April 26, 1960 T. LINDENBERG 2,934,611

ELECTROSTATIC SPEAKER

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Fig. 2

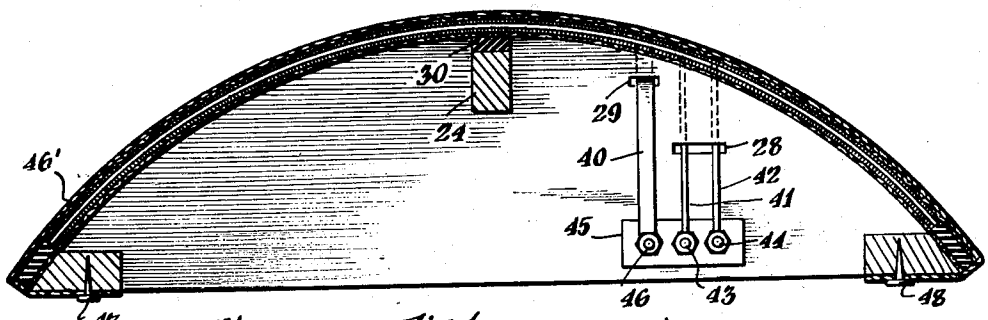


Fig. 1

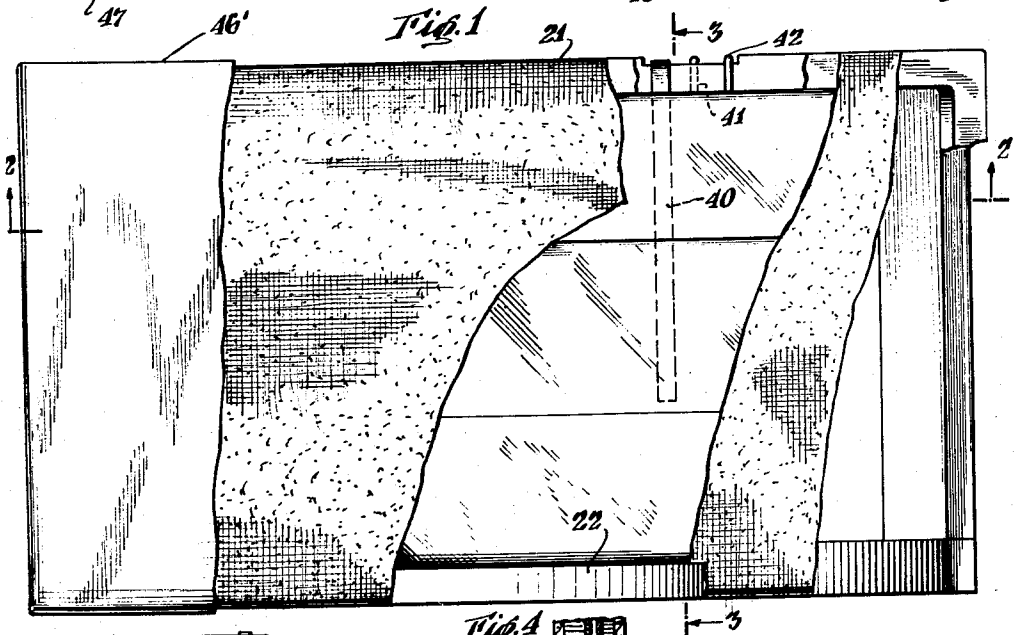


Fig. 4

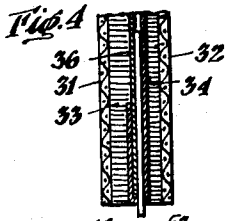


Fig. 3

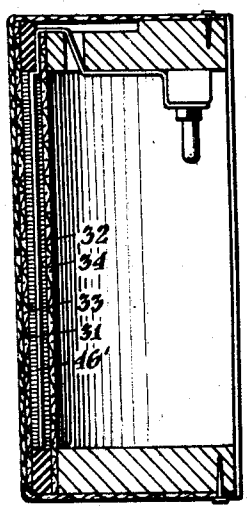
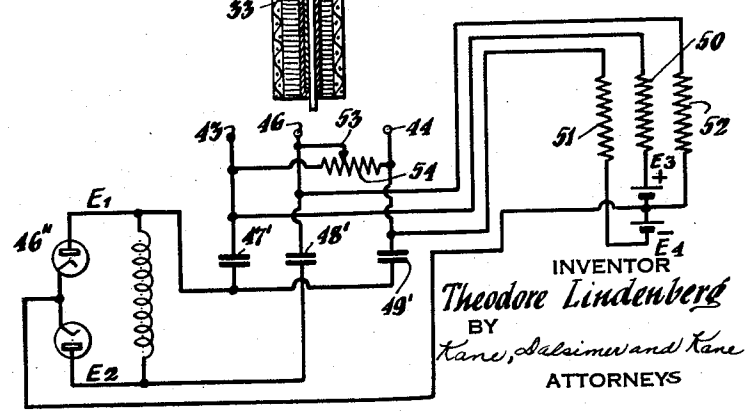


