June 18, 1968 E. P. PEABODY 3,389,226

ELECTROSTATIC LOUDSPEAKER

Filed Dec. 29, 1964

FIG. 1

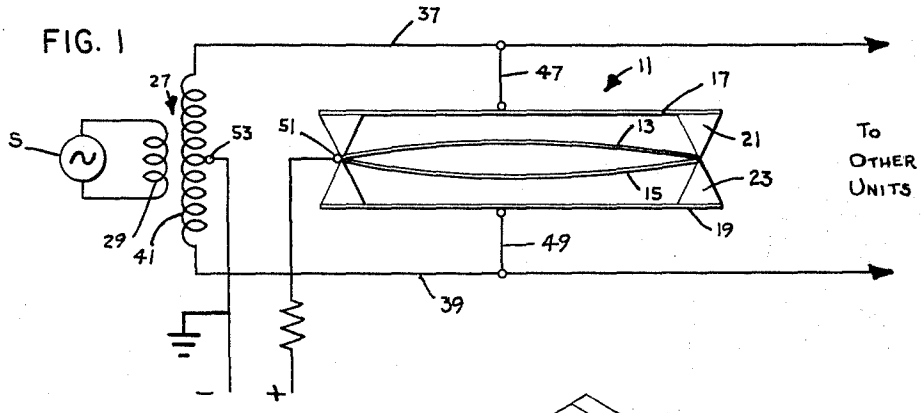


FIG. 2

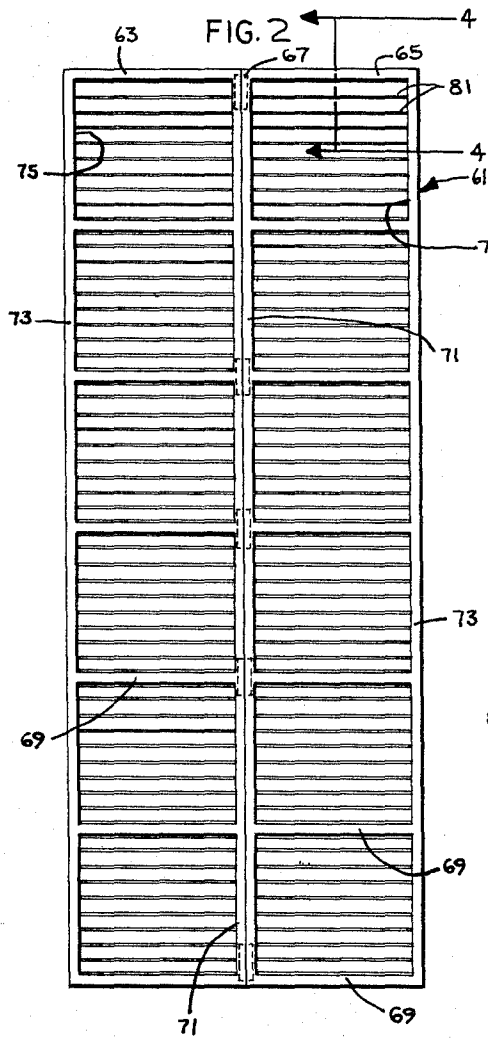
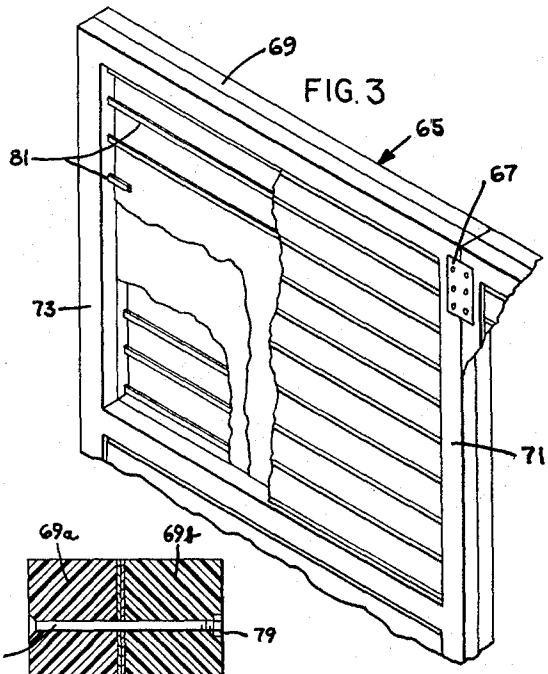


