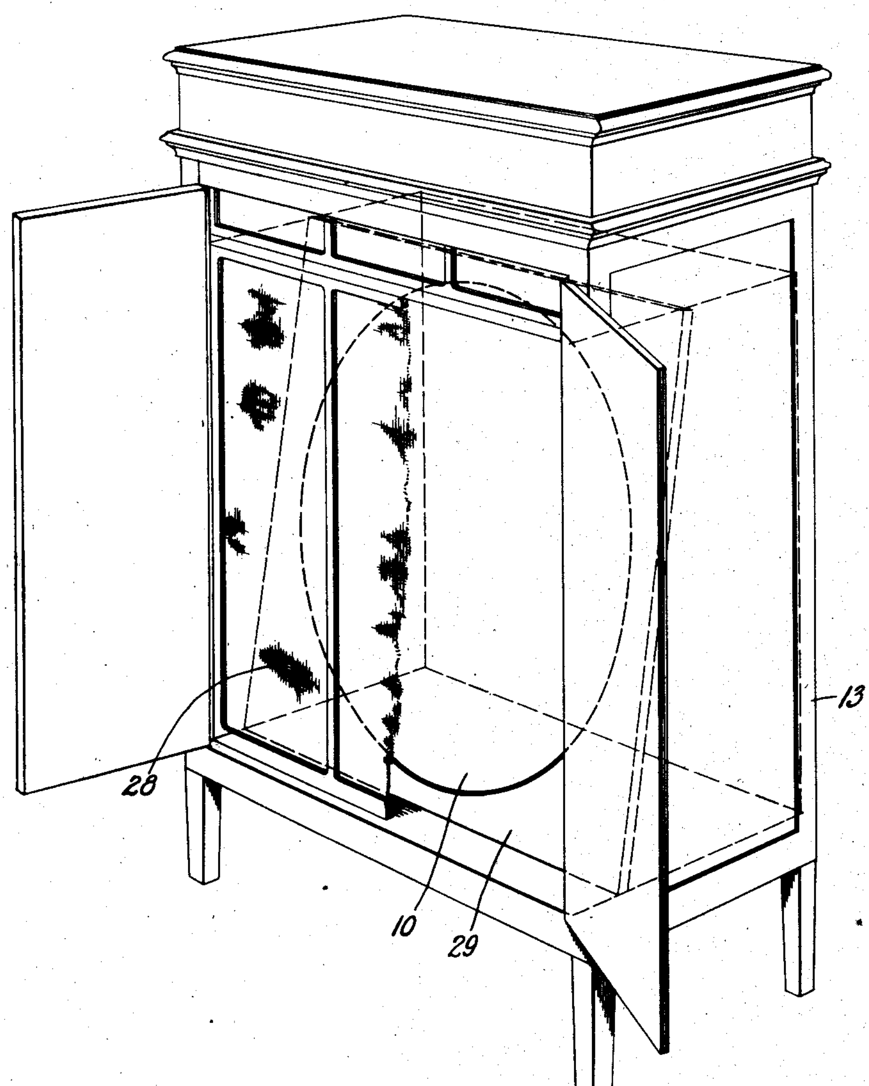
July 12, 1932. V. A. SCHLENKER 1,866,603

ACOUSTIC DEVICE

Filed May 11, 1927 4 Sheets-Sheet 1

FIG. 1.



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ACOUSTIC DEVICE

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FIG. 2.

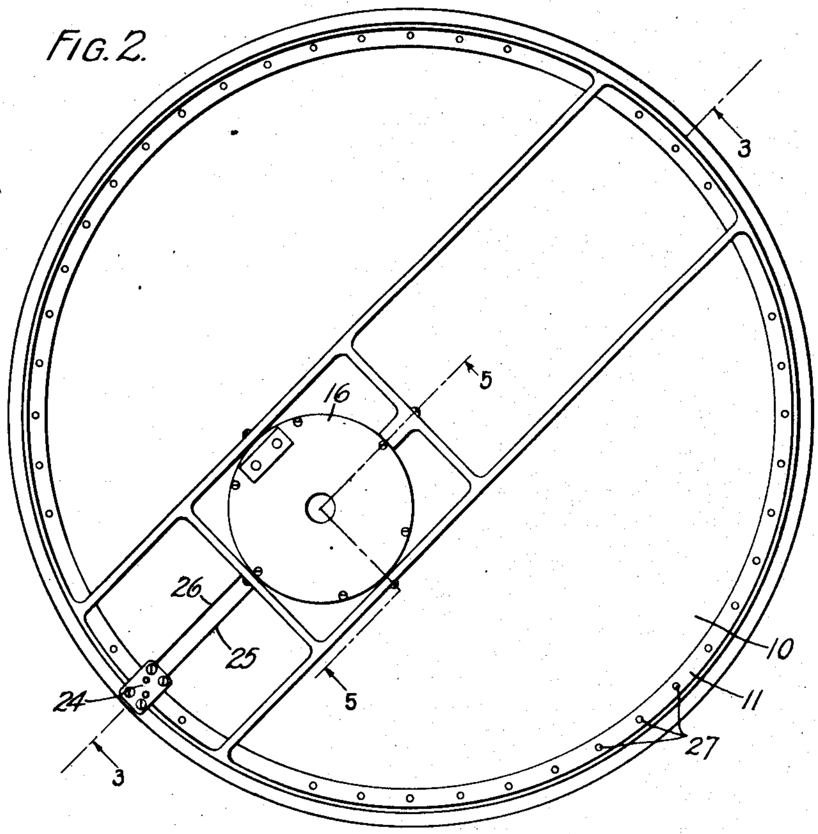

FIG. 3.

