

Oct. 18, 1932.

V. A. SCHLENKER

1,882,974

ACOUSTIC DEVICE

Filed May 22, 1928

2 Sheets-Sheet 1

FIG. 1.

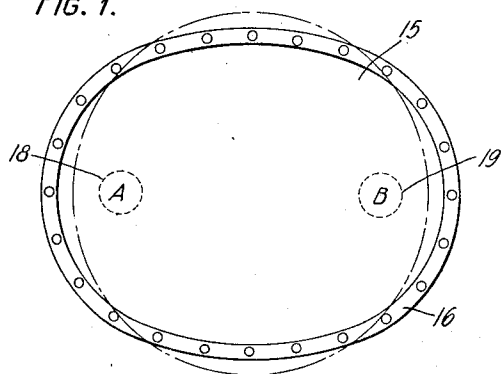


FIG. 2.

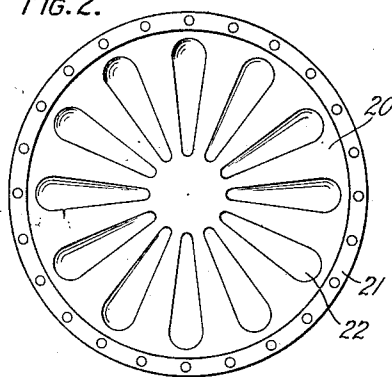


FIG. 3.

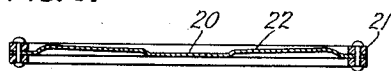


FIG. 4.

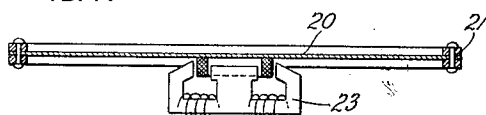


FIG. 5.

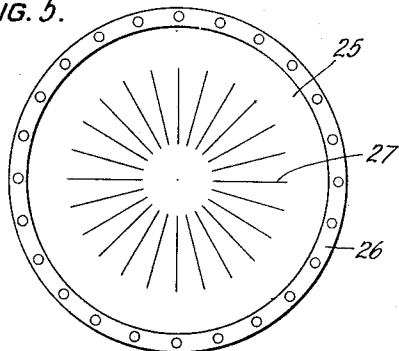


FIG. 6.

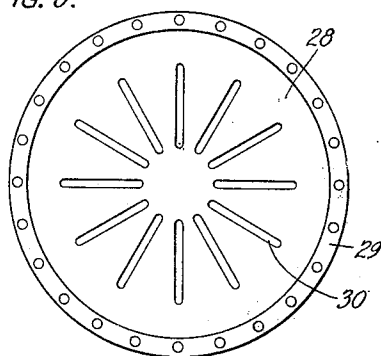


FIG. 7.

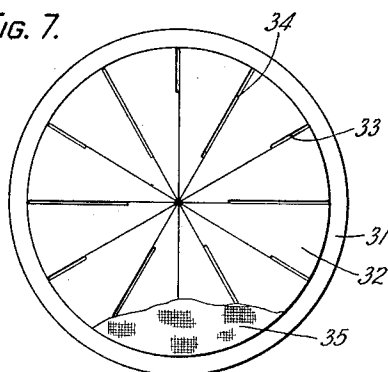
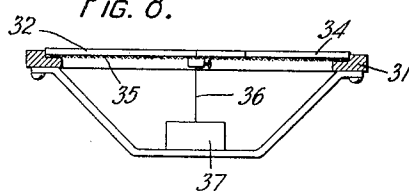


FIG. 8.



INVENTOR
VESPER A. SCHLENKER
BY *Walter C. Kiesel*

ATTORNEY

Oct. 18, 1932.

