March 4, 1930. E. GERLACH 1,749,635

DIAPHRAGM FOR ELECTROACOUSTIC APPARATUS

Filed March 14, 1928

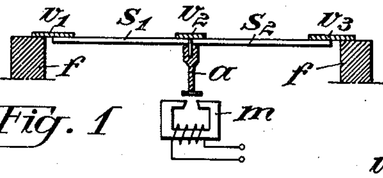


Fig. 1

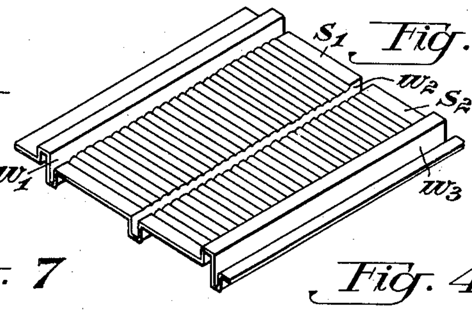


Fig. 2

Fig. 3

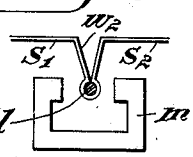


Fig. 7

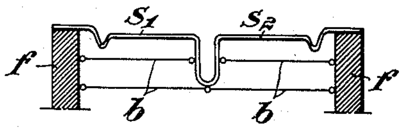
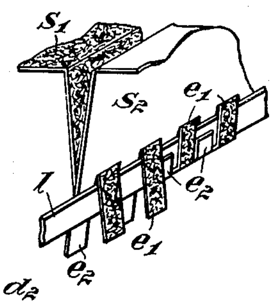


Fig. 4



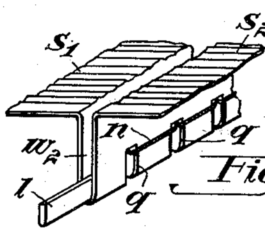


Fig. 5

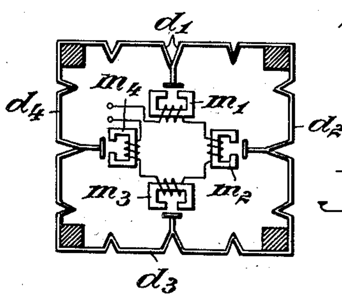


Fig. 8

Fig. 6

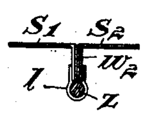


Fig. 10

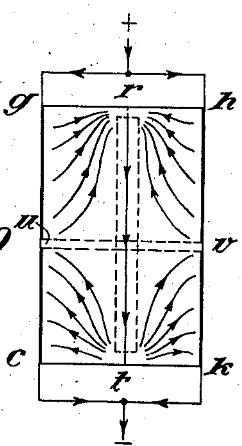


Fig. 9

Fig. 11

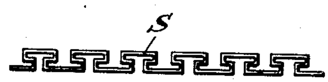
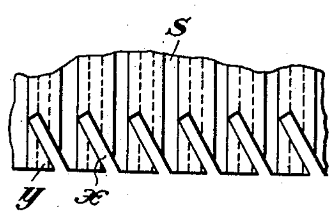


Fig. 12



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UNITED STATES PATENT OFFICE

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DIAPHRAGM FOR ELECTROACOUSTIC APPARATUS

Application filed March 14, 1928, Serial No. 261,680, and in Germany March 12, 1927.

This invention relates to a new type of diaphragm, more particularly for acoustic purposes, for instance for loud-speakers, transmitters, phonographs. The diaphragm is chiefly characterized by the fact that it is constituted by two or more, component elements or bodies, rigid in themselves and preferably having a rectangular form, which are interconnected flexibly with one another at the inner edges and connected flexibly to the fixed parts of the system at their outer edges, so that the joints, acting as hinges, enable the diaphragm to oscillate around the outer edges, if it is vibrated in the center, and particularly at the joint between the rigid parts of the diaphragm.

The advantages of such a diaphragm, as compared with the types used hitherto, consist, on the one hand, in the fact that the diaphragm, owing to the provision of the hinges, is very flexible as a whole and presents only a minimum rigidity, so as to enable it to oscillate to the fullest extent even at the great amplitudes of the lower frequencies and, on the other hand, either of the two plain or curved component elements of the diaphragm is rigid so that they oscillate as a rigid unit within the greatest part of the voice frequency range. For the highest sounds, however, the co-phasal motion of all points is no longer possible, but the injurious effect may be avoided by making the diaphragm sufficiently rigid to enable the waves to propagate over the diaphragm (from the actuated center towards the edges) at a high speed, for instance at the speed of sound in the air.