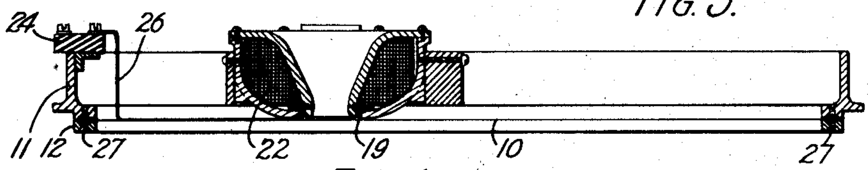

FIG. 4.

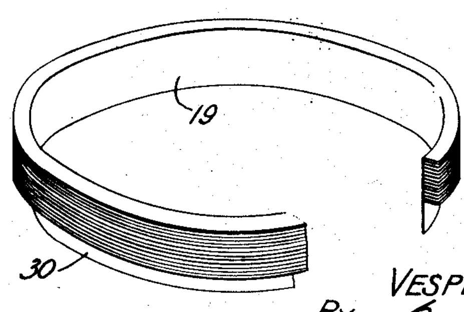

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FIG. 5.

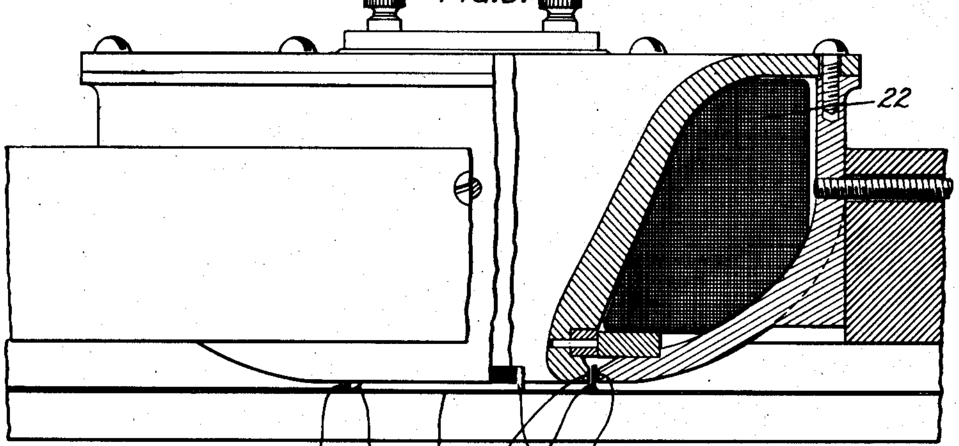
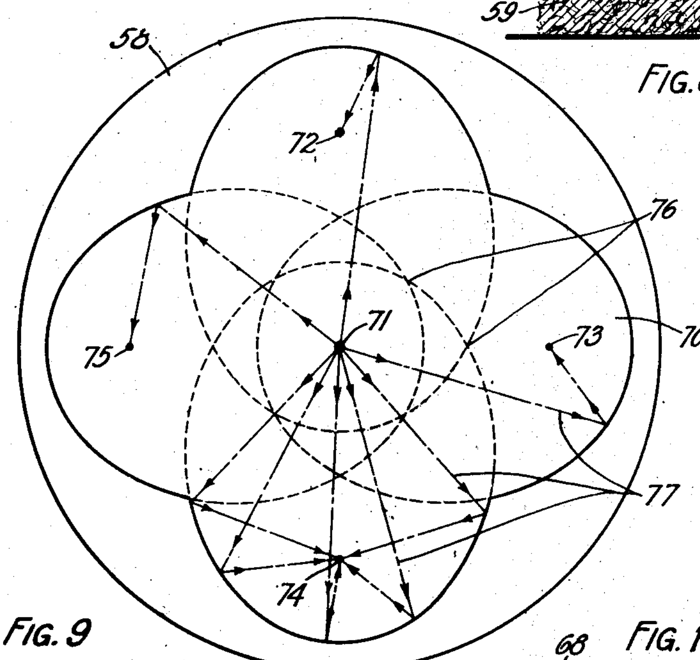


FIG. 11.



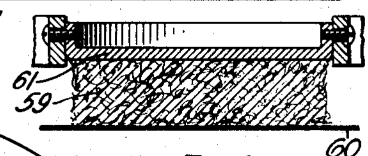


FIG. 8.