Fig. 8



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ELECTROSTATIC SPEAKER

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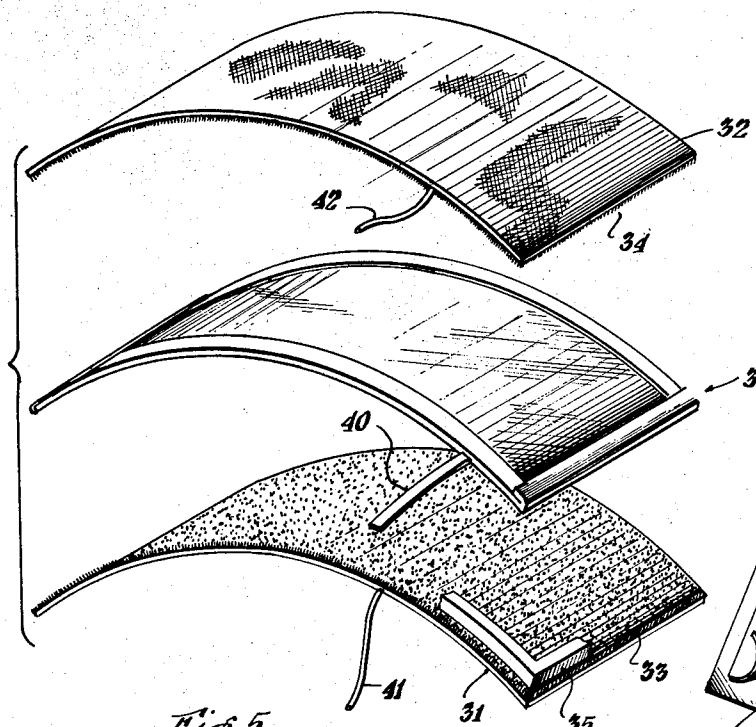


Fig. 5

Fig. 7.

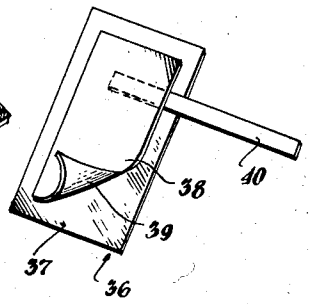
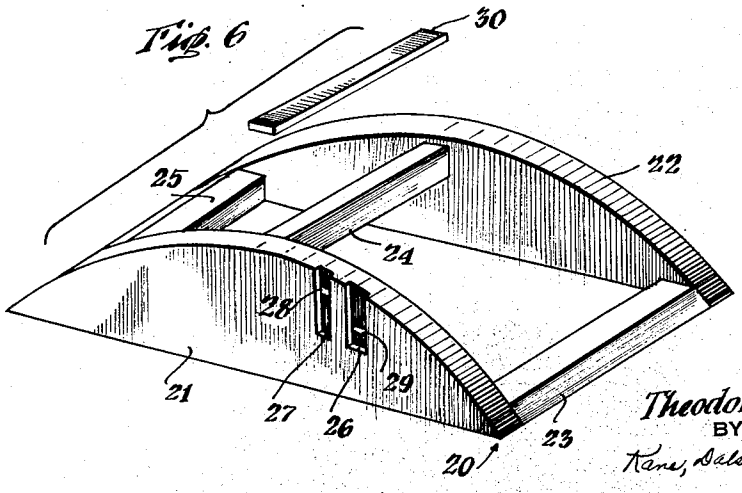