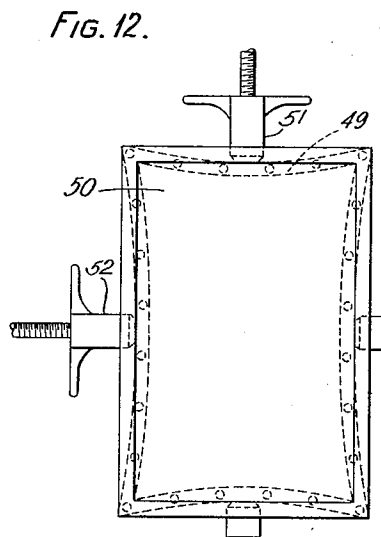
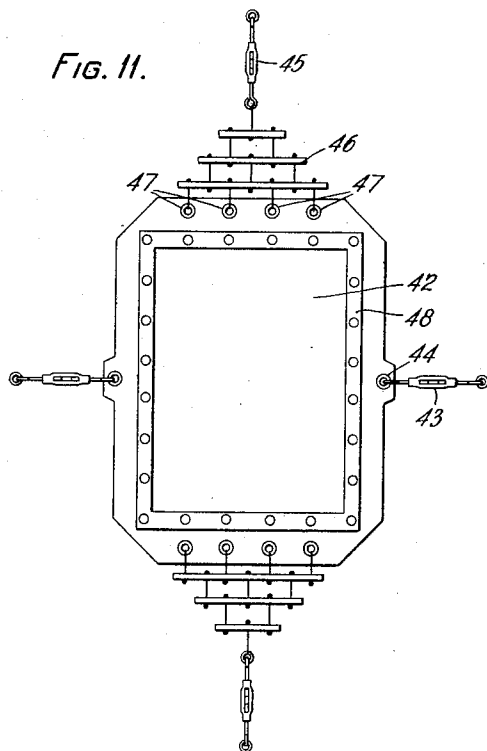
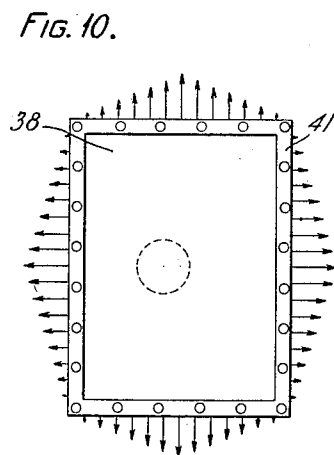
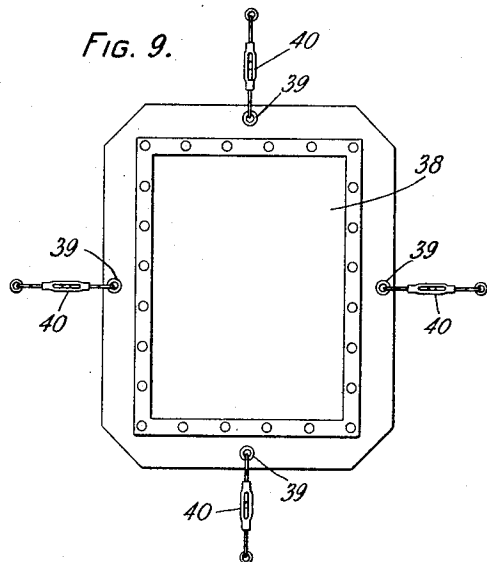
V. A. SCHLENKER

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2 Sheets-Sheet 2



INVENTOR
VESPER A. SCHLENKER
BY *Walter C. Kiesel*

ATTORNEY

UNITED STATES PATENT OFFICE

VESPER A. SCHLENKER, OF ORANGE, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

ACOUSTIC DEVICE

Application filed May 22, 1928. Serial No. 279,792.

This invention relates to acoustic devices and particularly those employing large direct acting diaphragms.

An object of the invention is to radiate sound with substantially uniform efficiency over the audible frequency range.

Another object of this invention is to increase the vibratory energy imparted to the air from a sound radiating surface.

When large radiating surfaces are employed as sound reproducers the sound wave energy imparted to the surface by the driving element is not normally radiated efficiently to the air due to reflection losses in the material of the diaphragm. This reflection takes place principally at the boundary of the diaphragm because the energy is not completely attenuated in traversing the path between the driving point and the boundary. When these reflections are overcome by employing damping material to dissipate the reflected energy in the surface, the range of frequencies which can be radiated is limited and generally the low frequency vibrations are not imparted to the air.

These difficulties are largely overcome in accordance with this invention by employing a sound radiating surface of uniform density and having tapered stiffness so that the velocity of wave propagation will decrease gradually from the driving element to the edge of the radiating surface.

