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ELECTROSTATIC LOUD SPEAKER

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Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

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My invention relates to loud speakers of the electrostatic type and more particularly to features therein for improving the operation thereof.

In a loud speaker of the type referred to, a large diaphragm is maintained in electrostatic relationship to a relatively immovable plate or plates by means of a direct-current potential impressed across the two, the gas space between the diaphragm and the plate constituting the dielectric. Variations in the impressed potential, as will be produced by superimposing potentials, at audio frequency, upon the direct-current potential, will cause the diaphragm to vibrate according to the variations of the audio-frequency potentials, to reproduce music or other sounds.

For large auditoriums and theaters, a loud speaker, operating on the electrostatic principle, should prove very desirable because of the fact that a speaker of this type may be constructed on a large scale and of a size comparable to that of a movie screen, the depth of a speaker of this size then being but a matter of inches.

As compared with speakers of the dynamic type, the electrostatic speaker is better adapted, because of its narrow dimensions, for table or wall operation, requires less weight and moving structure, and the expense of manufacture is materially lower.

In the operation of a speaker of the above specified type, however, as the diaphragm is shifted from its normally stable position, the capacity between the diaphragm and the plate increases, as a result of the reduction in spacing and, consequently, the electrostatic force, because of the direct-current potential acting between the diaphragm and plate, increases. This increase in force tends to stretch the diaphragm to a position favoring a breakdown in dielectric or a direct short circuit of the apparatus.

Various schemes involving the creation of restoring forces have been suggested for combating this undesirable inherent characteristic, among which may be cited a method relating to the production of a spring action at the clamping edges of the diaphragm, but this, obviously, necessitates an increase in apparent mass of the diaphragm, giving the diaphragm a natural period of vibration within the ordinary range of signal frequencies, a condition tending toward unsatisfactory reproduction of transmitted composition, as the diaphragm response is no longer free to follow the electrostatic forces set up by the audio-frequency potentials.

If the apparent mechanical stiffness of the diaphragm is made so great as to carry the natural period of vibration outside of the audio range, the device will become quite insensitive to the variations in the electrostatic forces playing upon it.

My invention constitutes an improvement over the prior art, as briefly outlined above.

It is an object of my invention to provide a device of the type described wherein the restoring force is electrical, as distinguished from mechanical.

Another object of my invention is to provide a device of the type described wherein the restoring force is uniformly distributed over the diaphragm surface.

Another object of my invention is to provide a restoring means, in an electrostatic loud speaker, which shall be independent of diaphragm characteristics.

Another object of my invention is to provide an electrostatic sound translator capable of utilizing an extremely light, and substantially massless, diaphragm, whereby an efficient translation of energy may be obtained.

Another object of my invention is to provide an apparatus of the type described having non-directional propagation characteristics.

An additional object of my invention is to provide a device of the type described which permits of operation with a minimum thickness of dielectric, whereby lower operating potentials may be employed.

Other features involved in my invention will be described and pointed out in the following detailed description of various species of my device, taken in conjunction with the accompanying drawings wherein;

Fig. 1 is a cross sectional representation, in a horizontal plane, of a double-acting electrostatic loud speaker embodying my invention.

Fig. 2 is a similar view illustrating a condition which the structure shown in Fig. 3 is designed to remedy.

Fig. 3 is a similar view representing a modification of the device shown in Fig. 1.

Fig. 4 is a similar view representing a single-acting speaker embodying another modification of my invention.

Figs. 5 and 6 are, respectively, a cross-sectional horizontal view and a vertical view in elevation of another modification.

Fig. 7 is a sectional view illustrating a slight modification of the structure shown in Fig. 5.

In accordance with my invention, the device disclosed in Fig. 1 comprises a pair of substan-
naires, 5 5

2 tially flat plates 1 and 3 of semi-conductive ma-

terial, as, for example, artificially prepared slate. The plates may be cast or otherwise formed with

holes out portions 5 and 7 comprising a ridge-like

structure having arcuate surfaces 9, 11, 13 and

15. Conductive surfaces 17 and 19 are provided on the exposed flat surface of the plates to which
can be made from any desired source of

electrical potential. If desirable, that portion of the

cast plate which defines the hollowed out portion may be added as a separate element to an

otherwise flat surface to obtain the desired

surface configuration.