Fig. 6



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ELECTROSTATIC SPEAKER

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Fig. 9

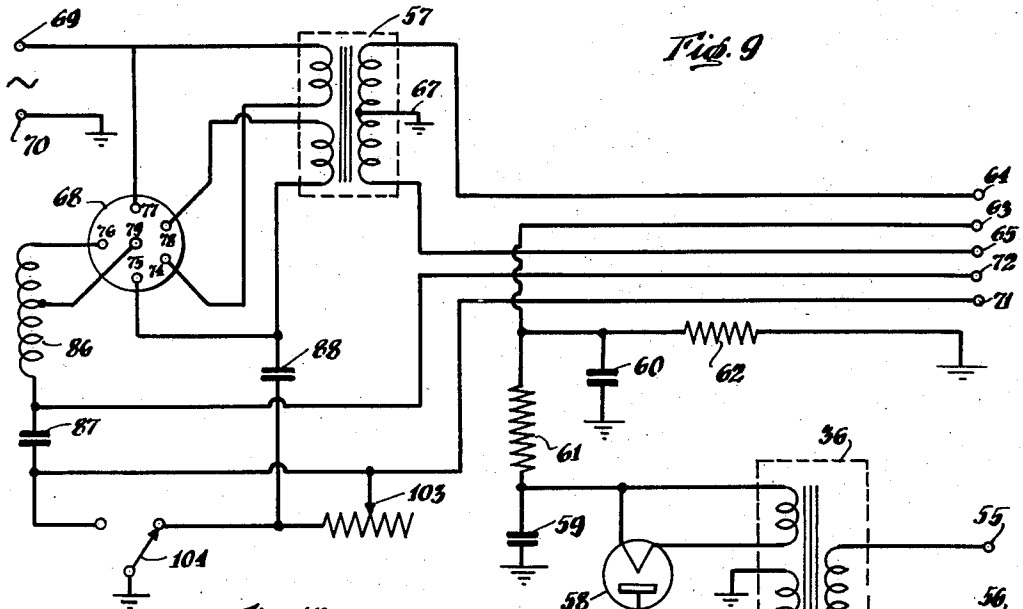


Fig. 12

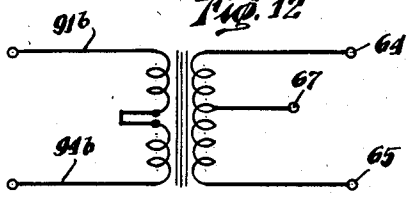


Fig. 10

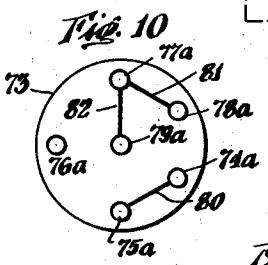


Fig. 11

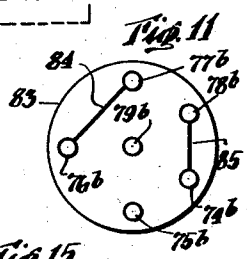


Fig. 13

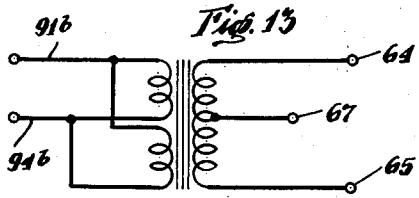


Fig. 14

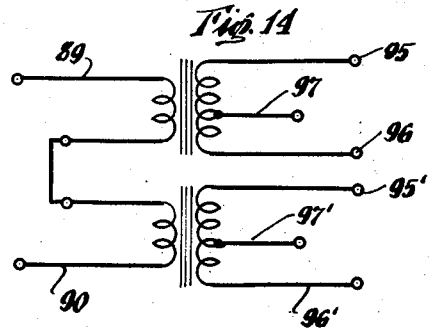
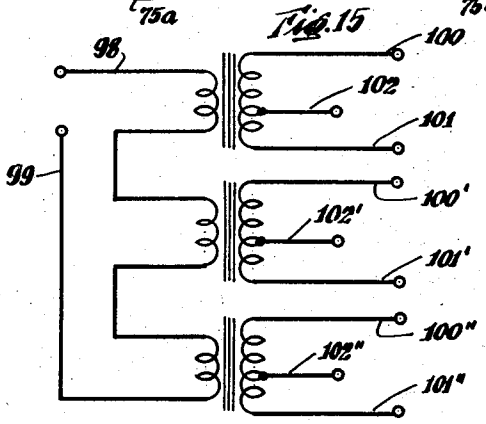


Fig. 15



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United States Patent Office 2,934,611 Patented Apr. 26, 1960

2,934,611

ELECTROSTATIC SPEAKER

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Application November 9, 1955, Serial No. 545,875

14 Claims. (Cl. 179—111)

This invention which is in part a continuation of my application, Serial No. 476,644 entitled "Electrostatic Speaker" which was filed in the United States Patent Office on December 21, 1954, now abandoned, 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 is a diaphragm which forms a condenser plate and acts with a single fixed plate, or in some designs with a plurality of fixed plates, to form a condenser which serves as the load or output unit of an electrical system. Variations in the output wave of the electrical system will then cause the diaphragm condenser plate 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.

In the past, the advantages of an electrostatic speaker have been recognized and particular forms have come into use. The electrostatic speakers used have been either "single-sided" in which forces act on one side only of the vibratory diaphragm or "push-pull" 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-side type or the push-pull type.

A chief advantage of an electrostatic speaker is that the force driving the diaphragm, being electrostatic, can be if the mounting is suitable, applied uniformly over its entire area. The electrostatic speaker is therefore free from the distortion which is present in speakers which have portions of the diaphragm vibrating out of synchronism. Another distinctive feature of the performance of electrostatic transducers is that the electrical signal energy acts directly on the diaphragm to effect vibrations thereof and no intermediate transducer or conversion element is necessary.

The electrostatic speaker as known heretofore suffers, however, from certain disadvantages which limit its use. Thus, the diaphragm or the air gap itself had usually been relied on to provide the protective insulation against electrical breakdown. This protection was often inadequate and limits were thereby imposed on the voltages that could be used and on the specific power output of the device. Also, due to electrical characteristics, the driving force often was not applied to the acoustical element uniformly and the frequency of response of the device was not uniform throughout.