This is accomplished in accordance with one embodiment of the invention by employing a sound radiating surface of a thin material of uniform thickness and density which is non-uniformly stretched in a clamping frame, for example, by expanding the surface so that the stiffness of the central area of the diaphragm is greater than in other portions thereof. A specific arrangement to accomplish this result comprises a master stretching frame of rectangular shape to which the thin metallic diaphragm is clamped. A concentrated stretching force is applied at or near the center of the four edges to cause the greatest tension at the center of the edges and a tapering tension on either side of each center. The diaphragm is driven at or near the center by a suitable

driving element and the wave vibrations propagated from the central portion will encounter a tapered stiffness in the surface which will cause a decreasing propagation constant or velocity. This, in turn, produces a low cut-off frequency so that the lower frequencies which can be radiated by the surface are not distorted by reflected waves.

A large variety of structures is possible with this invention to accomplish the desirable results of a non-uniformly stretched radiating surface depending on the distribution of tension in the areas of the surface. Furthermore the invention is not limited to a rectangular form of diaphragm or a diaphragm of metallic material.

A more detailed description of the invention follows and is shown in the accompanying drawings.

Fig. 1 is an exaggerated view of form of the invention in which a circular diaphragm is stretched in one direction so that the wave front of the vibrations imparted to the diaphragm are substantially elliptical in form.

Fig. 2 illustrates another form of the invention in which a circular diaphragm is clamped in a ring under a low tension and provided with radial grooves which taper from the center to the boundary thereof.

Fig. 3 is a cross-sectional view of Fig. 2.

Fig. 4 is a cross-sectional view of the same diaphragm of Figs. 2 and 3 after the diaphragm has been stretched to a uniform plane surface and coupled to a movable coil driving system.

Figs. 5 and 6 show other forms of the invention in which non-uniform stiffness of a stretched diaphragm is secured by radial slits as shown in Fig. 5 and radial grooves as shown in Fig. 6.

Fig. 7 shows a modification in which wood segments are arranged to form a circular diaphragm in which tapered stiffness is secured by cutting alternate short and long radial slots in the edge of the diaphragm.

Fig. 8 is a cross-sectional view of Fig. 7 and shows the diaphragm driven by an electromagnetic element.

Fig. 9 illustrates means for securing non-

uniform stretching in a rectangular diaphragm in accordance with this invention in which the stretching force is concentrated at the center of the four edges of the diaphragm.

5 Fig. 10 illustrates diagrammatically the tapered tension applied to the rectangular diaphragm in accordance with the stretching means of Fig. 9.

Fig. 11 shows another method of securing non-uniform stiffness in a diaphragm of uniform density by applying a uniform stretching force to the short edges of the rectangular diaphragm and a concentrated stretching force to the center of the long edges thereof; and

Fig. 12 illustrates a modified arrangement for securing tapered stiffness in a rectangular diaphragm in accordance with this invention by compressing the sides of the frame prior to clamping the diaphragm to the frame.

Referring now particularly to Fig. 1 of the drawings, the diaphragm 15 is maintained in a non-uniformly stretched condition by the clamping ring 16. The diaphragm material preferably employed in accordance with this invention is a metallic alloy composed of approximately 98.5% aluminum and 1.5% manganese which is rolled down to a thickness less than 0.005 inch and preferably 0.001 inch or 0.002 inch. This material has the desirable property of high tensile strength such that the diaphragm may be stretched, without going beyond its elastic limit, to give it such a degree of stiffness that the velocity of transverse vibrations therein is at least one quarter of and preferably equal to the velocity of sound in air. Other properties of this material are low mass per unit area and low inherent stiffness. While this material has been found satisfactory for the purpose of this invention other materials having properties similar to this material may be used. In Fig. 1 the non-uniformly stretched diaphragm 15 is exaggerated in shape to signify the direction of stress along one diameter of the diaphragm surface. Actually the shape of the diaphragm does not vary materially from the circular shape of the diaphragm shown in dotted line since the elasticity of the material is low compared to its tensile strength. One method of securing tapered stiffness, or non-uniform tension in a circular diaphragm of this type is to cut a circular diaphragm slightly larger than the surface which is to be encompassed by the clamping ring and apply a stretching force to the opposite edges of the circular diaphragm on one diameter so that the diaphragm is stretched to a greater tension in one direction than it is at right angles thereto. While the diaphragm is maintained in its non-uniformly stretched condition a two-part clamping ring is applied to the diaphragm surface and the two parts clamped together by means of screws until the portion of the diaphragm

