April 26, 1960 W. O. STANTON 2,934,612

ELECTROSTATIC SPEAKER

Filed Oct. 24, 1957 2 Sheets-Sheet 1

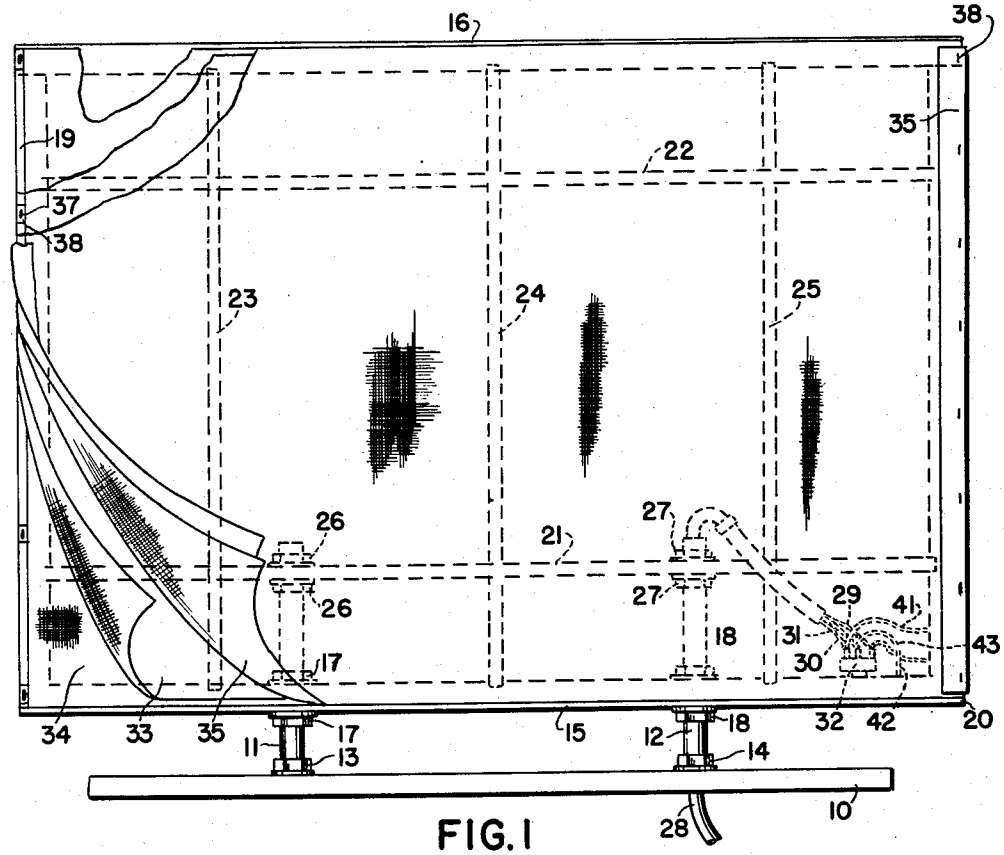


FIG. 1

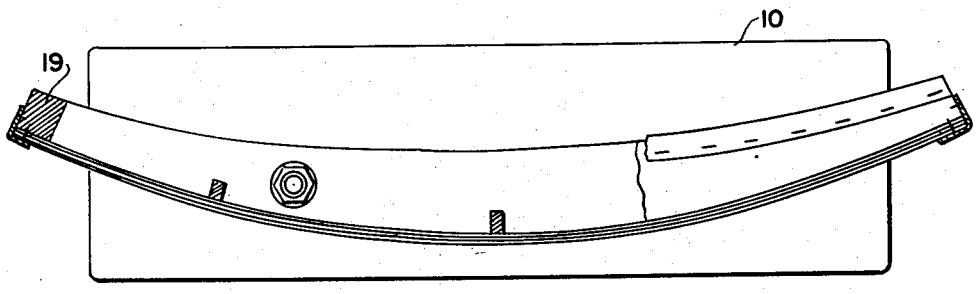


FIG. 2

INVENTOR
Walter O. Stanton
BY
Kane, Dalsimer and Kane
ATTORNEY

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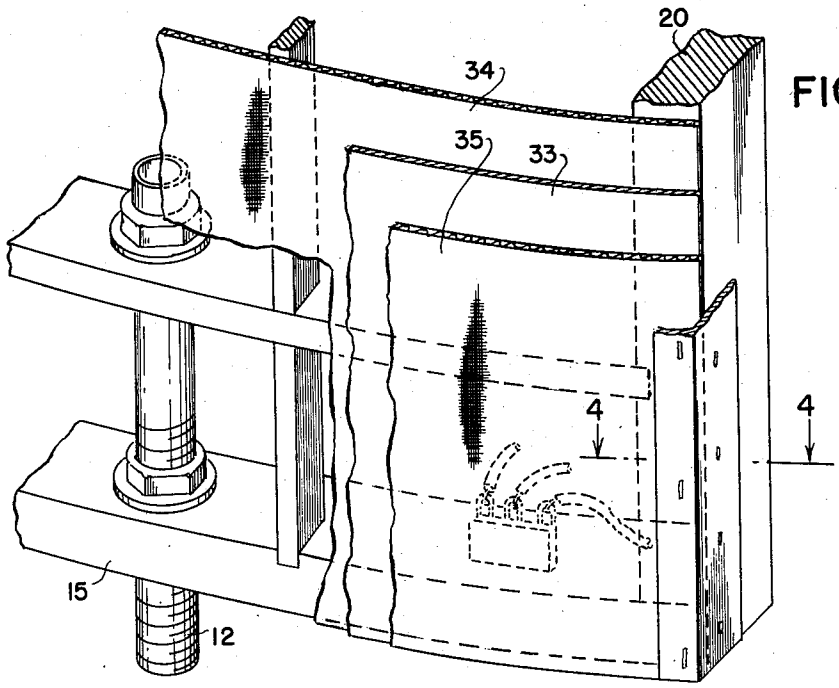


FIG.3

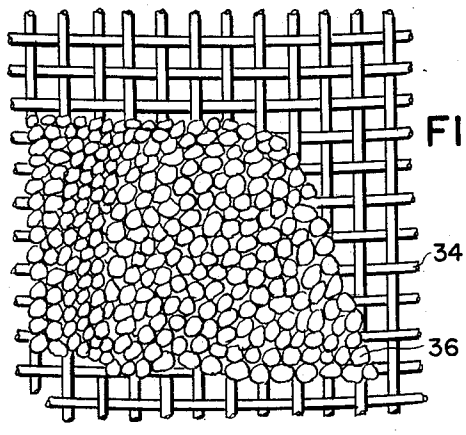


FIG.5

FIG.4

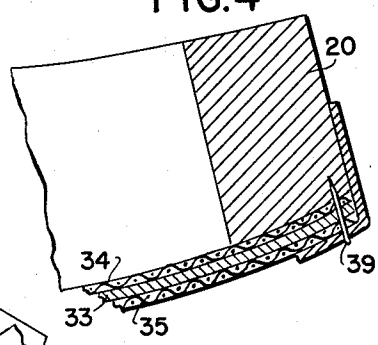
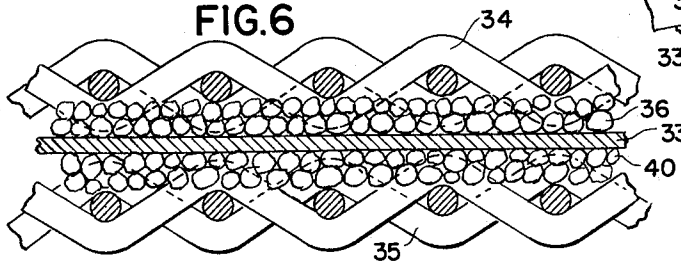


FIG.6



INVENTOR
Walter O. Stanton
BY
Kane, Dalsimer and Kane
ATTORNEY

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ELECTROSTATIC SPEAKER

Walter O. Stanton, Laurel Hollow, N.Y.

Application October 24, 1957, Serial No. 692,063

7 Claims. (Cl. 179—111)

This invention relates generally to transducers for translating electrical waves into sound waves, or the reverse, and more particularly relates to an electrostatic speaker.

A speaker is a device which translates electrical signals applied to it into sound waves. This translation is effected by the action of electrical signals on an acoustical element which generates sound waves in response to the electrical signals. In an electrostatic speaker, the acoustical element and a fixed plate are charged relatively to form a condenser which serves as the load or output unit of an electrical system. In some designs a plurality of fixed plates is used and the acoustical element is maintained between the two fixed plates. Variations in the output wave in the electrical system can then cause the acoustical element to move in synchronism therewith since condenser plates are attracted or repelled as a function of electrical potential as well as of spacing and dielectric substance.