Often close spacings, a film of trapped air, stiff diaphragm materials and inadequate methods of mounting the diaphragm combined to restrict to very small amplitudes the allowable diaphragm motion, required high

mass diaphragms to be used and prevented the moving parts from operating in synchronism with one another.

These disadvantages had confined the electrostatic speaker in practice to use for reproducing a small range of very high audio frequencies where the output power requirement was least.

The invention herein disclosed has as its main object the provision of an improved electrostatic speaker having increased sensitivity and fidelity of response over a wide range of frequencies.

Another object of this invention is to provide an improved electrostatic speaker assembly having a high dielectric breakdown potential, in which the driving force is applied to the acoustical element uniformly and in which the diaphragm will have uniform response at all frequencies.

Still another object of the invention is to provide an improved mounting assembly for the diaphragm of an electrostatic speaker which will permit the use of a low mass diaphragm as the vibratory acoustical element, permit the diaphragm to vibrate at large amplitudes, provide 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.

A further object of the invention is to provide an improved electrostatic speaker assembly including circuitry which will allow the speaker to be utilized as the sole acoustic output of a system or in combination with multiple acoustic system outputs.

These and other objects are accomplished by furnishing an electrostatic speaker assembly in which the diaphragm (a conductive, flexible, thin, member of low mass and stiffness) is supported between two electrodes in the form of woven conductive metal screens or perforated plates which are coated on the sides facing the diaphragm with resilient bristles (flocking) of non-conductive material in such a manner that the spacing between each outer electrode and the diaphragm 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 flocking will permit motion of the diaphragm in a linear manner as though many small springs were being compressed on that side while expanding on the opposite side.

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

Fig. 1 is a partially sectional front elevational view of a speaker constructed in accordance with the teachings of this invention;

Fig. 2 is a partially sectional plan view of the speaker shown in Fig. 1;

Fig. 3 is a sectional elevation taken along the line 3—3 in the direction of the arrows, indicated in Fig. 1;

Fig. 4 is a detailed view of portions of two flocked screens supporting a diaphragm between them;

Fig. 5 is an exploded view showing in perspective the cooperation of two stationary screens and the vibratory acoustical element;

Fig. 6 is a perspective view of the speaker frame;

Fig. 7 is a detailed view of the construction of the vibratory acoustical element;

Fig. 8 is a diagrammatic illustration of one form of circuit arrangement for operating an electrostatic speaker embodying this invention;

Fig. 9 is a schematic diagram showing the circuit which is used in order to couple an electrostatic speaker to the output circuit of a conventional amplifier;

Fig. 10 illustrates the connections on a plug which can cooperate with the cross-over receptacle in Fig. 9 to allow cross-over at a high frequency;

Fig. 11 illustrates the connections on a plug which can cooperate with the cross-over receptacle in Fig. 9 to allow cross-over at a low frequency;

Fig. 12 is a schematic diagram of the connections used for the transformer shown in Fig. 9 in order to couple quadruple electrostatic speakers to the output circuit of a conventional amplifier;

Fig. 13 is a schematic diagram of the connections used for the transformer shown in Fig. 9 in order to couple a single electrostatic speaker to the output circuit of a conventional amplifier;

Fig. 14 is a schematic diagram of the connections used for the transformer shown in Fig. 9 in order to couple eight electrostatic speakers to the output circuit of a conventional amplifier; and

Fig. 15 is a schematic diagram of the connections used for the transformer shown in Fig. 9 in order to couple twelve electrostatic speakers to the output circuit of a conventional amplifier.

Construction of speaker

The electrostatic speaker shown diagrammatically in the figures consists of a frame which is designated generally as **20** and has thin wooden sections **21** and **22** in the form of identical segments of a circle which form a top and base respectively. Wooden beams **23**, **24** and **25** are of rectangular cross section and are each attached at one end to top **21** and at the other end to base **22** in such manner that the top and bottom are held rigidly parallel to one another. Top **21** has grooves **26** and **27** therein, containing slots **28** and **29** respectively. Center beam **24** has placed thereon a thin layer of foam rubber rib **30**. This rubber rib, as will be seen later, absorbs vibration and isolates the center of screen **31** which is placed upon it. Screen **31** is one of two metal screens **31** and **32** which are identical and of such construction as to be acoustically transparent. These screens are preferably made of woven galvanized iron wire having, for example, about 15 wires to the inch, the wire size being about .010 inch, so as to provide relatively large openings to give acoustical transparency. Each of the screens is flocked with fibers of cotton, rayon, fiber glass or other dielectric material. The flocking on screen **31** is designated generally as **33** while the flocking on screen **32** is designated generally as **34**.