FIG. 3



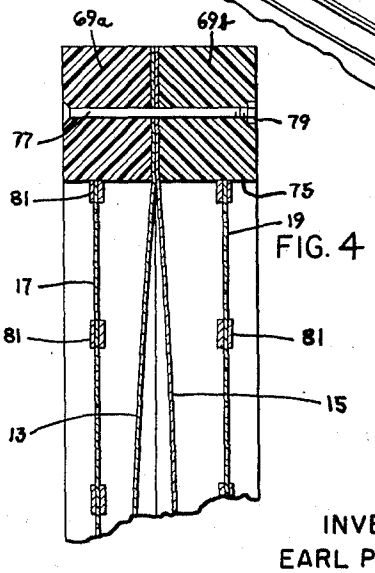


FIG. 4

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ELECTROSTATIC LOUDSPEAKER

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ABSTRACT OF THE DISCLOSURE

An improved electrostatic loudspeaker having a composite vibrating diaphragm composed of two sheet-like membranes supported together at their edges. These membranes are electrically conductive and arranged to bulge mutually apart in response to electrostatic forces, thereby rendering the membrane taut, to reduce rattle or flutter.

This invention relates to an improvement in electrostatic loudspeakers. More particularly, the invention concerns itself with electrostatic loudspeakers of the type which depend for their action upon a force of electrostatic attraction between a movable or flexible diaphragm electrode and a rigid plate electrode.

Certain prior art electrostatic loudspeakers of the nature referred to have utilized a diaphragm comprising two membranes mounted at their periphery. However, such loudspeakers as these have been found to be somewhat limited in application by either relatively limited frequency response, or inefficiency of operation. Accordingly, an important object of the present invention is to provide a new and improved electrostatic loudspeaker which utilizes a double membrane diaphragm and provides a wide range of frequency response.

Another object of my invention is to provide an improved electrostatic loudspeaker which involves substantially minimal rattle or fluttering.

Still another important object of my invention is to provide a novel electrostatic loudspeaker which includes a pair of tensioned membranes supported at their periphery between fixed plates and arranged in such a manner that electrostatic repulsion of the membranes produces a resultant tautness which tends to inhibit rattle or flutter.

A further object of my invention is to provide an improved electrostatic transducer which is characterized by an improved frequency response and is economical to manufacture.

In carrying out my invention, in one form thereof, I provide a pair of contiguously disposed sheet-like membranes which are supported together at their peripheral edges. Each of these membranes is electrically conductive, and the membranes are supported between, but insulated from, a pair of fixed spaced-apart plates. A means is provided for applying audio frequency signals to the plates. Means is also provided to furnish electrostatic forces to the membranes with respect to the plates. With such an arrangement, the membranes are allowed to bulge mutually apart from each other when electrostatic forces are applied thereto, for rendering the membranes taut so that they do not rattle or flutter. Such a loudspeaker structure also achieves an efficient frequency response in the frequency range of 40–20,000 cycles per second (c.p.s.). Such a frequency response is achieved with relatively low distortion and without the necessity of providing any crossover networks or other more expensive form of frequency response smoothing means.

Further aspects of my invention will become apparent hereinafter, and the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which I regard as my invention. The invention, however, as to organization and method of operation, together with further objects and advantages thereof,

may be best understood by reference to the following description, when taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a schematic diagram of an electrostatic loudspeaker stage, embodying one form of my invention;

FIG. 2 is a front elevation view of a multiple electrostatic loudspeaker unit including a series of electrostatic loudspeakers constructed in accordance with my invention;

FIG. 3 is a fragmentary perspective view illustrating part of the loudspeaker unit of FIG. 2; and

FIG. 4 is a fragmentary sectional view taken along the lines 4—4 of FIG. 2 to illustrate in further detail the construction of the loudspeaker arrangement of FIG. 2.

Referring first to FIG. 1 of the drawing, there is shown in accordance wtih one form of my invention, by way of example, an electrostatic loudspeaker **11** which comprises a pair of uniformly configured flexible diaphragms or membranes **13** and **15** effectively sandwiched between two closely-parallel fixed plates **17** and **19**. The diaphragms **13** and **15** may be constructed from a plastic sheet material such as Mylar having a thickness of 0.250 mil, to thus provide a pair of thin flexible membranes. Each of the diaphragms **13** and **15** has a conductive coating surrounding it, such as, for example, aluminum. The plates **17** and **19** are of rigid metallic construction and are suitably perforated so that sound can pass through them. By way of example, the fixed plates **17** and **19** may be made of perforated screen sheets disposed in parallel relationship and mounted on a wooden supporting frame.

The diaphragms **13** and **15** are secured in tension between the plates **17** and **19** by being clamped together in mutually contiguous relationship and disposed in spaced apart insulated relationship from the plates **17** and **19**. As shown schematically in FIG. 1, the diaphragms **13** and **15** are thus disposed in generally parallel relationship with each other and peripherally supported in tension by means of insulative members **21** and **23** which space the diaphragms **13** and **15** from their adjacent respective plates **17** and **19**.