Another advantage of the invention is that the diaphragm may be actuated at its central hinge throughout its length, which is of special importance in the case of an electro dynamic drive. But a concentrated drive by an electromagnetic system is also very effective, provided only the central hinge presents a great longitudinal rigidity, so that the force may act on the greatest possible length of the hinge, thus simultaneously putting the entire diaphragm in motion.

The hinge-like parts of the diaphragm may be constituted in different ways: The two rigid component surfaces may, for instance, be interconnected and joined with the outer edges to the rigid frame or case of the system by means of a flexible material such as pertinax, or by a thin sheet. It is however more convenient to use for these joints the same material, preferably part of the rigid surfaces, for instance a U- or V-shaped ripple or fold of the diaphragm, made integral therewith, which runs along the straight lines designed to act as hinges. In order to make the remaining plain parts of the diaphragm in this case sufficiently rigid, they may preferably be provided with rigid elements, for instance in the shape or ribs running at angles, preferably at right angles to the hinges, or the surfaces may be covered with an additional layer, or coated with a lac varnish. Instead of ribs, the rigid component surfaces may also be provided with corrugations, preferably having a rectangular profile.

In the case of an electrodynamic drive, the central hinge part of the diaphragm is made to act as an electrical conductor, which, provided the diaphragm is an insulator, is achieved by applying (riveting, screwing or the like) to it a conducting wire, rod or bar. If the diaphragm is all of one piece and the central hinge is constituted by a longitudinal corrugation, the conducting bar is fitted into the corrugated part or riveted to it or the like. In case of metallic diaphragms, this involves insulating the diaphragm from the said bar or conductor, for instance by using an intermediate thin layer of paper or oxidizing the conductor or even the diaphragm in a manner well-known in itself.

In the latter case, currents passing through the conductor can induce, in the parts of the diaphragm adjacent to the conductor, that is, mainly in the central fold, opposed currents which, in so far as they equally flow through the magnetic field, check the motion. In order to avoid this, the central part of the diaphragm is provided with slots running transversely to the direction of the current flowing through the conductor, so as to prevent the inductive currents from flowing. In case the whole diaphragm consists of one piece of conductive material, the corrugated central part itself may also act as a current conductor; a propagation of the current over the entire surface is then preferably avoided by slots provided in the rigid elements and running at an angle (preferably a right angle) to the hinge.

In order to ensure a correct parallel motion of the central hinge-like part of the diaphragm, this part may be suspended by means of elastic threads or ribbons, whose ends are fastened to the frame or case of the system.

In order to obtain the propagation of sound in several directions several diaphragms of the type described emitting sounds in different directions may be made to form a unit, preferably in such a manner, that, seen in cross-section, it constitutes a closed polygon.

In order to avoid disturbing natural oscillations, the natural frequency of the diaphragm should be below the lower limit of audibility. This has, however, the drawback that the practically inaudible low voice frequencies often contained in the tone spectrum to be reproduced, on account of their great amplitudes represent an unnecessary load for the diaphragm. This can be avoided by providing the unit with a selective damping device. It consists for instance of a cavity within the diaphragm which is completely airtight except for one or several small openings. This opening or aperture is so dimensioned that for most of the frequencies, the pressure of the enclosed air is not equalized through the holes, but rather acts like an elastic cushion. This action ceases for the lower frequencies; the enclosed air whose pressure slowly becomes uniform under the action of a strong friction, thus causes a damping.

The drawing shows several constructional examples of the invention.

Fig. 1 is a cross-section of a first embodiment of the invention.

Fig. 2 is a perspective view of another embodiment of the invention.

Fig. 3 shows a cross-section of an embodiment utilizing a diaphragm of the type shown in Fig. 2.

Figs. 4 and 5 are perspective views of two modifications of the invention.

Figs. 6 and 7 are cross-sections of further constructions.

Fig. 8 is a cross-section of another modification.

Fig. 9 illustrates in plan a modification which is applicable to Fig. 6 for instance.

Figs. 10, 11 show cross-sections and Fig. 12 a view of special details of Fig. 6.