FIG. 9

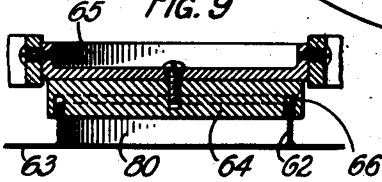


FIG. 10.

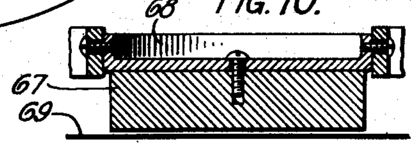


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FIG. 6.

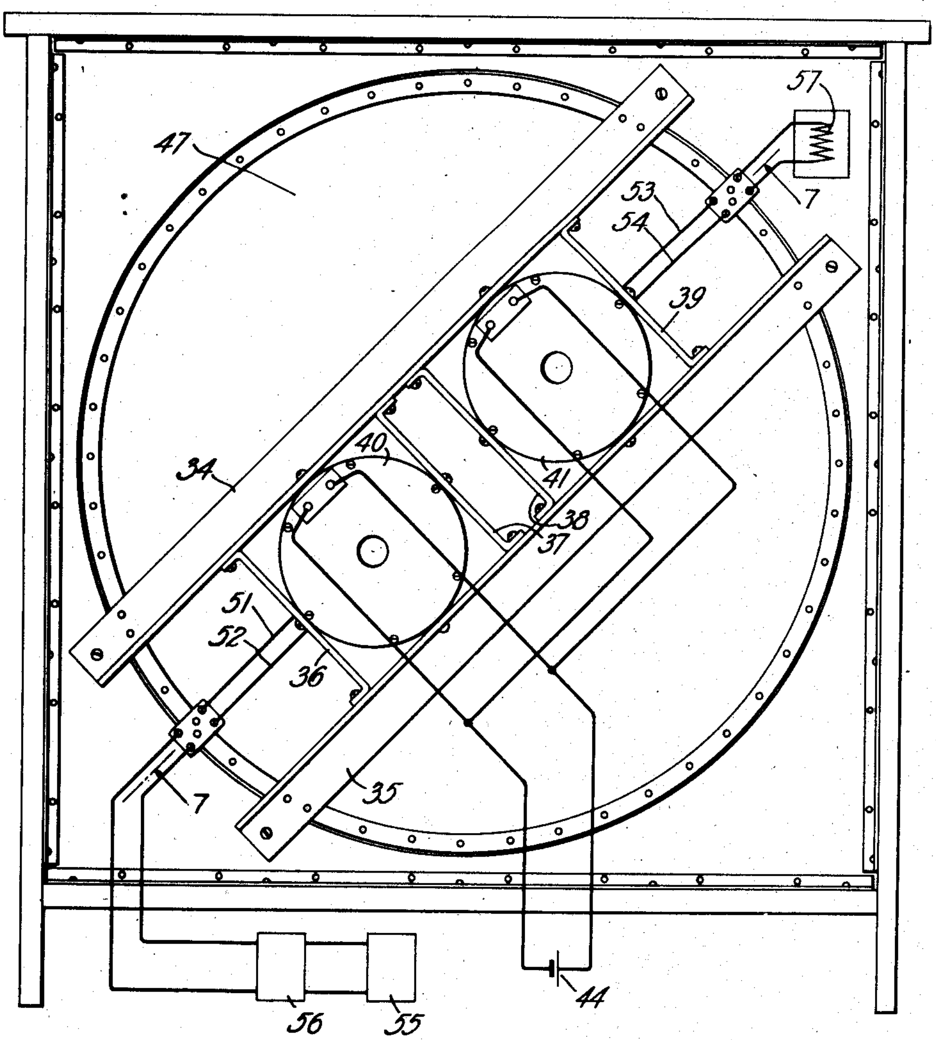
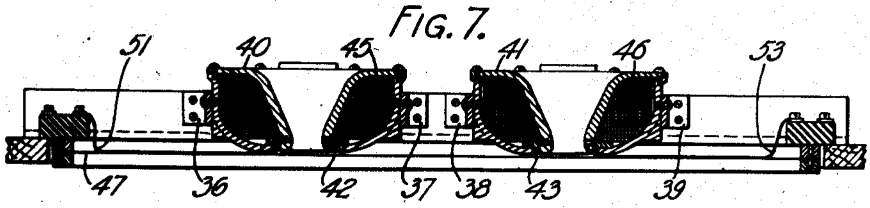


FIG. 7.



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UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

Application filed May 11, 1927. Serial No. 190,484.

This invention relates to acoustic devices and particularly to a sound radiator having a high and substantially uniform efficiency over at least a large portion of the frequency range employed in speech and music.