The advantages of an electrostatic speaker are well recognized and particular forms have come into use. The electrostatic speakers presently in use are of the "single-sided" type in which forces act on one side only of the vibratory diaphragm, or of the "push-pull" type in which the electrostatic forces act on both sides of the vibratory diaphragm. The present invention is described in terms of a push-pull type electrostatic speaker. However, the inventive concept herein presented comprehends an improved electrostatic transducer, whether it be receiver or speaker, of the single-sided type or the push-pull type.

A chief advantage of an electrostatic speaker is that the force driving the diaphragm being electrostatic can, if the mounting is suitable, be applied uniformly over its entire area. It is seen therefore that the mounting for an electrostatic speaker is of extreme importance. The mounting must be such that portions of the diaphragm will not be forced to vibrate out of synchronism due to mechanical stresses, and also the electrical signal energy should be arranged to act directly on the acoustical diaphragm to effect vibrations thereof rather than upon an intermediate transducer.

The invention herein disclosed has, as its main object, the provision of an improved mounting for an electrostatic speaker which will allow the driving force to be applied to the acoustical element uniformly.

Another object of this invention is to provide an improved electrostatic speaker assembly having a high dielectric breakdown potential.

Still another object of this invention is to provide an improved mounting assembly for the diaphragm of an electrostatic speaker which will allow the use of a low mass diaphragm as the vibratory acoustical element and permit the diaphragm to vibrate at large amplitudes and not become distorted.

A further object of this invention is to provide an electrostatic speaker mounting which will allow for the provision of uniform spacing between the diaphragm and a fixed condenser member, and which will allow the moving parts thereof to move in synchronism with one another.

And, still another object of this invention is to provide an improved electrostatic speaker assembly having increased sensitivity and fidelity of response over a wide range of frequencies.

These, and other objects are accomplished by furnishing an electrostatic speaker assembly in which the acoustical element or diaphragm is a conductive member of a low mass and stiffness and is supported between two electrodes in the form of woven conductive metal screens, or acoustically transparent plates, which have small particles of foam rubber or other foam material having the characteristics of rubber adhesively secured to the sides facing the diaphragm in such a manner that the spacing between each outer electrode and the acoustical element is uniform when the diaphragm is static, and of such assembly that when the diaphragm is drawn toward one electrode by an unbalance of charge on it in relation to the other electrode, the small particles will engage and support the diaphragm while permitting motion of the diaphragm in a linear manner.

The construction of the speaker mounting and assembly, and manner of using the same is described herein with reference to the drawings in which:

Fig. 1 is a partially sectional front elevation of an electrostatic speaker assembly constructed in accordance with the teachings of this invention showing the acoustically transparent fixed plates and acoustical diaphragm mounted on the frame;

Fig. 2 is a partially sectional plan view of an electrostatic speaker assembly constructed in accordance with the teachings of this invention;

Fig. 3 is a segmental view of a portion of the speaker assembly shown in Fig. 2;

Fig. 4 is a partially sectional view taken along the line 4—4 in the direction of the arrows as indicated in Fig. 3;

Fig. 5 is a detail view of one of the acoustically transparent outer screens used in connection with the speaker shown in Fig. 2, and showing the particles adhering thereto; and

Fig. 6 is a top segmental view which shows the relative positions of the acoustical element and the fixed screens.

In the figures, the numeral **10** designates the base of the electrostatic speaker assembly. Base **10** can be formed from any suitable material of sufficient weight to maintain the speaker assembly in an upright balanced position. I prefer to use, for the base, a rectangular piece of mahogany and I have attached thereto an end of tube **11** and an end of tube **12** so that tubes **11** and **12** are maintained perpendicular to base **10** by means of attachment nuts indicated generally by the numerals **13** and **14**.

Tubes **11** and **12** support bottom member **15** of the speaker frame. Bottom member **15** is a slightly arcuate, non-conducting member of rectangular cross section, and top **16** of the frame is of like configuration. The bottom member has two holes extending from its upper surface through to its lower surface through which tubes **11** and **12** can pass. These tubes are fastened to the bottom member by means of nuts **17** and **18** so that a rigid mounting for the frame is achieved. Side members **19** and **20** are rigidly connected to the top and bottom member so that a rigid unit is achieved. Thus, as seen in the figures, an end of side member **20** is attached to an end of bottom member **15**, and an end of side member **19** is attached to the other end of bottom member **15**, while the remaining ends of the side members are attached to either end of top member **16**.