According to Fig. 1 s_1 and s_2 are two rigid diaphragm elements or bodies interconnected by the link v_2 and, by means of links v_1 and v_3 connected to rigidly mounted parts f of the system in a hinge-like manner. As hereinbefore mentioned these links or connecting members may consist of "pertinax" or other suitable flexible material. The diaphragm is driven at its center, preferably at several points along the central joint, for instance, by an armature a set in motion by a magnet system m.

Fig. 2 shows a diaphragm, made all of one piece, in which hinge-like portions or joints are constituted by longitudinal corrugations w_1, w_2, w_3, whereas the rigid component diaphragm elements s_1 and s_2 are corrugated transversely.

Fig. 3 shows a cross-section of a diaphragm operated electrodynamically: The corrugation w_2 interposed between the rigid diaphragm elements s_1 and s_2 embraces an electrical conductor l running between the poles of a magnet m, which preferably extends over the entire diaphragm length.

Fig. 4 shows another manner of fastening the conductor to the diaphragm, which is of particular importance in the case of sheet diaphragms: The rigid diaphragm elements s_1 and s_2 which are not made integral with each other end in strips or fingers e_1 and e_2 at the edges to be interconnected. As shown by the drawing these strips are, first, fitted into one another or interlocked, the conductor l then being placed between the strips ($e_1 \ldots$) and ($e_2 \ldots$) in such a manner that all the strips of one diaphragm element (s_1) are situated on one side and all the ends (e_2) of the other diaphragm element (s_2) on the other side of the conductor. The ends are then bent over the conductor, as shown at the right-hand portion of Fig. 4.

Fig. 5 illustrates another type of fastening. The central corrugation w_2 of the diaphragm, made all of one piece, embraces the conductor l and is provided with transversal slots q, projecting slightly above the upper edge of the conductor. Two threads n or wires are then passed through these upper slot parts and crossed or twisted to hold the conductor in place.

Finally the conductor l can be made V-shaped, as shown by Fig. 6 and placed around the edge of the central corrugation w_2, in which case this edge should be slightly strengthened, say by being bent over or by inserting a wire z, in order to support the bent-over conductor. The outer edges are preferably connected flexibly to stationary parts in the same manner as shown in Fig. 2.

If in any one of these types of conductor-fastening the diaphragm should be of conductive material, an insulating layer should be placed between the conductor l and the diaphragm, say a layer of paper or guttapercha, or the conductor and, in case of need also the diaphragm, might be covered with an oxide-layer.

According to Fig. 7 the diaphragm s_1, s_2 is provided with a suspension consisting of threads or ribbons b placed preferably at several points along the movable edge.

Fig. 8 shows a polygon-like construction of the system, more particularly for super-loud-speakers, designed for open-air use. Four diaphragms d_1—d_4 are arranged in a square. The operation is for instance achieved by means of a magnet system m_1—m_4.

In order to secure an extremely reliable and simple type of fastening of the current conductor *l*, Fig. 6, the central part of the diaphragm may be provided with ribs and grooves running at right angles to its longitudinal direction and arranged in two or several groups, forming an angle with one another. The conductor is now pressed on the central piece prepared, in the described manner, sufficiently tightly to enable it to be fitted over the ribs or into the grooves. The angular position of the groups of ribs or grooves in respect to one another prevents the conductor from gliding off in any direction. The group of grooves should be formed by slots, which, in the case of a metallic diaphragm, prevents the conductor from inducing currents in the diaphragm.

The ribs are preferably constituted as shown in Fig. 10, using rectangular corrugations which also stiffen the surfaces of the diaphragms, and flattening these corrugations to give them the **T**-shape shown in Fig. 11. Hence the points presenting normal thickness of material alternate with others where the material comprises three superposed flattened layers. In case the conductor proper is tightly pressed on this flattened material—for instance by using jaws of lead or a similar material which is softer than conductor and diaphragm—it is pressed into, or interlocked with, the grooves and no longer able to glide off in the direction of the fold. In order to avoid a gliding off in this very direction the slots *x* are arranged slantwise to the direction of the folds *y* as shown in Fig. 12. Into these oblique slots, the conductor is filled uniformly. If these slots alone were provided (without corrugations) the conductor might glide off slantwise in the direction of these slots. However, as the corrugations *s* are at an angle to the grooves *x*, the conductor is held against sliding in either the direction of the grooves or that of the corrugations.