The invention has its preferred embodiment in a sound radiator comprising a thin, highly tensioned diaphragm of light material, such as an alloy consisting largely of aluminum, and of large size. In a specific form of the invention which has been chosen for the purpose of illustration, the diaphragm consists of a circular sheet of aluminum-manganese alloy 0.002 inch thick and 29 inches in diameter clamped at its periphery to a metal ring which maintains it under a tension of 40 lbs. per inch. The diaphragm is driven by an electrodynamic unit of the type disclosed in Patent No. 1,707,544 to A. L. Thuras, issued April 2, 1929. The coil of this unit is made very light and is preferably secured to the diaphragm at a position slightly off center in order to reduce distortion due to reflected waves reaching the driving unit.

It has been found that a sound radiator of this type has substantially uniform efficiency over at least a large portion of the frequency range essential to speech and music. This appears to be due, in part at least, to the action of the large mass of air which is in effect coupled to the diaphragm at low frequencies as compared with the effect of the air at high frequencies. The diaphragm may be placed in a cabinet in a manner to increase this effect. It is found also that very high efficiency is obtained in accordance with this invention.

In accordance with another feature of the invention, which is applicable both to large and small diaphragms, those which are tensioned and those which are not, there is provided a diaphragm so shaped, and driven at such a position that vibrational waves reflected from the supported edge, or other reflecting portions, intersect within one or more small areas on the diaphragm remote from the driven portion, and means are provided at these areas for dissipating the reflected wave energy. A desirable form of diaphragm in which this feature is embodied is a circular stretched diaphragm supported at its periphery, driven at a position on its surface between the periphery and the center, and provided with a damping unit located symmetrically with respect to the driving means and on the opposite side of the center of the diaphragm.

The invention may be readily understood by referring to the following description and the accompanying drawings in which:

Fig. 1 is a perspective view of a sound radiator constructed in accordance with this invention;

Fig. 2 is a rear view of the sound radiator removed from the cabinet in which it is shown mounted in Fig. 1;

Fig. 3 is a sectional view taken along the line 3—3 of Fig. 2;

Fig. 4 is an enlarged perspective view showing the construction of the coil which is employed for driving the diaphragm;

Fig. 5 is an enlarged view partially in section taken along the line 5—5 of Fig. 2;

Fig. 6 is a rear view of a sound radiator which is a modification of the sound radiator shown in Fig. 2;

Fig. 7 is a sectional view taken along the line 7—7 of Fig. 6;

Figs. 8, 9 and 10 are views partly in section showing various modifications of the damping unit employed in conjunction with the sound radiator shown in Figs. 6 and 7; and

Fig. 11 is a diagrammatic view of a modified form of diaphragm constructed in accordance with the present invention.

Referring now particularly to Figs. 1 to 5 of the drawings, the diaphragm 10 is maintained under high tension uniformly in all directions by the supporting frame 11 and the clamping ring 12 which is secured to the frame by the screws 27. This frame and ring are preferably of a material having the same coefficient of expansion as the diaphragm material so that the tension of the diaphragm is not affected appreciably by changes in temperature. A diaphragm material of an alloy composed of approximately 98.5% aluminum and 1.5% manganese and rolled down to a thickness less than 0.005 inch and preferably 0.001 inch or 0.002 inch has been found satisfactory although other materials having properties similar to those possessed by this material may be used. Among the desired properties for a diaphragm material are low mass and a 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-fourth of and preferably equal to the velocity of sound in air. This material possesses a low mass per unit area which is about 5×10^{-4} lbs. per square inch for the 0.005 inch thick material and about 2×10^{-4} lbs. per square inch for the 0.002 inch thick material. The inherent stiffness of the material is very low, that is, it is very flexible before being tensioned. The inherent stiffness of the material has been tested by clamping a strip of the 0.005 inch thick material 1 inch in width so that a piece 1 inch long is free. A uniformly distributed force was applied to the edge of this strip opposite the clamped edge and the deflection noted. For forces within the elastic limit of the material the stiffness was found to be about 0.3 lbs. per inch deflection. Because of the low internal resistance possessed by this material (which is also characteristic of other metals which are not tensioned beyond their elastic limit) practically no energy is dissipated within the diaphragm itself.

The purpose of low mass and high tension is to enable the radiator to respond effectively at the higher portion of the speech and music frequency range. Attempts have heretofore been made to design radiators to employ highly tensioned diaphragms, but so far as known, all such attempts fall short of producing a practical radiator having a substantially uniform frequency-response characteristics in the lower part of the frequency range as compared with the higher. The present invention is based on the discovery that by sufficiently increasing the size of the highly tensioned diaphragm the benefits of high tension are retained and at the same time a substantially uniform response is obtained throughout a very large part of the range of desired frequencies due to a broadening of the range at the lower frequency side to a very low point. This appears to be due to the fact that the diaphragm of increased size has effectively coupled thereto a sufficient amount of the air adjacent thereto to produce this extension of the band of radiated frequencies without deleteriously affecting the characteristic in the upper portion of the frequency range. This broadening of the band at the low frequency side may perhaps be looked upon as being due in large part to lowering the natural fundamental frequency of the diaphragm in air by virtue of loading it with the air adjacent thereto.