Flocked screens have been known in the past but they have been used for quite different purposes, one common use being as the cover for the opening in front of the speaker of a radio or phonograph. The technique of flocking a screen is well known and the flocking may be accomplished electrostatically or by mechanical vibration. In each of these techniques the wire of the screen is first coated with an enamel or the like which is in a liquid or semi-plastic state.

Electrostatically flocking the screen consists of spraying fibers of uniform length on the enamel, before it hardens, from a gun while maintaining a potential difference in the order of 10,000 volts between the gun and the screen. The electrostatic action causes the fibers to stand largely on end on the screen forming a nap. They attach themselves to the enamel coating and when the enamel hardens, they are permanently held to the screen as a myriad of short bristles projecting to a substantially uniform extent from the screen and generally normal to its plane. If the mechanical technique is used for flocking, the screen is mechanically vibrated as the fibers are sprayed or dropped upon the coated enamel. The preferred method is the electrostatic method since the individual flocked hairs stand normal to the screen when the enamel hardens, whereas if the mechanical technique is used, the individual flocked hairs lay at different angles to the screen. However, in the mechanical method a more even distribution of flocking is obtained. Although two techniques of obtaining a flocked screen are mentioned herein, I do not exclude other techniques.

The term "flocked screens" as used in this specification is meant to define a screen prepared in accordance with this description in which the flocking on the screen is of uniform dimension, a portion of each of the fibres engaging the screen, and each fibre is separate from the other.

Disposed about the periphery of screen **31** and glued to the free ends of the flocks **33** thereon is a rubber gasket strip **35**. Gasket **35** is preferably no thicker than the thickness of two fiber lengths added to the thickness of one diaphragm assembly which is situated between screens **31** and **32** and designated generally in the drawings as **36**. The diaphragm should be 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 flocked mounting and its resonant frequency. Thus, the diaphragm may be made of a metalized film of synthetic resin and for this purpose I prefer to use a film made of mylar polyester resin having a thin metallic coating. Diaphragm assembly **36** consists of two films of dielectric material **37** and **38** preferably fiims of mylar polyester resin each having a thickness of .00025 inch. Mylar film **38** is coated with aluminum or other electrically conductive material **39** on one of its surfaces. The conductive coating is applied by any well known metallizing technique and is preferably of a thickness of the order of 1 micro-inch. Aluminized face **39** is adjacent mylar film **37** and film **37**, which is a bit larger than film **38**, has its edges overlapped about the non-aluminized side of film **38** thereby enveloping this piece. Electric conductor **40**, which is shown extending from the diaphragm assembly, is in contact with aluminum face **39** and serves as a means whereby voltage may be applied to the aluminum coating as will be explained later.

The diaphragm assembly **36** provides the vibratory condenser plate which is the acoustically effective element of the speaker. The mylar serves to insulate the conducting or aluminized face **39** and to prevent electrical leakage since this film adds dielectric strength to that provided by the air and by the flocking itself. The diaphragm could be a separate layer of foil with or without adjoining films of insulating material, but the novel construction shown in which a thin coated film serves as a dielectric element and an acoustic element is preferred. Mylar film **37** also may be omitted. However, it is desirable as insulation because it permits the maintenance of a higher potential difference between the fixed plate and the vibratory plate.

The diaphragm assembly is positioned inside of gasket **35** and mounted on the free ends of bristles **33** and **34**. This construction leaves the diaphragm assembly inert and also tends to center the assembly due to the presence of the flocking which supports the assembly. The flocking is in effective engagement with the vibratory diaphragm in the sense of engaging it to space it and support it, whether the fibers be in direct contact with the metal layer or in contact with an insulating film such as described above.

The flocking fibers press against opposite sides of the diaphragm so that the diaphragm is resiliently supported in floating fashion midway between the fixed screens. The resistance of the diaphragm to displacement as well as its resonant frequency, can be varied and controlled by varying the relative spacing and stiffness of the flocking. Thus, increasing the relative number and stiffness of the flocking fibers increases the diaphragm resistance to displacement and raises the resonant frequency while decreasing the relative number and stiffness of the fibers results in descreasing the resistance to displacement and lowering the resonant frequency. The flocking fibers should be so spaced and should be 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 is displaced in either direction and the potential removed. In this manner a substantially uniform response free from distortion over a wide frequency range is obtained. Within these limits, the relative number or spacing of flocked fibers may be greatly varied.

When a suitable biasing or polarizing potential is applied to the screens and diaphragm, as described in detail at a later point, an electrostatic attractive force is set up between the two screens 31 and 32 and also between each of these screens and the diaphragm. The effect of this is that the motion of the diaphragm can then be resisted only by the flocking since the fibers are pressed against the interposed diaphragm which is thereby well supported over its entire area but in such a way that the diaphragm is still free to vibrate.

