July 25, 1933. C. D. HAIGIS 1,919,632

SOUND RADIATOR

Filed April 4, 1930

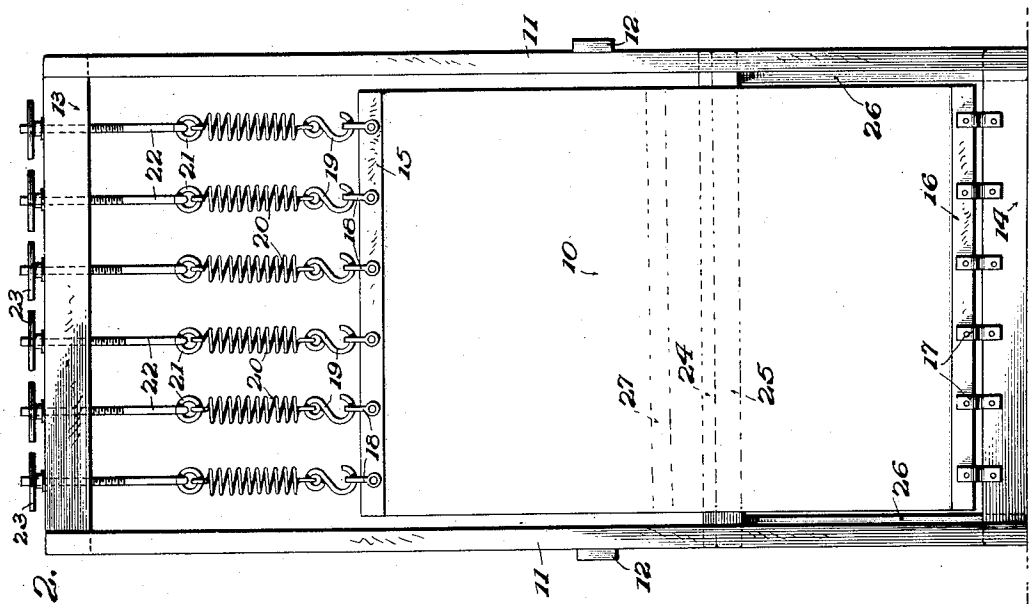


Fig. 2.

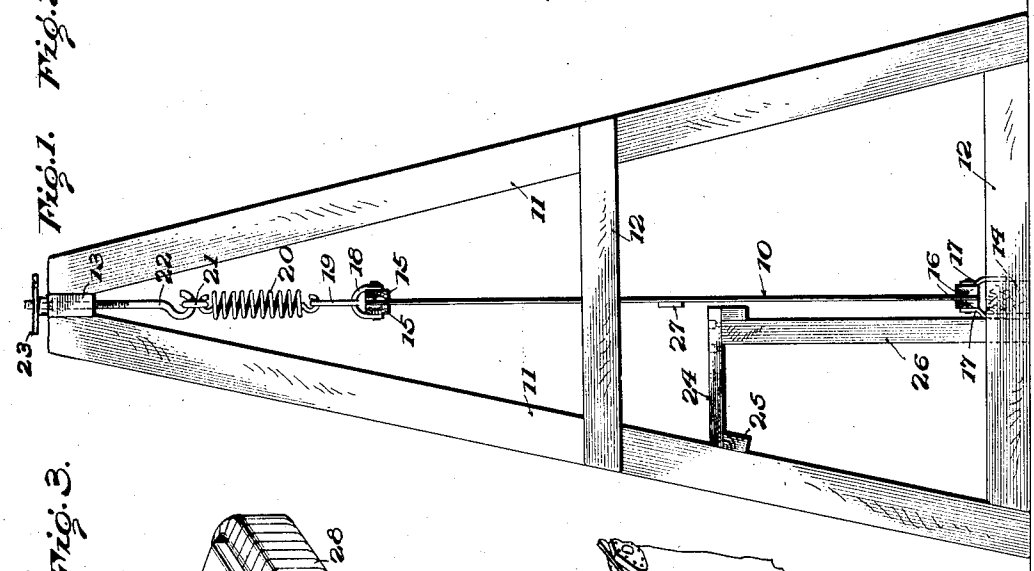


Fig. 1.