Satisfactory results have been obtained by applying a tension of approximately 40 lbs. per inch to the diaphragm (this giving it a propagation velocity of about one-half the velocity of sound in air), and making the diameter of the diaphragm about 29 inches or its area approximately 660 square inches. This degree of tensioning is well below the elastic limit of the material which has a tensile strength of approximately 70 lbs. per inch.

It has been found that the effectiveness of the air adjacent to the diaphragm to lower the lower cut-off point of the frequency response characteristic of a highly tensioned diaphragm of the kind herein disclosed may be substantially increased by partially confining the air in proximity to the diaphragm. This may be done by placing the diaphragm in a container so that the walls of the container project forwardly or backwardly or both from the plane of the diaphragm a short distance. Thus in Fig. 1 the diaphragm 10 is placed in the cabinet 13 in a wooden partition 29, which is inclined somewhat to the vertical. Protective screens 28 which may comprise a silk covering mounted on a suitable frame are positioned in the openings in the front and back of the cabinet 13. This covering has very little effect, if any, on the frequency-response characteristic of the complete apparatus. The partial enclosure for the air at the front or back of the diaphragm or both appears to act somewhat as a horn and somewhat as a baffle in the plane of the diaphragm. If desired, space may be provided in the cabinet for phonograph or radio apparatus for use in conjunction with the sound radiator.

The lower cut-off frequency of a sound radiator employing a diaphragm 29 inches in diameter tensioned to 40 lbs. per inch has been found to be about 100 cycles per second when employed without a baffle or sound chamber of any kind. This cut-off frequency may be lowered about 10% by employing a baffle in the plane of the diaphragm or by positioning the diaphragm in a relatively shallow cabinet. A sound radiator employing a diaphragm of this type positioned in a deeper cabinet, such as shown in Fig. 1, measuring 22 inches between its open sides, has been found to have a lower cut-off frequency at about 75 cycles per second. A sound radiator having a lower cut-off frequency at approximately 250 cycles per second may be obtained by employing in free air a diaphragm having an area of about 45 square inches and tensioned to have a propagation velocity of one-fourth the velocity of sound in air, i. e. to about 15 lbs. per inch.

The diaphragm 10 is driven by an electrodynamic unit 16 which is supported by the cross members of the frame 11, preferably in the form of a unitary casting. The coil 19 of the electrodynamic unit 16 is secured to the diaphragm so as to drive it along a circular line and is positioned between the annular pole faces 20 and 21 of its magnetic structure. The polarizing winding 22 is positioned within and substantially fills the hollow magnetic structure. Good results have also been obtained by employing a permanent magnet of cobalt steel shaped similarly to the electromagnet shown and preferably of laminated construction. It should be noted that the shape of the magnetic structure is such that the cross-sectional area of the space between it and the adjacent portion of the diaphragm tapers from the coil outwardly. The central opening in the magnetic structure likewise has a tapered cross-sectional area. This arrangement serves to avoid the effect of an enclosed or resonant body of air.

As best shown in Fig. 4, the coil 19 is made of a thin ribbon conductor preferably of copper and of the order of 0.002 inch thick and 0.014 inch wide, wound so that the plane of the ribbon is perpendicular to the axis of the coil. The adjacent turns of the ribbon conductor may be insulated from each other by applying a thin coating of a solution of "bakelite" dissolved in acetone, or other suitable insulating material, to the conductor both before and after winding the coil. This coating not only serves as an insulating medium but also to give rigidity to the coil when dried. Such an insulating material, moreover, takes up so little space that when the coil is positioned between the pole faces 20 and 21 of the magnetic structure of the electromagnetic unit 16, the air gap between the pole faces is substantially filled with the conducting material of the coil. A strip 30 of oiled silk or other thin, light fabric is cemented along one edge to the inner surface of the coil. The opposite edge of the strip is cemented to the diaphragm as shown in Fig. 5 and a coating of the bakelite solution is applied to the strip to increase its rigidity.

For a diaphragm tensioned to a certain degree, the mass and size of the driving coil are important factors in determining the upper cut-off frequency of the sound radiator, that is, the frequency at which the radiation efficiency decreases sharply from a high to a relatively low value. Between this upper cut-off frequency and the lower cut-off frequency of the sound radiator, referred to above, the radiation efficiency is high and substantially uniform. Satisfactory results have been obtained by employing a coil 2 inches in diameter having a total mass less than 0.011 lb. and preferably about 0.003 lb. or, in other words, one having a mass per unit length of coil periphery less than 0.002 lb. per inch and preferably about 0.0005 lb. per inch, respectively. It has been found that to a certain extent the mass of the coil employed for driving a diaphragm which is under a given tension may be increased without lowering the upper cut-off frequency of the sound radiator provided that the size of the coil is correspondingly increased. A sound radiator having an upper cut-off frequency of approximately 1050 cycles per second is obtained by employing a diaphragm tensioned to approximately 15 lbs. per inch and a driving coil 2 inches in diameter and weighing approximately 0.011 lb., the ratio of the tension applied to the diaphragm to the mass of the coil per inch length of periphery being about 8500. A diaphragm tensioned to approximately 40 lbs. per inch and a coil 2 inches in diameter and weighing about 0.003 lb. are preferably employed and this sound radiator has its upper cut-off frequency at about 5000 cycles per second.