Conductor 41, which is attached to screen 31, and a conductor 42, which is attached to screen 32, extend along member 21 in groove 26 and through slot 28 and are then attached to terminal posts 43 and 44 respectively of terminal block 45 which is fastened to top 21 inside the frame. Likewise, conductor 40 extends in groove 27 in top 21 through slot 29 and is attached to a third terminal post 46 of terminal block 45. The potential may be readily applied to the screens and the diaphragm through the terminal posts.

An acoustically transparent, decorative cloth 46′ is wrapped over outer screen 32 and attached to frame 20 by nails 47 and 48.

The term "acoustically transparent" as used herein is intended to define a material through which sound waves or waves audible to the human ear can pass with ease and with a minimum of attenuation.

Circuit description

My electrostatic speaker may be used as the only speaker of a system or it may be used as the high frequency speaker or tweeter along with a conventional low frequency speaker or woofer. The manner of using my speaker in either arrangement and the circuitry therefor will now be described.

The circuit arrangement shown in Figure 8 is utilized when my speaker is to be the sole system output and includes a conventional form of push-pull audio amplifier stage which is designated by the numberal 46′ wherein the plates and cathodes of the tubes are shown only, which delivers the signal voltages E_1 and E_2 of substantially equal magnitude but of opposite instantaneous polarity, being 180° out of phase within usual limits of adjustment. These two voltages representing the signal are applied to the fixed plates 31 and 32 through condensers 47′, 48′, 49′; the voltage E_1 from one side being applied to each of the fixed plates 31 and 32 and the voltage E_2 from the other side being applied to the diaphragm 36.

The D.C. polarizing voltages E_3 and E_4 are of opposite polarity and of equal magnitude, and are applied respectively to the two fixed plates 31 and 32 through high resistances 50 and 51. Illustrative magnitudes are 500 volts and −500 volts, creating a potential difference of 1000 volts between the fixed plates 31 and 32. The resistances are of the order of 2 to 5 megohms to afford a high degree of isolation of the A.C. signal from the power supply. The current is thereby so small that there is no material absorption of the signal current.

The diaphragm 36 can be connected through a high resistance 52 to the midpoint of the D.C. supply, which relatively is a ground, so as to create an equal potential difference and equal electrostatic force between it and each of the fixed plates when the plates are equally spaced; but since it is difficult to assure equal spacing of the plates, I prefer also to connect the diaphragm 36 to a variable tap 53 on a resistance 54 connected across the fixed plates as shown, so that the potential differences between the diaphragm 36 and the two fixed plates can be adjusted and made unequal to compensate substantially for small differences in the spacing of the diaphragm from the fixed plates. The effect of such adjustment is to establish more nearly equal electrostatic forces on the diaphragm so that it is subject to no substantial unbalanced force tending to displace it before the signal voltage is applied.

With the electrostatic system in substantial balance under the influence of the polarizing voltages, application of the signal voltage E_1 to the fixed plates and of E_2 to metal layer 39 on diaphragm 36 causes what in effect is a modulation of the polarizing voltages and of the electrostatic forces acting on the diaphragm. Since the push-pull voltages E_1 and E_2 are out of phase, the modulation effect is a multiple of the change in E_1 and E_2 individually, and in consequence the speaker has greater sensitivity. For example, if the peak signal voltage is 50, then when E_1 is +50 and E_2 is −50, the effect on the inter-plate potential differences is as follows, in a case where the polarizing voltages are equal:

	Individual Voltages			Differential	
Plate	"31"	"36"	"32"	"31"—"36"	"32"—"36"
Bias voltages	+500	0	−500	500	500
Signal voltage	+50	−50	+50		
Resultant	+550	−50	−450	600	400

The same resultant voltage values are found, but at the opposite fixed plates, when the signal voltage goes negative on those plates. The differentials likewise are of the same magnitude but are reversed, "31"—"36" being 400 and "32"—"36" being 600.

Thus the modulation effect of the signal voltage is to bring about an unbalance of the potential differences which create an unbalanced electrostatic force tending to move the diaphragm, the unbalance reversing as the signal voltage reverses in polarity. In the example above, at peak signal voltage, the diaphragm is subject to the driving force of a 200 volt unbalance of the potential differences, or a four-fold multiplication of the peak signal voltage.

The electrical circuit shown in Fig. 9 is also designed for use with the speaker heretofore described. The circuit, which serves to supply direct current polarizing voltage to the electrostatic speaker in the proper relationship to the applied audio frequency voltages to produce the maximum speaker sensitivity with lowest distortion, also provides a means of electrically coupling my improved tweeter to conventional existing systems.

In conventional systems the woofers have been found to be satisfactory, whereas heretofore it has been the tweeters which have proved themselves unsatisfactory. Because of this, the system shown in Fig. 9 is designed so that an electrostatic speaker constructed in accordance with the teachings herein, can be used specifically as a tweeter in combination with a system employing a conventional woofer. Thus, a unit may have a conventional woofer plus my tweeter. Also, by use of the present circuitry more than one tweeter may be coupled to the output of a conventional system in order to give greater acoustic loudness.