which is to be employed as the sound radiator is maintained in its non-uniformly stretched condition solely by the clamping ring. The stretching force applied to the diaphragm may then be released and the portion of the diaphragm extending outside of the clamping ring may be cut away. The diaphragm may be employed as the radiator of sound by connecting it to any suitable means for vibrating it. For instance, a movable coil element 18, of the electrodynamic type, disclosed in Patent 1,707,544, issued April 2, 1929, to A. L. Thuras, may be employed. The coil 18 of this unit may be attached to the diaphragm at the focus A while an energy absorbing or dissipating unit such as a dash pot, or electrical damping unit 19, similar to the electrodynamic unit 18, may be applied to the diaphragm surface at the conjugate focal point B. The energy dissipating unit is, however, not essential.

The velocity of disturbance imparted by the vibrating unit 18 will be greater in the direction of stress in the diaphragm 15 than the velocity of the disturbance at right angles thereto so that the propagation of the wave motion at right angles in the diaphragm surface will vary toward the boundary of the diaphragm surface 15. Furthermore, the shape of the wave front originating at the driving unit 18 will be substantially elliptical and due to the difference in the tension of the diaphragm surface the wave will encounter a tapered stiffness while traveling from the driving point to the periphery of the diaphragm surface. This tapered stiffness in the diaphragm surface will dissipate to a large degree the wave energy flowing along the surface of the diaphragm from the driving unit to the clamping ring. The reflected waves set up in the highly tensioned portions of the diaphragm will be dissipated on coming to a focus at the point B.

Referring to Figs. 2, 3 and 4, the invention may be applied to a circular diaphragm which is uniformly stretched, but having tapered or non-uniform stiffness so that reflection is eliminated in the vibrating diaphragm by gradually decreasing the wave propagation velocity of the sound energy imparted to the diaphragm. In the modification shown in Fig. 2 the metallic diaphragm 20 of uniform thickness and density is clamped in a frame 21 and uniformly stretched to a low tension. Radial tapered grooves 22 are then formed in the surface of the diaphragm 20 so that the grooves taper from a point adjacent the center toward the boundary of the diaphragm surface. The grooved diaphragm is then stretched to a high tension until the grooved portions 22 are in the same plane as the diaphragm surface 20 as shown in Fig. 4. In this stretching process the central portion and the boundary

portions of the diaphragm will be subjected to a higher degree of tension than the intermediate circular portion in which the grooves 22 are located. Similarly the portion of the diaphragm in which the smaller end of the tapered grooves is located will be subjected to a higher tension than the circular portions of the diaphragm in which the large end of the tapered groove is situated. In effect the diaphragm 20 shown in Fig. 4 is divided into circular sections in which the stiffness varies gradually from the center to the boundary thereof so that the velocity of wave propagation imparted to the diaphragm surface by the electrodynamic unit 23 will gradually decrease as it reaches the boundary, thereby dissipating the wave energy before it reaches the clamping ring where reflected waves originate.

Referring to Figs. 5 and 6 the same effect of tapered stiffness in a diaphragm may be accomplished. In Fig. 5 the circular diaphragm 25 is stretched to a high degree in a clamping ring 26 and radial slits 27 are cut in the diaphragm surface. These slits should be very narrow to prevent coupling of the air at the front and rear of the diaphragm. If the slits are wide it may be well to seal the slits with thin material, such as silk. Similarly the slits may be made discontinuous instead of continuous as shown, or the slits may follow a discontinuous circular course. When such a diaphragm is driven by a vibrating system, the vibration pattern can be very easily governed by these methods of slitting. For example, if the radial nodes and loops are not desirable in a centrally driven diaphragm the slits may be cut as shown in Fig. 5. This will decrease the circular stiffness of the diaphragm surface to a very small value. For the same reason the velocity of disturbance from the center to the boundary will be decreased. In Fig. 6 the same effect may be accomplished by stretching the diaphragm 28 to a high degree in a clamping frame 29 and thereafter forming radial grooves 30 in the diaphragm surface.