Turning now to a description of the operation of my new and improved loudspeaker **11**, attention is further directed to FIG. 1. As shown therein, an audio frequency signal voltage is applied to the fixed plates **17** and **19** by means of a signal output transformer **27**. More particularly, the audio signal from source S is supplied to the primary winding **29** of the signal output transformer **27**. The transformed signal voltage from transformer secondary **41** is transmitted by conductors **37** and **39** from the secondary **41** to the fixed plates **17** and **19**, respectively. Conductors **37** and **39** are each connected at one of their ends to the ends of the secondary transformer winding **41** and are connected at their other ends to the fixed plates **17** and **19**, via the short conductors **47** and **49**, respectively. It will be understood by those skilled in the art that the signal output transformer **27** may also provide an audio signal to various other loudspeaker units similar to the schematically illustrated unit **11**, as is indicated by the arrows on the right side of FIG. 1.

The electrostatic loudspeaker unit **11** and any other accompanying units, are polarized by connecting a suitable DC source of relatively high tension between diaphragm terminal **51**, which is common to both of the diaphragms **13**, **15**, and a center tap **53** of the transformer secondary **41**. By way of example, a polarizing voltage of between 800 and 1500 volts DC has been found advantageous. It will thus be seen that by means of the polarizing voltage applied between terminals **51** and **53** the conductive coatings of the plastic membranes **13** and **15** are polarized with respect to the plates. The tensioned double diaphragms **13** and **15** will thereupon vibrate between plates **17** and **19** due to the varying forces acting

between the charge on diaphragms 13 and 15, and the instantaneous voltages on plates 17 and 19 due to the applied signal.

In view of the DC voltage applied to terminals 51 and 53, plate 17 has an opposite polarity from its adjacent diaphragm 13, and as a result of this opposite polarity the diaphragm 13 is attracted to plate 17. In addition, the DC voltage applied to terminals 51 and 53 also causes the plate 19, which is opposite in polarity from its adjacent diaphragm 15, to attract diaphragm 15. Since diaphragms 13 and 15 are of the same polarity, they thereupon tend to repel each other. The diaphragms 13 and 15 thus tend to bow away from each other at their centers, as indicated in FIG. 1.

It will thus be seen, that my improved diaphragm arrangement helps to keep both of the membranes 13 and 15 under tension at all times due to the mutual repulsion of the diaphragms 13 and 15 and the attraction of each diaphragm 13 and 15 to its adjacent respective fixed plate 17 and 19. Such a structure permits relatively low prestressing of the membranes and a resultant lower resonant frequency. It also tends to keep the membranes relatively tight against their supporting means, thereby effectively avoiding any tendency of rattling or flutter. Since the electrostatic forces are acting in a push-pull fashion, harmonic distortion is effectively obviated. In addition, controlled air leakage of the volume between the diaphragms may allow for changes in ambient pressure and temperature.

Turning now to FIGS. 2, 3 and 4, as shown therein, I have illustrated an operative embodiment of my invention which incorporates a series of twelve electrostatic loudspeaker units 11 arranged in a room divider 61. The illustrated room divider 61 includes a pair of vertically elongated insulative frames 63 and 65 (e.g. constructed from wood) which are secured together in pivotal relationship by a series of hinges 67. Each of the frames 63 and 65 has the same configuration and includes a series of spaced-apart horizontal ribs 69 which extend between and are connected to elongated inner and outer vertical legs 71 and 73. As further shown in FIGS. 3 and 4, each of the frames 63 and 65 is of two ply construction so that the horizontal ribs 69 and the inner and outer legs 71 and 73 of each frame consist of two identical parts suitably secured together, such as by way of example, the two parts of the upper rib 69 illustrated in FIG. 3.

The horizontal ribs 69 are in parallel relationship and are spaced apart in equidistant fashion from each other, as illustrated in FIG. 2, so that each frame 63 and 65 provides a series of six rectangularly configured apertures or windows 75. In each of the apertures 75, there is arranged in tension a contiguous pair of the aforementioned membranes 13 and 15. More particularly, the Mylar diaphragms 13 and 15 are clamped together between the peripheral sides of each window framework 75 in the manner suggested by FIG. 4. Thus, as indicated in FIG. 4, the peripheral edges of the two membranes 13 and 15 are sandwiched together in contact with each other, between the mating portions of the window periphery, such as horizontal rib portions 69*a* and 69*b*. A series of bolts 77 with nuts 79 (one of which is illustrated by way of example in FIG. 4) may be utilized to securely clamp the peripheral edges of the two membranes 13, 15 to the surrounding portion of the frame window 75. Connections of the leads 47 and 49 (FIG. 1) to the aluminized surfaces of the membranes 13 and 15 may be achieved by means of pressure contact (not shown) at the frame edges.

In the illustrated embodiment of my invention, to provide additional support for the thin fixed plates 17 and 19 between their upper and lower ends, I have also provided a series of horizontal wooden ribs 81 which are arranged in parallel spaced-apart fashion and connected to the inner and outer vertical legs 73 and 71.