In Fig. 9, numerals 55 and 56 designate terminals to which are applied A.C. power such as that available from an ordinary wall socket, for example, 115 volts at 60 cycles. This voltage is applied to transformer 66 and rectifying tube 58 which converts the A.C. voltage to D.C. voltage in the conventional manner. Condensers 59 and 60 in combination with resistor 61, form a filter which decreases the ripple on the rectified D.C. voltage while resistor 62 is a conventional bleeder resistor.

Terminal 63 is connected to post 46 which is shown in Fig. 1 and supplies positive polarity voltage to dia-

phragm 36 through conductor 40. Terminals 64 and 65 which are connected to posts 43 and 44 respectively, shown in Fig. 1, place the secondary of transformer 66 across fixed plates 31 and 32. The secondary of transformer 66 is grounded at center tap 67.

Transformer 66, depending upon connection and design, can match one or more of my tweeters to the regular speaker output line of a conventional output amplifier. The turns ratio of step-up transformer 66 is changed for each case so that the output amplifier in use is loaded by approximately the same capacitance for one or more tweeters. As shown in Fig. 9, transformer 66 is arranged to match a single tweeter to the conventional output amplifier. The connections to the primary of transformer 66 are made at receptacle 68 and the manner of connecting transformer 66 for various matching conditions will be described below.

The output audio frequency voltage of a conventional output amplifier is applied to the circuit shown in Fig. 9 at 69 and 70. The circuit shown provides a means to pass the low frequency audio currents from an output amplifier to a woofer connected at 71 and 72 while passing the high frequency audio currents to transformer 66 and thence to the tweeter connected at 64 and 65. The frequency at which this division of current takes place (known as the cross-over frequency) can be changed in this circuit, according to the total area of the tweeters in use. The cross-over frequency for use with a single tweeter is in the region of 1200 to 1400 cycles per second and for quadruple tweeters is in the region of 350–550 cycles per second. These figures are representative only and the actual choice of frequencies can be made over a wide range.

The connections used in order to accomplish the cross-over are made by the insertion of plug 73 which is shown in Fig. 10 in receptacle 68 when a single tweeter is used. When this is done, terminals 74 through 79 mate with terminals 74*a* through 79*a* respectively. Terminals 74 and 75 are thereby connected by conductor 80, terminals 77 and 78 are connected by conductor 81 and terminals 77 and 79 are connected by conductor 82.

If quadruple tweeters are to be used, a plug 83 which is shown in Fig. 11 is inserted in receptacle 68 rather than plug 73, thereby mating terminals 74 through 79 with terminals 74*b* through 79*b* respectively. This connects terminals 76 and 77 by conductor 84 and terminals 74 and 78 by conductor 85. Fig. 13 shows schematically the manner in which the primary of transformer 66 is connected when plug 73 is inserted in receptacle 68, while Fig. 12 shows the connections of the primary when plug 83 is used.

The cross over is accomplished by use of a cross-over network in the system. One leg of the cross-over network is composed of inductor 86 and condenser 87 in series and the other leg of the cross-over network consists of condenser 88 in series with the primary of transformer 66. These legs are parallel and the woofer is connected across condenser 87, while the tweeter is connected to the secondary of transformer 66. Thus, the input voltage to the woofer is developed across condenser 87 and the input voltage to the tweeter is developed at the secondary of transformer 66. Since condenser 87 has greater impedance at lower frequencies, the greatest amplitude voltage input to the woofer will be at low audio frequencies, while the transformer 66 will have developed at its secondary the greatest amplitude voltage when a high frequency audio signal is received. The circuit, therefore, is selective and switches high audio frequency currents to the tweeter and low audio frequency currents to the woofer.

Figs. 14 and 15 show schematically other transformer connections which may be utilized to connect a number of tweeters to a conventional output amplifier. Fig. 14 shows primary and secondary transformer connections which enable eight tweeters to be connected to a single conventional amplifier output, while Fig. 15 shows connections which enable twelve tweeters to be utilized. Windings in either case are designed to present to the conventional amplifier the same capacitive reactance thereby maintaining the same load on that amplifier.

The connections in Fig. 14 are such that leads 89 and 90 serve as the input to transformer 66 as did leads 91*b* and 94*b* in Fig. 12. Lead 95 is connected to a fixed plate of each of four tweeters and lead 96 is connected to the other fixed plate of each of the tweeters. Lead 97 is grounded. Leads 95′ and 96′ are connected in like manner to the fixed plates of four other tweeters and lead 97′ is grounded.