Another modification of the invention is shown in Figs. 7 and 8 in which tapered stiffness is secured in a relatively stiff diaphragm material such as balsa wood or wood-veneer. In this arrangement a ring frame 31 of wood supports the wood segments 32 which are arranged to form a circle with their apices converging at the center. Short slits 33 are cut in the adjacent edges of alternate sections of the diaphragm and long slits 34 are cut in the adjacent edges of the segments intermediate the short slits. A layer of thin gauze or silk 35 may be glued to the rear of the diaphragm to eliminate coupling between the air at the front and rear of the diaphragm surface. In Fig. 8 this diaphragm is shown coupled to a driving system comprising a driving pin 36 which is connected to the center

of the diaphragm surface and driven by an electromagnetic unit 37 attached to the supporting frame. This driving system may be of any well known type, for example as shown in Patent 1,365,898 to H. C. Egerton of January 18, 1921.

The invention may also be applied to rectangular shaped sound radiators as shown in Figs. 9 and 10 in which the diaphragm 38 is stretched non-uniformly to provide tapered stiffness without increasing the mass of the diaphragm by applying a concentrated stretching force to the center of the four edges of the diaphragm material. This is accomplished by reinforcing the diaphragm with eyelets 39 to which is attached the turn-buckle 40 to apply the stretching force to the diaphragm. After the desired tension is secured the frame 41 is clamped together to maintain the diaphragm 38 in its non-uniformly stretched condition. Fig. 10 shows by means of arrows the graduated tension of the diaphragm surface 38 with the highest degree of tension at the center of the four edges while the tension on either side gradually tapers off to the corners of the diaphragm surface which are maintained at an extremely low tension. This diaphragm may be driven at or near the center by any suitable driving system and the waves propagating from the central portion will encounter a tapered stiffness along the diaphragm which will cause a decreasing propagation constant or velocity. This in turn produces a lower cut-off frequency so that the lower frequencies may be more efficiently radiated.

Referring to Fig. 11 a similar effect may be accomplished by applying a concentrated force to the center of the long edges of the diaphragm 42 by means of the turn-buckle 43 attached to the eyelet 44 and applying a uniform stretching force to the short edges of the diaphragm by means of the turn-buckle 45 coupled to a distributing frame 46 which is attached to the eyelets 47 in the short edges of the diaphragm 42. After the desired tension is secured in the diaphragm surface the frame 48 is clamped together to maintain the diaphragm in its non-uniformly stretched condition. In Fig. 12 the tapered stiffness of the diaphragm is accomplished by a method in which the frame 49 is clamped between vises 51 and 52 so that the sides of the frame are flexed inwardly. The diaphragm 50 is then pulled taut and the clamping frame securely attached to the edges of the diaphragm surface. The pressure of the vises is then gradually relieved until the frame assumes a normal rectangular shape. It will be seen that the same degree of tapered stiffness may be secured in the diaphragm surface by this method as was obtained by the pulling force described in connection with Fig. 9.

While the invention has been disclosed in various embodiments to effect a varying de-

gree of stiffness in a diaphragm surface without increasing the mass or density of the diaphragm it is to be understood that various other arrangements may be practiced in accordance with this invention without departing from the scope of the invention as defined in the appended claims.

What is claimed is:

1. An acoustic device comprising a plane diaphragm stretched symmetrically and non-uniformly and means at all portions of the periphery of said diaphragm to maintain it so stretched.

2. An acoustic device comprising a plane diaphragm stretched non-uniformly in more than one direction and means at all portions of the periphery of said diaphragm to maintain it so stretched.

3. An acoustic device comprising a stretched diaphragm having uniform density, and means for producing symmetrical tapered stiffness therein, said means being secured to the periphery of said diaphragm at all portions thereof.

4. An acoustic device comprising a vibratile plane metallic diaphragm, and means for maintaining various portions of said diaphragm under different stretched conditions, said means being secured to all portions of the periphery of said diaphragm.