The screen-like plates 17 and 19 are secured to the frame by means of contact cement (not shown). Plate 17 is in generally parallel adjacency to membrane 13 and located outwardly therefrom. Plate 19 is in generally parallel adjacency to membrane 15 and located outwardly therefrom. A spacing of 60 mils between each of the plates 17, 19 and the closest surface of their adjacent membranes 13, 15, has been found to be particularly desirable. Suitable conductors may be soldered to each of the plates and brought out through the framework for external connection to the circuit.

It will be understood by those skilled in the art that suitable grille cloth of fabric or insulative plastic may be readily draped over the room divider frames 63, 65 after the assembly of the electrostatic loudspeaker units 11 thereto, to help appropriately insulate the speaker assembly from the operator and also to enhance the attractiveness of the overall device. It will also be understood that the electrostatic speaker units 11, or a plurality of room dividers 61 may be connected in such a manner as to effectively transmit stereophonic sound.

It will now therefore be understood that in accordance with the present invention I have provided an improved electrostatic loudspeaker which effectively utilizes a pair of co-operating membranes arranged in taut fashion so that they do not rattle or flutter. It will be further realized that my improved electrostatic loudspeaker units provide relatively low distortion and full range frequency response without the necessity of utilizing any crossover networks or the like. It shall be understood that my invention provides a simplified electrostatic loudspeaker which is characterized by very efficient and stabilized operation. It will also be seen that I have provided an improved electrostatic loudspeaker enclosure wherein my loudspeaker units may be effectively utilized.

While the illustrated diaphragms 13 and 15 are constructed of the plastic sheet material Mylar having a conductive surrounding coating of aluminum, it will be understood that my invention is not necessarily limited to such a diaphragm structure as this. For example, it may be desirable to construct the diaphragms 13 and 15 in such a manner that only the inwardly facing and opposite sides of each diaphragm have a conductive coating formed thereon. With such an alternative arrangement, the outwardly facing peripheral edges of each diaphragm would be insulative and could be placed in contiguous relationship with the peripheral edges of the fixed plates 17 and 19. Such a structure would readily lend itself to economy of manufacture.

It will be further understood that the illustrated diaphragms 13 and 15 may be constructed in such a manner that only their outwardly facing sides have a conductive coating formed thereon, and the inwardly facing surfaces are of the insulative Mylar. With such an arrangement, a bracketing type terminal 51 (not shown) could be utilized for connecting the periphery of the diaphragms 13, 15 to the positive side of the polarizing source.

While in accordance with the patent statutes, I have described what at present are considered to be the preferred embodiments of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from my invention, and I, therefore, aim in the following claims to cover all such equivalent variations as fall within the true spirit and scope of this invention.

What I claim and desire to secure by Letters Patent of the United States is:

1. An electrostatic loudspeaker system comprising first and second outer plate electrodes disposed in parallel relationship, first and second vibratable diaphragm electrodes of flexible sheet material disposed between, spaced from and insulated from said outer plate electrodes, said first and second diaphragm electrodes being disposed in contiguous relationship, driving means for applying audio-frequency signals to the plate electrodes, and means for continuously applying a polarizing voltage to said dia-

phragms with respect to said plate electrodes, said polarizing means causing said diaphragms to bulge mutually apart thereby to render said diaphragms taut for enhancing the stability of operation of said electrostatic loudspeaker system.

2. The loudspeaker system of claim 1 wherein the diaphragm electrodes are constructed of thin plastic material and surrounded by a coating of a conductive material.

3. The loudspeaker system of claim 1 wherein the inwardly facing surfaces of said diaphragm electrodes are coated with conductive material and the outwardly facing surfaces are insulative.

4. The loudspeaker system of claim 1 wherein the outwardly facing surfaces of said diaphragm electrodes are coated with conductive material and the inwardly facing surfaces are insulative.

5. An electrostatic loudspeaker system comprising a pair of two ply supporting panels arranged in pivoted relationship, each of said panels including a plurality of two-ply window frames, and an electrostatic loudspeaker unit disposed in each of said window frames, said loudspeaker unit comprising first and second outer plate electrodes disposed in parallel relationship within said window frame, first and second vibratable diaphragm electrodes of flexible sheet material disposed between, spaced from and insulated from said outer plate electrodes, said first and second diaphragm electrodes being disposed in contiguous generally parallel relationship, driving means for applying audio-frequency signals to the plate electrodes of each loudspeaker unit, and means for continuously applying a polarizing voltage to said diaphragms of each unit with respect to said plate electrodes thereof, said polarizing means causing said diaphragms to bulge mutually apart thereby to render said diaphragms taut for enhancing the stability of operation of each electrostatic loudspeaker unit.

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