Horizontal support members **21** and **22** extend parallel to bottom member **15** and serve to further rigidify the frame. As shown in the figures, an end of horizontal

support member 21 is rigidly fastened to side member 20 and an end of horizontal support member 22 is also rigidly fastened to side member 20, while the other ends of these horizontal support members are rigidly connected to side 19. Also vertical support members 23, 24 and 25 support the structure vertically as each has one of its ends rigidly connected to bottom member 15 and the other of its ends rigidly connected to the top member 16.

It is preferred that the frame and support members be constructed of a non-conducting material. However, the identical material suggested and configuration of these members shown in the figures, is not required for the successful practice of my invention. The uppermost ends of tubes 11 and 12 extend through openings in horizontal support member 21 and are fastened thereto by means of bolts 26 and 27.

Cable 28 which extends through tube 12 is brought out at the uppermost end of this tube, and leads 29, 30 and 31 of this cable are soldered to individual terminals on terminal strip 32. The purpose of this will be explained later. However for the moment, it is to be noted that cable 28, and the leads composing the cable, are insulated from contact with all surfaces except the particular terminal to which each is attached at terminal strip 32.

Figs. 1, 3, 4 and 6 show the relative positions of the acoustical element 33 and the two surrounding fixed plates or electrodes—inner electrode 34 and outer electrode 35. Each of these electrodes is a woven conductive metal screen and is acoustically transparent as illustrated in Fig. 5.

The acoustically transparent screens 34 and 35 are preferably formed of woven galvanized iron wire having, for example, about fifteen wires to the inch, the wire size being about .010", so as to provide relatively large openings to give acoustical transparency. Each of the screens is coated on one of its sides with small particles of foam rubber which are adhesively secured thereto. I prefer to use for this purpose rubber particles of foam rubber or powdered foam rubber. However, it should be understood that either natural or synthetic rubber may be used and also other foam materials having the characteristics of rubber, as for instance a plastic such as foam polyethylene. The granules of rubber are maintained in position on the fixed plate by means of a lacquer applied to the fixed plates upon which the granules are scattered prior to the hardening of the lacquer. Thus in Fig. 5 foam rubber particles indicated by the numeral 36 generally are shown adhering to surface of screen 34.

The coating process is a well known one of the type wherein screen 34 is maintained in a horizontal position and lacquered. The divided foam rubber or rubber particles are then applied to the lacquered side of the screen as it is vibrated so that the foam rubber is distributed substantially equally throughout the surface of screen 34. The lacquer is then allowed to dry and any excess foam rubber is blown from the screen by means of an air blast leaving screen 34 with the particles 36 firmly adhering thereto.

Screen 34 is attached to the frame assembly by means of staples 37 so that the particles face forwardly as seen in Fig. 1. Staples 37 are covered with tape tabs 38 in order to insulate the staples from the conductive screen 34. Acoustical element or diaphragm 33 is positioned upon the rubberized surface of the inner screen 34. And screen 35 which is identical with screen 34 is placed in position over acoustical element 33 with the surface of screen 35 which contains the rubber particles lying adjacent the acoustical element. Screen 35 is applied at such tension that contact is maintained as closely as possible over the entire diaphragm area between the acoustical element and the rubberized sides of the acoustically transparent plates. Other screen 35 is maintained in position by staples 38' and the edges whereat the staples are located are covered with insulating tape 39 which insulates the staples and further serves to maintain the screens in position.

Diaphragm 33 is made of a very light, thin, flexible film having a high strength to mass ratio, and both the low mass and the low stiffness of the diaphragm are negligible factors in determining the resistance of the diaphragm to displacement in the mounting. The diaphragm may be made of a metalized film of synthetic resin and I have obtained good results by using a film made of mylar polyester resin having a thin metallic conductive coating.

A portion of the completed assembly is shown in Fig. 6 wherein diaphragm 33 is shown in effective engagement with particles 36 on inner screen 34 and particles 40 on outer screen 35. The rubber particles which engage the acoustical element and space it from fixed screens 34 and 35 also serve to insulate the acoustical element from the screens so that it is electrically isolated therefrom in its mounting.

The particles press against opposite surfaces of the diaphragm so that the diaphragm is resiliently supported midway between the fixed screens. The resistance of the diaphragm to displacement as well as its resonant frequency, can be controlled by varying the relative stiffness of the particles. Thus, increasing the relative stiffness of the particles increases the diaphragm resistance to displacement and raises the resonant frequency, while decreasing the stiffness of the particles results in decreasing the resistance to displacement and lowering the resonant frequency.