The ends 25 and 26 of the coil winding are brought out to the terminal block 24 in any suitable manner. The coil 19 is secured to the diaphragm preferably at a position slightly off center so that vibrational waves reflected from the edge of the diaphragm will not reach the driving unit. Good results have been obtained by making the distance between the center of the diaphragm and the center of the coil about 1 or 2 tenths of the diameter of the diaphragm. For this condition, the number of peaks and valleys in the frequency response curve is small. As the distance between the center of the diaphragm and the coil is increased, the number of peaks and valleys in this response characteristic becomes larger, but their amplitude is somewhat decreased.

While various methods may be employed for mounting the diaphragm material 10 on the frame 11, one method which has been found satisfactory is as follows: A sheet of aluminum alloy is placed between clamping rings which have an inside diameter slightly larger than the outside diameter of the frame 11 and ring 12 and which are made of iron, "invar" steel, or other material having a relatively low coefficient of expansion compared with that of the diaphragm material. The iron or "invar" steel rings and the diaphragm are now placed in an oven and raised to a high temperature at which they are maintained while screws are secured through the clamping rings and the diaphragm material. The temperature is then lowered, thus subjecting the diaphragm to tension due to the fact that the diaphragm material contracts at a higher rate than the iron or invar steel clamping rings. When the diaphragm 10 is cool the frame 11 and the clamping ring 12, of a material having the same coefficient of expansion as that of the diaphragm material, are placed inside of the iron or invar steel rings and secured to the diaphragm and to each other by means of the screws 27. The iron or invar steel rings are now removed and the diaphragm is ready to be mounted in the partition 29 of cabinet 13.

In Figs. 6 and 7 is shown a sound radiator which differs from the one shown in Figs. 1

to 5 respectively, and described above, in that means are provided for dissipating vibrational energy reflected from the peripheral support for the diaphragm. Two similar electrodynamic units 40 and 41 are employed respectively, for driving and for damping reflected waves in the diaphragm 47. These units are supported by the angle bars 34 and 35 and the cross bars 36 to 39 inclusive, which are secured to the angle bars 34 and 35. The movable coils 42 and 43 of these units are secured to the diaphragm 47 so that the centers of the coils lie substantially on a diameter of the diaphragm and are approximately equidistant from the center. These coils are positioned between the annular pole faces of the magnetic structures of units 40 and 41 and the battery 44 supplies current to the polarizing windings 45 and 46, respectively, of these units. A source of electrical energy 55 such as an electromagnetic phonograph reproducer, or radio receiving apparatus is coupled to the leads 51 and 52 of the coil 42 through the amplifying equipment 56. The leads 53 and 54 of the coil 43 are connected to the external resistance 57 which is preferably made of such a value that the impedance of the electrodynamic damping unit 41 is substantially a pure resistance, and is approximately equal to the impedance of the diaphragm measured at the position where the coil 43 is attached. It is possible that the coil 43 employed in the damping unit 41 may be made as a closed solid metallic ring, in which case the external resistance 57 is not required. The resistance of this metallic ring together with the density of the linkage flux will determine the amount of damping. Instead of employing electrodynamic units for driving and damping the diaphragm other units such as those of the electromagnetic type may be used.

While a damping means similar to the unit employed for driving the diaphragm is in some cases preferable, in many cases other damping means such as those shown in Figs. 8, 9 and 10, may be employed if desired. In Fig. 8, opposite surfaces of a porous material 59 such as felt are secured to a diaphragm 60 and a supporting structure 61, respectively. As the diaphragm vibrates, air is alternately forced into and out of the pores of the material 59 and this action serves to dampen the vibrations reaching this portion of the diaphragm.

In Fig. 9 is shown a dash-pot arrangement for damping vibrations in a diaphragm. An annular member 62 is secured to the diaphragm 63 and fits into a recess 66 in the member 64 which is secured to a support 65. As the diaphragm 63 vibrates, air is forced in and out of the chamber 80 through the recess 66 thereby damping vibrations in this portion of the diaphragm 63. In some cases it may be preferable to employ a plurality of concentric annular members and a plurality of oppositely disposed recesses. A large amount of damping may be obtained with a small unit in which the annular member and the oppositely disposed recess are in the form of a spiral.

In Fig. 10, a cylindrical member 67 is secured to a support 68 so that one of the plane surfaces of the cylinder 67 lies substantially parallel and in close proximity to the surface of diaphragm 69. With this arrangement, as with that shown in Fig. 9, vibrations of the diaphragm are damped due to the air being forced in and out of the space between the diaphragm 69 and the cylinder 67.

In the case of the sound radiator employing a circular diaphragm driven and damped as described above, it is seen that waves set up in the diaphragm by the driving means travel in all directions therefrom towards the supported edge of the diaphragm and are then reflected.