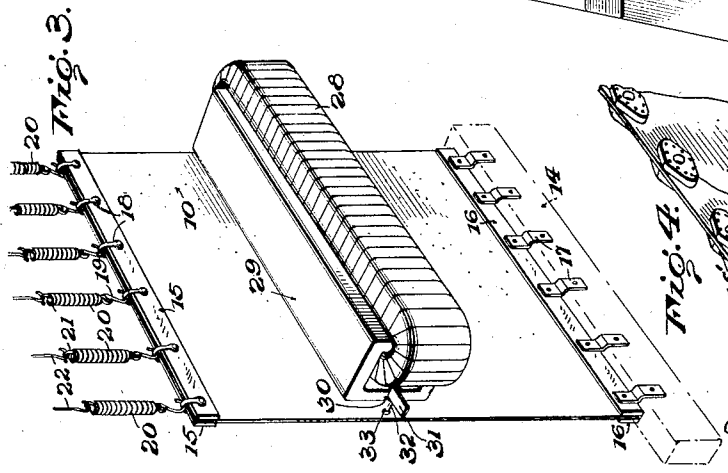


Fig. 3.

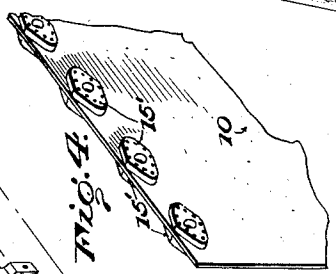


Fig. 4.

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UNITED STATES PATENT OFFICE

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SOUND RADIATOR

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This invention relates to acoustic devices, and more particularly to sound radiators of the large direct-acting type.

It has heretofore been proposed to provide sound radiators or loud speakers with large direct-acting diaphragms, having an area for sound radiation of several square feet, where large volumes of sound are desired, as in auditoriums and the like, but in all such devices as heretofore employed, so far as I am aware, it has been proposed to employ diaphragm material which has low internal viscosity. The rate of propagation of sound in a diaphragm is proportional to the square root of the tension divided by the mass, and in order to minimize the setting up of standing waves in the diaphragm material, with consequent disadvantageous resonances and interferences which are productive of non-uniform sound propagation, the diaphragm material has been subjected to high tension in the direction of its plane—the desideratum being to so tension the diaphragm material that the time required for the sound to travel to the periphery of the diaphragm from the point or points at which the driving force is applied thereto is less than the time required for the propagated wave to travel half a wave length in the air at right angles to the plane of the diaphragm, so as to minimize the phase difference between the center and periphery of a wave front radiated from the diaphragm. The desired goal can be approached by increasing the tension and decreasing the mass of the diaphragm, but experience has demonstrated that there are no known materials which are both strong enough to withstand the necessary tension and light enough to have the desired mass to accomplish successfully the end desired. Therefore devices of the type under consideration as heretofore proposed have been open to the objection that within a certain range of the wave lengths reproduced standing waves are set up in the diaphragm material, and interferences, phase distortion and resonances are produced, with a consequent non-uniformity of sound reproduction.

It is an object of this invention to provide a large direct-acting sound radiator which overcomes the above objections and which is capable of high quality reproduction of music and speech without the interferences, phase distortions and resonances that have heretofore characterized devices of this type.

Another object of this invention is to provide a large direct-acting sound radiator which employs a diaphragm of high internal viscosity so as to minimize the setting up of standing waves in the diapragm material and the consequent non-uniformity of sound reproduction.

Another object of this invention is to provide a relatively large direct-acting sound radiator of the type referred to in combination with a novel driving unit of relatively high efficiency which is particularly adapted to the actuation of such a sound radiator.

Another object of this invention is to provide a driving unit which is coupled with a source of audio frequency current wherein the impedance of the source is matched with the total impedance of the radiator, including the electrical resistance and reactance of mechanical reaction as well as the electrical constants of driving unit, so as to obtain a maximum transfer of energy and power and consequent high efficiency.

Other objects will appear as the description of the invention proceeds.

The invention is capable of receiving a variety of mechanical expressions, one of which is shown on the accompanying drawing, but it is to be expressly understood that the drawing is for purposes of illustration only, and is not to be construed as a definition of the limits of the invention, reference being had to the appended claims for that purpose.

In the drawing, wherein like reference characters are employed to designate corresponding parts in the several views—

Fig. 1 is an end elevation of an embodiment of the present invention;

Fig. 2 is a side elevation of the embodiment of Fig. 1;

Fig. 3 is a perspective view illustrating the improved driving unit in conjunction with a diaphragm embodying the present invention removed from its supporting frame; and

Fig. 4 is a fragmentary view to illustrate how the mounting means may be attached to the diaphragm.

In accordance with the present invention the diaphragm is composed of a material having a high internal viscosity, so that after a wave has traveled through the diaphragm material for a distance of approximately half a wave length from the point or line at which the driving force is applied thereto, the energy of the wave is largely absorbed, and hence standing waves, due to reflection from the edges of the diaphragm, are largely, if not completely, suppressed by absorption in the material, due to its high internal friction. This means that only a portion of the diaphragm around or on either side of the point or line at which the driving force is applied thereto is used as a sound radiator, the active area of the diaphragm for any given frequency varying inversely to the frequency.

