said rigid plate for the purpose of adjusting the distance between the centers of the said plate and diaphragm.

9. An electrostatic telephone comprising a rigid plate, a vibratory diaphragm, both mounted in a common supporting ring so as to be insulated with relation to each other, and a protective grid or the like on either side of the said supporting ring for preventing the plate and the diaphragm from the deleterious effect of mechanical and temperature influences, the said protecting grids consisting preferably of perforated metal sheets bulged towards the outside and covered with a silk fabric or the like on the inner side and attached to the said supporting ring.

In testimony whereof, I have affixed my signature at Berlin, Germany, this 24th day of August, 1927.

HANS VOGT.