These reflected waves come to a focus within a small area on the diaphragm at which a damping means is applied for dissipating the reflected waves. Instead of employing a diaphragm which is circular in shape, diaphragms of other shapes may be employed, as for instance, an elliptical shaped diaphragm which is driven at one focal point and in which the reflected waves come to a focus substantially at the conjugate focal point where they are dissipated.

The diaphragm 70, shown diagrammatically in Fig. 11 has a periphery formed by portions of four ellipses having a common focal point 71 at which the diaphragm is driven and four conjugate foci 72, 73, 74 and 75 at which means are supplied for damping reflected vibrations in the diaphragm. The dotted lines 76 indicate that the shape of the diaphragm is equivalent to four superposed ellipses having one common focus. The dash lines 77 represent various radii of a circular vibrational wave initiated at the common focus 71. These waves are reflected from the fixed edge of the diaphragm and arrive at the conjugate foci as circular waves. This follows from these facts: that the distance between the common focus and any of the conjugate foci measured along a line perpendicular to the wave front is constant; that for each ellipse lines drawn to the foci from any point along the periphery are equally inclined to the tangent at that point; and that the rate of propagation of transverse waves is the same throughout the diaphragm. In the case of a circular diaphragm driven off center such as shown in Fig. 6 the waves reflected from various portions along its periphery, instead of coming to a focus at a point as is the case when an elliptical shaped diaphragm is employed, come to a focus within a small area to which the damping means is applied.

While the invention is independent of the theory of operation, the following theory is believed to be correct: When the diaphragm material used is set into vibration there is practically no shearing effect between adjacent elements of the diaphragm which tends to resist, and therefore dissipate transverse vibrational energy propagated therein. When this metallic diaphragm is made very thin and of a material having a low density it possesses practically no inherent stiffness and its mass is very low compared with the mass of the air which the diaphragm sets into motion at low frequencies. At low frequencies of vibration the effective mass of the air coupled to a diaphragm which is exposed on both sides thereto is given by the formula

$$M_A = 2/3\rho D^3$$

where ρ=density of the air=0.00129 grams per cubic cm. and D=diameter of diaphragm (cm.) then M_A=348 grams or 0.765 lbs. for a diaphragm having a diameter of 29 inches. This makes the mass of the air per unit area of the diaphragm about 0.00115 lbs. per sq. in.

The mass per sq. in. of the diaphragm itself (the diaphragm material being 0.002 inch thick) is equal to mass per unit area multiplied by

$$\text{thickness} = 0.098 \times 0.002 = 0.000196$$

lbs. per sq. in. Hence it will be noted that at low frequencies of vibration the mass per unit area of the diaphragm is only approximately 17% of the mass of the air per unit area of diaphragm coupled to it.

The coil preferably used for driving the diaphragm is about 2 inches in diameter, weighs about 0.003 lbs. and is a negligible factor in determining the radiation efficiency of the sound radiator at low frequencies. However, at higher frequencies the mass of the air coupled to the diaphragm is relatively small. Therefore, the mass of the coil becomes an important factor in determining the upper cut-off frequency of the sound radiator. The cut-off frequency of a vibrational system is a function of the ratio of its stiffness to its mass and the stiffness of this sound radiator is proportional to its tension. The mass of the sound radiator at high frequencies is substantially equal to the mass of the coil alone and when the diaphragm is tensioned to have a propagation velocity of approximately one-half the velocity of sound in air and the 2 inch diameter coil weighing about 0.003 lbs. is used the upper cut-off frequency is about 5,000 cycles per second. Since at low frequencies the stiffness factor is again proportional to the tension applied to the diaphragm, and since the mass at low frequencies is substantially equal to the mass of the air coupled to the diaphragm, the low frequency cut-off point depends on the area of the diaphragm. For a diaphragm tensioned to have a propagation velocity one-half that of sound in air and having a diameter of approximately 29 inches this low frequency cut-off point is approximately 100 cycles per second. When the tensioning of the diaphragm is decreased so that it has a propagation velocity approximately one-fourth the velocity of sound in air and the mass of the driving coil is increased to .011 lbs., the high frequency cut-off point will be approximately 1050 cycles per second. The radiation efficiency of the sound radiator decreases rapidly at the cut-off frequency, perhaps about 10 transmission units, and then decreases slowly with increasing frequency. If at the same time, the area of the diaphragm is decreased to 45 sq. in., the low frequency cut-off point will be raised to about 250 cycles per second.

Although satisfactory results have been obtained by driving the diaphragm at the center it has been found that the radiation efficiency of the sound radiator is made more uniform over a wide range of frequencies by displacing the driving unit slightly from the center. It is believed that this is due to the fact that vibrational waves reflected from the edge of the diaphragm do not come to a focus at the driving unit but are concentrated at a small area remote therefrom. Additional improvement in the frequency response characteristic of the sound radiator was obtained by applying a damping means to this small area, at which the reflected waves come to a focus for dissipating the reflected wave energy.