In case of diaphragms presenting no corrugation, use may also be made of two groups of slots on the central part, which are arranged in the manner indicated above. Instead of the folds or slots, two groups of ribs may be constituted, more particularly in case of non-metallic diaphragm, by means of projections, ribs or the like secured to the central part of the diaphragm. For the purpose of the electrodynamic drive, the central part of the diaphragm is usually provided with a current conductor. The speech currents are applied to this movable conductor by means of wires, placed at both extremities of the conductor bar as indicated in Fig. 9.

If desired, the currents may be applied to the conductor by means of the diaphragm itself, or by electric conductors placed on its surface, that is from the firmly clamped lateral edges, so that the points of the current supply to the diaphragm will be stationary.

In case of metallic diaphragms the diaphragm should be provided in the center with an insulating strip electrically insulating from another the two diaphragm halves, lying on both of its sides and running crosswise to the direction of the conductor. The insulated conductor fastened to the diaphragm is connected at either extremity with one of the two diaphragm halves the two ends of the external leads are then connected each to one of the insulated parts of the diaphragm, that is to the lateral rigid edges.

According to Fig. 9 the metallic diaphragm *g*, *h*, *i*, *k* contains in its center a current conductor *r*, *t*, which, as is shown by the dotted lines, is insulated from the diaphragm throughout its length and is only at its ends in contact with the diaphragm surface. The upper and lower diaphragm surfaces are electrically insulated from one another by means of the slot *u*, *v*, shown by the dotted line, which should preferably be made acoustically impermeable by an insulating compound, such as a rubber film. The current is supplied to one or several points between the diaphragm points *g*, *u* and *h*, *v* and leaves the diaphragm at the edges *u*, *c* and *v*, *k*. The arrows indicate the distributions of the lines of force. The electrical connection between the diaphragm and the conductor at the ends *r* and *t* should preferably be established by welded joints (point welding).

The system can be so arranged that one half of the diaphragm is used for the current input and the other for the output. The two halves are in this case, completely insulated from one another and only at one end connected to the conductor.

The invention may also employ non-metallic diaphragms. In this case the diaphragm is provided at any two points with current conductors, for instance with tinfoil strips and wires fastened to it in any suitable manner.

The diaphragm can also be made **V**-shaped by folding or joining two plates.

What I claim as my invention and desire to be secured by Letters Patent is:

1. A diaphragm for electro-acoustic apparatus, having a plurality of elements each rigid in itself, the adjacent edges of said elements being straight, and a flexible connection following a straight-line hinge between the adjacent edges of such rigid elements.

2. A diaphragm for electro-acoustic apparatus, having a plurality of substantially

rectangular elements and a flexible connection following a straight-line hinge between the straight adjacent edges of said rectangular elements.

3. A diaphragm for electro-acoustic apparatus having a plurality of elements of substantially rectangular form, a flexible connection between the straight adjacent edges of said rectangular elements, and means for connecting the distant edges of said elements flexibly to stationary supports.

4. A diaphragm for electro-acoustic apparatus, having a plurality of substantially rectangular elements and a central hinge connecting the adjacent edges of said elements.

5. A diaphragm for electro-acoustic apparatus, having a plurality of substantially rectangular elements, a central hinge connecting the adjacent edges of said elements, and means for connecting the distant edges of said elements to stationary supports.

6. A diaphragm for electro-acoustic apparatus, having a plurality of substantially rectangular elements, a central hinge connecting the adjacent edges of said elements, and a metallic current-carrying member attached to said central hinge.

7. A diaphragm for electro-acoustic apparatus, having a plurality of elements located side by side, a hinge connecting adjacent edges of said elements, and a metallic member embracing said hinge and clamped firmly thereon.

8. A diaphragm for electro-acoustic apparatus, having a plurality of substantially rigid elements provided at their adjacent edges with straight portions extending substantially at right angles to the plane of the diaphragm, said portions being provided with grooves and projections, and a thin metallic plate clamped on said portions.

9. The method of connecting a metallic rib to a diaphragm which consists in producing projections and grooves at the central portion of diaphragm, then flattening said projections in such a manner that at some points three layers of the diaphragm lie above one another and at intermediate points only one layer of the diaphragm exists and pressing a metallic rib on the thus prepared surface of the diaphragm.

In testimony whereof I affix my signature.

ERWIN GERLACH.