Any suitable material of high internal viscosity may be employed. Wood, of sufficiently strong texture, such as pine, or laminated wood and fabric as canvas, as well as certain impregnated canvas or other suitable fabrics provided as substitutes for veneering, sheathing, etc., have been found to give excellent results. For example, heavy cloth impregnated with a phenol-resin or the like, such as the material known commercially as "Celeron" is very satisfactory. With such material the central area of the diaphragm, depending upon the particular frequency being radiated, becomes the sound generating surface, and beyond an area represented by approximately half a wave length from the point or line of application of the driving force to the diaphragm, the energy of the wave is largely absorbed by the internal friction of the material, so that the setting up of standing waves is minimized and the consequent resonances, phase distortions and interferences heretofore existing by reason of standing waves, and the consequent non-uniformity of sound radiation, are largely eliminated.

The diaphragm may be of any suitable size. For example, a diaphragm having free area on the order of six feet by three feet has been found to give excellent results, but if preferred narrower or greater widths or greater or shorter lengths, or both, may be employed. The diaphagm may also be of any suitable thickness depending in part on the character of material employed and the size used.

In order to normally maintain the diaphragm in its neutral position, a relatively light tension is applied thereto in the direction of its plane, so that the diaphragm is properly restored to its neutral or intermediate position whenever deflected therefrom by the driving force applied thereto, but the restoring tension thus applied to the diaphragm is to be sharply differentiated from the tension heretofore employed on large diaphragms for the purpose of so tensioning the diaphragm material that the rate of vibration propagation in the diaphragm material shall be large as compared with the rate of vibration propagation in the air. In fact, the amount of tension applied to the diaphragm in accordance with the present invention is not of great importance and can be varied through considerable limits without affecting the action of the diaphragm. Hence, it is only at the relatively low frequencies, under a thousand cycles, where the relationship first above discussed ceases, that the tension applied to the diaphragm has any substantial effect on its action as a sound radiator.

The diaphragm embodying the present invention may be mounted in any suitable way. As shown, the diaphragm 10 is supported in a framework of any suitable construction, shown as composed of angularly related end frame pieces 11 suitably braced by transverse pieces 12 and connected at the top and bottom by longitudinals 13 and 14. In Figs. 1 to 3 the diaphragm is shown as provided at its top and bottom edges with bracing strips 15 and 16, and at its lower edge the diaphragm is fixedly secured to the longitudinal 14 by a plurality of suitably spaced clips or clamping members 17. At its upper edge the diaphragm is resiliently supported so that a moderate tension may be applied thereto in the direction of the plane. Any suitable tension support may be employed, that shown comprising a plurality of bails 18 suitably attached to and spaced along the upper bracing strips 15 and into which are engaged hooks 19 carried by coiled tension springs 20, which at their opposite ends are connected through rings 21 to threaded adjusting bolts 22 suitably threaded into the upper longitudinal 13 of the frame or nuts carried thereby, hand wheels 23 being shown as applied to each of said bolts for the purpose of varying or applying the desired degree of tension of said springs 20.

In place of the bracing strips 15 and 16, the diaphragm as shown in Fig. 4 may have secured thereto along each of its upper and lower edges and at each side thereof a plurality of lozenge shaped elements 15′ of suitable material, as Bakelite, suitably attached thereto, as by rivets, each of said members having a central aperture through which the attaching means for the tension springs and the lower mounting clips or clamps may be applied.

One or more driving units of any suitable type or construction are mounted on the frame in any suitable way and suitably attached to the diaphragm, preferably along a line approximately midway between its upper and lower edges. As shown, a platform 24 is suitably carried on the frame by cleats 25 and struts 26. A plurality of electro-

magnetic driving units may be mounted on the platform 24 and attached to the diaphragm 10 in any suitable way at 27.

I prefer to operate the diaphragm however by a novel driving unit of the character illustrated in Fig. 3 and which extends substantially the entire width of the diaphragm 10. As here shown, the driving unit comprises a field coil 28 and a magnet core 29 of substantially the width of the diaphragm, said core having an air gap 30. Disposed in the air gap 30 is a conductor for audio frequency currents in the form of a strip 31, preferably of relatively light material, which is suitably attached to the diaphragm, as by a plurality of extensions 32 which extend through apertures disposed along the width of the diaphragm at approximately its mid-length, and which extensions are suitably secured to the diaphragm rigidly as by nuts 33 threaded onto said extensions at opposite sides of the diaphragm. Said strip 31 may be made of aluminum or other light metal or alloy and may be stamped or pressed from a single sheet of metal, a strip on the order of a quarter of an inch in width and a sixteenth of an inch in thickness having been found suitable. The extensions for attachment to the diaphragm should be of small dimension so as to prevent deviation of the audio current from the main path, and they should be spaced relatively close together so that a driving force may be generated uniformly along the strip for all frequencies likely to be transmitted, and prevent the flexure of the strip between the extensions and consequent resonance of the strip at the higher frequencies.