As disclosed in the drawings, a pair of the

above plates are arranged with their edges adja-
cent to each other to define an unrestricted

sound chamber 21 and, clamped between them, is a diaphragm 23 of very thin material possess-
ing electrical conductive properties. Aluminum

foil is generally known as being a very suitable

material for the diaphragm, although a thin dia-

phragm of insulating material made conductive

by a coating of conductive material may also be

used to advantage. Sound outlets 26 are pro-

vided through the plates for obvious reasons.

The electrical circuit involved in the operation

of the above described device comprises an audio

transformer 27, the secondary of which is shown

connected between the two plates 1 and 3 through the conductive coatings 17 and 19, a

variable resistor 20 being inserted in the con-
nexion to each plate. A direct-current-poten-
tial source 31 is connected in a lead joining the
diaphragm to the midpoint of the transformer

secondary to impress biasing voltage on the

plates.

At the physical midpoint of the transformer

and the electrical center do not coincide or if

some differences exist in the physical and/or
electrical characteristics of the structure ele-
ments, the biasing potential on one plate may not

equal that on the other; where, it should for
efficient operation, with the result, that the dia-

phragm, because of an unequal pull which would then exist, would be distorted out of its nor-
mally desired stable position. Adjustment of the

cell 20 may then be made by removing the dia-

phragm back to its desired position.

Referring more particularly to the arcuate sur-

faces 9, 11, 13 and 15, defining the depression

boundaries, it is noted that their contact

with the diaphragm 23 is substantially a linear

one, as distinguished from an area contact, and

the value of current leakage between the dia-

phragm and the plates is extremely small. Dur-

ing reception periods, alternating-current poten-
tials impressed upon the transformer, alter-

nate, and act from the direct-current poten-
tial on the plates, with the result that the
diaphragm will vibrate in synchronism therewith.

Assume that, during vibration, an alternating-
current pulsation causes the diaphragm to be

pulled over to a position such as is illustrated

by the broken line in Fig. 1. Because of an

increase in capacity on one side and a decrease on the other, an additional pull will be exerted to

stretch the diaphragm closer to the right-hand plate, thereby increasing the output of the speaker

and producing a condition favoring breakdown

of the dielectric or a short circuit of the device.

However, in my device, the tendency of the

diaphragm to vibrate beyond the desired ampli-
tude corresponding to the alternating-current

potential component of the electrostatic force

is prevented. The contact of the diaphragm

with the plate toward which it has shifted has

now changed from that of substantially a line

contact to that of an area contact many times the

value, as clearly disclosed in the figure. The

leakage current through that plate will increase in a substantial drop of po-
tential across the plate sufficient to reduce the

electrostatic force tending to swing the dia-

phragm beyond its desired extent. The con-
trol, therefore, becomes automatic in its opera-
tion. The slope and the curvature of the con-

trolled surface may be varied to suit conditions, as it becomes apparent that the sharper the slope

the greater will be the swing of the diaphragm

before it can make an area contact of a pre-
determined value, and the reverse holds true for

a more gradual slope.

It will be possible, therefore, to cut down the

thickness of the loud speaker by substantially

reducing the depth of the depressions 5 and 7,
giving the proper considerations to the slope of

the control surfaces. In general, the shallower

the depth of the depression, the more gradual

should be the slope of the control surfaces, as

a very quick change in contact area would be desirous under the circumstances.

In order to prevent the polarizing direct-cur-
ent field from imparting an initial "skew" dis-

placement of the diaphragm, as illustrated in

Fig. 2, the control surface of one of the plates

may be given a different slope than the other, as

clearly shown by plate 33 in Fig. 3. This will

cause the diaphragm to assume a new position

to the left of the geometrical axis in the device

closed, the exact position determined by the

relative values of the contact areas and electrostatic forces existing on each side of the
diaphragm.

The modification disclosed in Fig. 4 illustrates

the use of compressed gas as a restoring force,
applied to a single-acting device, that is, one

utilizing only one plate. A jacket 35 is affixed

to the speaker in gas-tight relationship thereto

to form a compression chamber 37 between the

diaphragm 23 and the jacket 35. Gas compressed, by means of suitable con-

nections, to build up and maintain any desirable

pressure within the speaker. The broken lines

illustrate the position ordinarily assumed by the

diaphragm without a restoring force, due to the

electrostatic force set up by the direct-current

biasing potential 41. The pressure of the com-

pressed gas is adapted to swing the diaphragm

to its desired zero position. If desirable, the

pressure may be increased to produce an

outward bulge in the diaphragm, in which case

the action of the restoring force will be very

quick, which might be advantageous under cer-

tain conditions.