If it is desired to connect twelve tweeters, then the transformer circuitry shown in Fig. 15 is used, wherein leads 98 and 99 serve as the input leads to transformer 66 as did leads 91*b* and 94*b* in Fig. 12. Lead 100 is connected to a fixed plate of each of four tweeters and lead 101 is connected to the other fixed plate of each of the tweeters. Lead 102 is grounded. Lead 100′ and 101′ are connected in like manner to the fixed plates of four other tweeters and lead 102′ is grounded. Likewise, leads 100″, 101″ and 102″ are connected in the same manner as are leads 100′, 101′, and 102′ respectively.

Also included in the circuit shown in Fig. 9 is provision for variable attenuation of either the low frequency currents or the high frequency currents in order to obtain a balance of acoustic loudness between the woofer and tweeter or between sets of woofers and tweeters. This is accomplished through use of a variable resistor 103 which can only be put in one leg of the cross-over network at a time due to switch 104. Thus, the attenuator is arranged so that it can be introduced into either the low frequency currents or the high frequency currents but not into both at the same time. When the tweeter is coupled to the circuit shown in Fig. 9, lead 63 is connected to conductor 40 at post 46 thereby applying positive D.C. voltage to diaphragm 36. A signal voltage from an output amplifier is received by the circut shown in Fig. 9 at terminals 69 and 70. Due to operation of the cross-over network, low frequency signals are applied at terminals 71 and 72 which are attached to a woofer, while high frequency signals are applied at terminals 64 and 65 which are attached to leads 41 and 42 respectively. When high frequency signal voltages are received they place charges on fixed plates 31 and 32. The effect of this is to apply electrostatic forces on diaphragm 36 alternately in one direction and then in the other as the high frequency signal voltage alternates in polarity. Due to the push-pull arrangement described here, which is the preferred embodiment, the diaphragm is driven positively in both directions by an alternating force rather than being subject to merely unidirectional electrostatic force which results when a single sided tweeter is used.

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 plate 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, the invention is useful also as a microphone or other transducer to translate sound waves into an electrical wave. I include this within the scope of the claims. As so used, the polarizing means would be essentially the same, but the circuit here shown for applying a signal voltage would be replaced by any suitable circuit for taking off the current and applying it, for example, to the grid of an amplifier.

Thus, among others, the several objects of the invention as specifically aforenoted, are achieved. Obviously, numerous changes in construction and rearrangement 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 formed of an electrically conductive material mounted on said frame, non-conductive bristles of uniform length each rigidly attached at one end to said plate and separate from each other; an acoustic element also formed of an electrically conductive material in effective engagement with the free end of each of said bristles; and means to electrostatically charge said plate and said acoustic element to establish an electrostatic force between said plate and said acoustic element.

2. An electrostatic speaker in accordance with claim 1 in which the caustic element is a film of dielectric material having on a side an adherent coating of electrically conductive material.

3. An electrostatic speaker in accordance with claim 1 in which the acoustic element is a film of metalized polyester resin.

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

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

6. An electrostatic speaker in accordance with claim 1 in which the non-conductive bristles are fiber glass threads.

7. An electrostatic speaker comprising in combination a frame, a relatively fixed plate formed of an electrically conductive material mounted on said frame, a surface of said plate, a second plate formed of an electrically conductive material mounted on said frame, a second surface of said second plate spaced from and parallel with said first surface, non-conductive bristles of uniform length each rigidly attached at one end to said first surface and separated from each other, second non-conductive bristles of uniform length each rigidly attached at one end to said second surface and separated from each other, an acoustic element also formed of an electrically conductive material with one surface thereof in effective engagement with the remaining ends of said first bristles and the remaining surface thereof in effective engagement with the remaining ends of said second bristles, and means to electrostatically charge said plates and said acoustic element to establish an electrostatic force between said plates and acoustic element.

8. An electrostatic speaker in accordance with claim 7, in which the acoustic element is a film of dielectric material having on a side an adherent coating of electrically conductive material.

9. An electrostatic speaker in accordance with claim 7, in which the acoustic element is a film of metallized polyester resin.

10. An electrostatic speaker in accordance with claim 7, in which the fixed plates are acoustically transparent members of electrically conductive material.

11. An electrostatic speaker in accordance with claim 7, in which the fixed plates are acoustically transparent screens of electrically conductive material.

12. An electrostatic speaker in accordance with claim 7, in which the non-conductive bristles are fiber glass threads.

13. An electrostatic speaker comprising in combination an electrically conducting diaphragm, parallel fixed acoustically transparent electrically conducting members positioned on opposite sides thereof with a surface of one of said electrically conducting members and a second surface of the other of said electrically conducting members spaced from and facing said diaphragm, non-conducting resilient supports rigidly attached to each of said surfaces, each of said resilient supports having one portion thereof rigidly attached to one of said surfaces and a second portion thereof engaging said electrically conducting diaphragm, said non-conducting resilient support supporting the diaphragm over substantially the whole of its area.

14. An electrostatic speaker in accordance with claim 13, in which the resilient supports constitute a plurality of fibers, and all of the fibers are uniform in dimension and each of the fibres is separate from the others.

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