5. An acoustic device comprising a vibratile diaphragm of uniform thickness and density, and means for maintaining the central and boundary portions of said diaphragm under a greater tension than the portions intermediate the central and boundary portions.

6. An acoustic device comprising a thin metallic diaphragm of uniform density, and a rigid frame maintaining said diaphragm non-uniformly stretched.

7. An acoustic device comprising a thin metallic diaphragm, means attached to said diaphragm for driving it, and means for maintaining said diaphragm non-uniformly stretched, whereby the velocity of wave propagation along said diaphragm will decrease gradually from the point of drive.

8. An acoustic device comprising a metallic diaphragm of uniform density and thickness, a rigid frame maintaining said diaphragm non-uniformly stretched, and a driving element adapted to vibrate said diaphragm near its center, the velocity of the vibrations along said diaphragm surface gradually decreasing from said driving element to the boundary of said diaphragm.

9. An acoustic device comprising a metallic diaphragm non-uniformly stretched in a clamping frame, in which reflection losses are substantially eliminated solely by the distribution of the non-uniform stretching force applied to said diaphragm surface.

10. The method of preparing a vibratory sound radiator of uniform density for a de-

crease in the wave propagation velocity therein as the wave travels outwardly therein from the center thereof, which comprises tapering the stiffness in said radiator from the center to the boundary thereof.

11. The method of making a plane vibratory sound radiator of uniform density to decrease the wave propagation velocity therein as the wave travels outwardly therein from the point of origin, which comprises stretching portions of said radiator to a greater degree than other portions.

12. The method of preparing a vibratory sound radiator of uniform density for a decrease in the wave propagation velocity therein as the wave travels outwardly therein from the driving point, which comprises stretching said diaphragm to a high degree in opposite directions.

13. The method of making a plane vibratory sound radiator of uniform density for decreasing the wave propagation velocity therein as the wave travels outwardly therein from the generating point, which comprises stretching portions of said radiator to a higher degree than other portions and maintaining said radiator in its non-uniformly stretched state.

14. The method of making a plane vibratory sound radiator for decreasing the wave propagation velocity therein as the wave travels outwardly therein from its place of origin, which comprises symmetrically stretching certain portions of the radiator surface while other portions are not subject to the same stretching tension.

15. The method of preparing a plane vibratory sound radiator for a decrease in the wave propagation velocity therein as the wave travels outwardly therein from the driving point, which comprises simultaneously stretching certain areas of the radiator to a high tension and other areas to a lesser tension.

16. The method of making a vibratory sound radiator of uniform density for decreasing the wave propagation velocity therein as the wave travels outwardly therein from the center thereof which comprises uniformly stretching the radiator to a high degree and tapering the stiffness of said radiator by relieving the tension intermediate the center and the boundary thereof.

17. The method of preparing a vibratory sound radiator of uniform density for a decrease in the wave propagation velocity therein as the wave travels outwardly therein from the point of origin, which comprises applying a stretching force simultaneously to equidistant points on the edge of the radiator to taper the stiffness in each area bounded by two equidistant points and the center of the radiator.

18. An acoustic device comprising a vibratile plane diaphragm stretched non-uniformly

formly in more than one direction and rigidly secured at its periphery.

19. An acoustic device comprising a vibratile diaphragm of uniform thickness and density and means for maintaining various portions of said diaphragm under different stretched conditions, the stretching force along a line extending perpendicularly through said diaphragm being substantially the same at all points thereon.

20. An acoustic device comprising a quadrilateral shaped diaphragm stretched in the direction of one dimension to a greater degree than in another direction, and means at all portions of the periphery of the diaphragm to maintain it in that condition.

21. An acoustic device comprising a quadrilateral shaped plane, stretched diaphragm, said diaphragm being stretched in the direction of each dimension to different degrees, and means at all portions of the periphery of the diaphragm to maintain it in that condition.

22. An acoustic device comprising a quadrilateral, stretched diaphragm of greater length along one dimension than along another, said diaphragm being stretched in the direction of each dimension, and means at all portions of the periphery of the diaphragm to maintain it in its stretched condition.

In witness whereof, I hereunto subscribe my name this 18th day of May, 1928.

VESPER A. SCHLENKER.