The particles should be so spaced and of such stiffness as to maintain all portions of the diaphragm centered between the two fixed screen plates in the absence of an electric potential, and to return all portions of the diaphragm to centered position after it has been displaced in either direction. In this manner a substantially uniform response free from distortion over a wide frequency range is obtained.

Inner lead 41 electrically connects the inner screen to the cable 28 since an end of lead 41 is soldered or otherwise connected to a terminal on terminal strip 32 at which point lead 29 is also attached. Outer screen lead 42 connects the outer screen electrically in like manner to lead 30 of cable 28 and diaphragm lead 43 connects the acoustical element to lead 31 of cable 28. Electrical potential therefore can be applied to the screens by means of cable 28.

When a suitable polarizing potential is applied to the screens and diaphragm, an electrostatic attractive force is established between the two screens and also between each of these screens and the diaphragm. The effect is to draw the diaphragm toward or repulse it from the screens according to the signals applied. The motion of the diaphragm as it is drawn or repulsed from the screens in the manner of a condenser is then resisted only by the particles and in such a way that the diaphragm is well supported over its entire area but is still free to vibrate.

An acoustically transparent decorative cloth which is not shown in the figures, can be wrapped over outer screen 35 and also inner screen 34 and attached to the frame by nails, staples or otherwise. The speaker described herein may be used as the only speaker of the system or it may be used as the high frequency speaker or "tweeter" along with a conventional low frequency speaker or "woofer" as long as the system has a push-pull output.

The electrical system having a push-pull output can be attached to the speaker by means of cable 28, and potentials would be applied by the electrical system to leads 30, 31 and 29 and thence to the screens and acoustical element.

Due to the push-pull arrangement, the diaphragm is driven positively in both directions by an alternating force, since as the diaphragm is displaced in either direction from its mid-position, its decreased separation from

the fixed plate it is approaching causes an increase in its attraction to that plate. A correspondingly increased separation from the other plates weakens the effect upon it of that plate. The resultant of these changes in the electrostatic forces incident to displacement of the diaphragm is to augment the effect of the potential differences which create the driving force.

While the invention is here described and claimed in terms of a speaker, it is also useful as a microphone or other transducer to translate sound waves into an electrical wave. I include this within the scope of the claims.

Thus, among others, the several objects of the invention as specifically aforenoted, are achieved. Obviously, numerous changes in construction and re-arrangement of parts might be resorted to without departing from the spirit of the invention as defined by the claims.

I claim:

1. An electrostatic speaker comprising in combination a frame, a relatively fixed plate which is capable of being charged electrically mounted on said frame, an acoustic element also capable of being electrically charged, granules of material having the characteristics of foam rubber secured to a side of said plate forming individual resilient supports supporting the acoustic element substantially uniformly over its area to hold it away from the surface of the plate and terminal means whereby an electrostatic force can be established between said plate and said acoustic element.

2. An electrostatic speaker in accordance with claim 1, in which the acoustic element is a diaphragm of light, thin, flexible film with high strength to mass ratio.

3. An electrostatic speaker in accordance with claim 1, in which the fixed plate is an acoustically transparent member of electrically conductive material.

4. An electrostatic speaker in accordance with claim 1, in which the fixed plate is composed of woven electrically conductive wires.

5. An electrostatic speaker having two fixed acoustically transparent members and a diaphragm arranged between and parallel to the members, all capable of being electrically charged characterized in that the surfaces of both members are provided with granules of material having the characteristics of foam rubber extending towards the diaphragm and forming individual resilient supports supporting the diaphragm substantially uniformly over its area to hold it away from the surfaces of the members.

6. An electrostatic transducer having two relatively fixed condenser plates, each comprising an acoustically transparent screen woven from electrically conductive wire, a diaphragm disposed between said plates, and granules of material having the characteristics of foam rubber secured to a side of each of said plates forming individual resilient supports supporting the diaphragm substantially uniformly over its area to hold it away from the surface of the plate.

7. An electrostatic transducer comprising in combination a relatively fixed woven electrically conductive wire screen, a second screen identical with said first screen, a diaphragm of light, thin, flexible film having a high strength to mass ratio disposed between said screens and granules of material having the characteristics of foam rubber secured to a side of said first screen and also secured to a side of said second screen, said granules forming individual resilient supports supporting the diaphragm substantially uniformly over its area to hold it away from the surfaces of said screens.

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