In the forms disclosed in Figs. 1, 3 and 4, the

restoring force, it will be noted, is uniformly dis-

tributed over the surface of the diaphragm, 13,

whereby uniform operation is obtained, and

buckling of the diaphragm is prevented. The di-
electric thickness may be reduced to a minimum

without danger of the diaphragm buckling or

striking the plate and short circuiting the de-

vice.

The above features are also incorporated in the

modifications of my invention disclosed in Figs.

5 and 6, together with additional refine-

ments. The diaphragm comprises a sheet of
paper or cloth 43 slightly impregnated with a conductive substance to render it semi-conductive, and is adably held between a pair of plates 45 and 47 of conductive material, each plate comprising a slitted or comb-shaped member, the teeth 49 of which constitute individual electrodes having arcuate edges 51 which serve the same purpose as the control surfaces 9, etc., referred to in the other forms. On those portions of the diaphragm exposed between the electrodes of the plates, I arrange a number of parallel strips of conductive material 53, such as a foil, and connect them to a common outlet or bus 55 at the top of the diaphragm. These strips serve to distribute the polarizing potential more uniformly over the semi-conductive sheet. With the construction noted above, it becomes impossible for the metallic portions of the diaphragm to strike the electrodes to produce a short circuit. Similar results may be obtained by making the diaphragm of conductive material and the plates of semi-conductive material.

To cure an inherent tendency of the electrostatic loud speaker to emit sound predominantly in a single direction, the speaker may be built as the section of a hollow cylinder or similar structure as shown in Fig. 7. The curved outline 57 of the device provides for uniform sound output in all directions along its radii of curvature. It lies within the scope of my invention to build a device partaking of the form of a complete cylinder, in which case, the volume output will be equal in all directions in a horizontal plane. A loud-speaker in which the diaphragm comprises a spherical surface, which may be complete except for a small area at each end of one diameter, is also within the scope of my invention. The members 51 and 53 would then be lunes of such a sphere.

It will be noted that the devices of Figs. 1 and 5 make use of a variable area of electrical contact between the diaphragm and its supports to minimize the effects of variation of electrical capacity with diaphragm displacement. While I have described these as applied to a double-acting loud speaker in which the electric field fills the space on each side of the diaphragm, it may be desirable to apply the variable-contact-area expedit to certain single-acting loud-speakers, such as that shown in Fig. 4, in which the electric field operates upon but one face of the diaphragm; and such construction is within the range of variations which I contemplate.

It will thus be obvious that I have disclosed structures which fulfil the objects of my invention. While I have illustrated and described, in detail, a plurality of such structures, I do not desire to be limited to the specific details except as is necessitated by the prior art and the appended claims.

I claim as my invention:

1. In an apparatus of the type described, a plate, a diaphragm in spaced electrostatic relationship thereto, and means for establishing a semi-conductive surface contact between said plate and said diaphragm and means for causing said semi-conductive surface contact to vary during movement of said diaphragm relative to said plate.

2. In an apparatus of the type described, a plate member, a diaphragm member in electrostatic relationship thereto and normally making a line contact therewith, one of said members being of a semi-conductive material, the other of said elements being of a conductive material, and means for causing said contact relationship to vary during changes in said electrostatic relationship.

3. In an apparatus of the type described, a plate comprising a slitted structure, a diaphragm electrostatically positioned with respect to said plate, and conductive elements on said diaphragm intermediate the tooth elements of said slitted structure.

4. In an apparatus of the type described, a plate comprising a slitted structure, a diaphragm electrostatically positioned with respect to said plate, conductive elements on said diaphragm intermediate the tooth elements of said slitted structure, said plate and diaphragm being curved to define a section of a hollow cylinder.

5. As an article of manufacture, a plate for an electrostatic loud speaker comprising a substantially flat member of semi-conductive material, a portion of said member defining a depression in one face of said plate, said portion comprising a ridge-like structure having an arcuate surface.

6. In an apparatus of the type described, a pair of plates of semi-conductive material having depressions therein, said plates being arranged face to face to define a substantially unrestricted chamber therebetween and a diaphragm of conductive material in said air chamber between said plates and making a direct semi-conductive contact with said plates at the edges thereof.

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