The powerful electromagnet 28, 29 provides a high flux density when high grade iron is used, a density of 15,000 lines per square inch being available in the gap, and when audio frequency current passes through the strip 31 across the path of the magnetic flux, a force is generated tending to move the strip 31 at right angles to both the current and the flux in accordance with Lenz' law. Thereby the strip, and the diaphragm attached thereto, are moved outwardly or inwardly with respect to the gap, depending upon the instantaneous direction of the audio frequency current. The electrical impedance measured between the ends of the strip 31 is relatively low, being composed of the true electrical resistance and reactance of the strip itself, together with the electrical constants generated in the strip by the mechanical reaction of the diaphragm thereon. As the electrical resistance and reactance, due to the mechanical reaction, are much greater than those of the strip itself, the maximum transfer of energy or power requires that the impedance of the source be matched with the impedance of the speaker. Where the total impedance is very low a special output transformer should be employed for transforming the high impedance of the vacuum tube plate circuit employed as a source to a low impedance to match the speaker. With a driving unit so constructed high efficiency is obtained in the actuation of the diaphragm and the sound produced, whether of music or speech, is found to be of high quality.

It will therefore be perceived that a large direct-acting sound radiator has been provided which avoids the difficulties heretofore experienced in producing uniform sound radiation with diaphragms of the character under consideration, and which enables a diaphragm of several square feet in area to be employed without setting up standing waves in the diaphragm material or introducing the resonances, distortions and interferences that have heretofore been characteristic of diaphragms of this character.

Moreover, a novel driving unit has been provided which operates at high efficiency and enables improved action of the speaker as a whole.

While the illustrated embodiment of the invention has been described with considerable particularity, it is to be expressly understood that the invention is not limited thereto, as other embodiment thereof will now readily suggest themselves to those skilled in the art, while changes may be made in the details of construction, arrangement, size and proportion of parts and material employed without departing from the spirit of this invention. A diaphragm embodying the present invention may be used with other driving units, and the driving unit of the present invention may be used in conjunction with other diaphragms, although it has been shown that the combination of the two is productive of highly desirable results and improved efficiency in the radiation of high quality speech and music. Also the shape of the diaphragm may be changed and the point or line of application of the driving force thereto may be varied within the contemplation of the invention. The direction of application of the tension springs may also be changed, it being immaterial whether the springs pull vertically, horizontally or at an angle.

Reference is therefore to be had to the appended claims for a definition of the limits of the invention.

What is claimed is:—

1. An acoustic device including a relatively large direct-acting thin sheet diaphragm of high internal viscosity and whose area is on the order of a plurality of square feet, a frame in which said diaphragm is mounted, means for rigidly attaching one end of said diaphragm to said frame, a plurality of flexibly mounted free tension springs for applying a restoring tension to the opposite edge of said

diaphragm without imposing an audio tension on the material thereof, a single high frequency responsive means operatively connected to said diaphragm substantially midway of its length for vibrating the same, said last named means including a single thin strip of light weight current conducting material rigidly secured to the diaphragm in a plane substantially at a right angle to the plane of the diaphragm and to the direction of tension in the diaphragm, and means for electrically energizing said strip of material uniformly throughout its length, whereby the diaphragm is caused to move directly by the strip of conducting material by electrical forces applied thereto.

2. In an acoustic device, in combination with a relatively large direct-acting sheet diaphragm, a single light weight conductor adapted freely to respond to audio frequency impulses, extending substantially the full width of the diaphragm and being rigidly attached thereto in a single straight line along its width and substantially midway between its ends, and a single means providing an electrical field for said conductor substantially throughout its length, said diaphragm having an area and an internal viscosity such that only a central area thereof is responsive for the generation of sound.

3. In an acoustic device of the character described, a sheet of phenolic-resin impregnated fabric providing a diaphragm, means connected with opposite edges of said diaphragm for resiliently mounting the same under tension in the direction of said edges, the remaining edges of the diaphragm being free, an audio frequency driving unit for said diaphragm including a single thin strip of light weight current conducting material rigidly secured to the diaphragm in a plane substantially at a right angle to the plane of the diaphragm and to the direction of tension in the diaphragm, said means being located substantially midway between the supported edges of the diaphragm, and means for electrically energizing said strip of conducting material whereby throughout its length it imparts motion uniformly directly to the diaphragm along the line of attachment thereto, said diaphragm having an area and an internal viscosity of material such that the sound generating surface thereof is limited to a central area adjacent to said conducting strip.

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