As pointed out heretofore the impedance of the means employed for damping reflected vibrations should be substantially a pure resistance equal in magnitude to the impedance of the sound radiator measured at the portion of the diaphragm to which the damping means is applied. When this is the case an optimum damping action takes place. If the resistance of the damping element is too high or too low, undesirable wave reflection will take place from this damping element as well as from the supported edge of the diaphragm. In some cases it may be desirable to employ a plurality of driving units working in phase in which case each of the driving units serves to dampen reflected vibrations initiated by the remaining units.

This invention has been described above as a sound radiator, but it may also be used as a sound receiver.

What is claimed is:

1. A diaphragm for radiating sound consisting of thin material tensioned to such a degree that the propagation velocity of transverse vibrational waves therein is greater than one-fourth the velocity of sound in air, said diaphragm having a sufficiently large

surface area as to have a low fundamental natural frequency.

2. A diaphragm for radiating sound consisting of thin material having low internal resistance and tensioned to such a degree that the velocity of propagation of transverse vibrational waves therein approaches the velocity of sound in air, said diaphragm being sufficiently large so that when tensioned it has a fundamental natural frequency in the lower part of the audible range.

3. An acoustic diaphragm of thin metallic material stretched uniformly in all directions and of sufficient size to have a natural fundamental frequency in air lying in the lower portion of the band of frequencies essential in the reproduction of speech and music.

4. A metal diaphragm less than .005 inch thick having a fundamental natural frequency in air less than 250 cycles per second.

5. An acoustic device comprising a diaphragm of a metallic material having low mass per unit area, low internal resistance and low inherent stiffness, said diaphragm being tensioned to such a degree that the velocity of transverse vibrations therein is high, and means secured to said diaphragm for driving it.

6. A stretched acoustic diaphragm of a material consisting almost wholly of aluminum and a material to increase the tensile strength.

7. A stretched acoustic diaphragm of a material consisting almost wholly of aluminum and manganese.

8. An acoustic diaphragm tensioned to such a degree that the velocity of propagation of transverse vibrational waves therein is greater than 275 feet per second and having its natural fundamental frequency in air below 250 cycles per second.

9. A metallic acoustic diaphragm, the mass per unit area of which is less than 5×10^{-4} lbs. per sq. in. and the area of which is greater than 45 sq. in., said diaphragm being tensioned to such a degree that the propagation velocity of transverse vibrations therein is greater than one-fourth the velocity of sound in air.

10. An acoustic device comprising a tensioned diaphragm and means secured to said diaphragm for driving it along a line, the ratio of the tensioning of said diaphragm in lbs. per in. to the mass of said driving means per unit length along said line in lbs. per in. being greater than 8,500.

11. An acoustic device comprising a tensioned diaphragm and means secured along a line on said diaphragm and within the boundary edge thereof for driving it.

12. An acoustic device comprising a tensioned diaphragm and means secured to said diaphragm for driving it along a line, said means having a mass per unit length of said line less than .002 lbs. per inch.

13. An acoustic device comprising a diaphragm tensioned to such a degree that the propagation velocity of transverse vibrations therein is greater than 275 feet per second, and means secured to said diaphragm for driving it, said means having a mass per unit length less than .002 lbs. per inch.

14. An acoustic device comprising a tensioned diaphragm and means secured to said diaphragm for driving it, the mass of said means being less than .011 lbs.

15. A large diaphragm for radiating sound consisting of sheet material having a mass per unit area less than 5×10^{-4} lbs. per square inch and tensioned to such a degree that the velocity of transverse vibrations therein is greater than 275 feet per second.

16. An acoustic diaphragm having a natural fundamental frequency of vibration in air below 250 cycles per second, consisting of a material which has an inherent stiffness such that for a piece of the diaphragm material one inch square rigidly supported at one edge the force applied to the opposite edge required to produce a given deflection thereof is less than 0.3 lbs. per inch.

17. An acoustic device comprising a substantially circular diaphragm supported at its periphery and tensioned substantially uniformly in all directions and means secured to the diaphragm for driving it at a position between its center and its periphery.

18. An acoustic device comprising a diaphragm of metal containing principally aluminum and having a thickness of less than .005 inch, means having a temperature coefficient of expansion of the same order as that of said diaphragm material for supporting said diaphragm at its periphery and maintaining it under tension, and means secured to said diaphragm at a position remote from its periphery for driving it.

19. A sound radiator comprising a metallic diaphragm having a thickness of the order of .002 inch stretched to have a tension of the order of 40 lbs. per inch, means for driving said diaphragm, said means having a mass of approximately .003 lbs., and means for fastening said first mentioned means to said diaphragm at a position remote from its periphery.

20. In combination, a diaphragm, driving means therefor, and means associated with said diaphragm for dissipating reflected vibratory energy therein.

21. In combination, a diaphragm, driving means therefor, and means positioned between said driving means and the periphery of said diaphragm for dissipating reflected vibratory energy therein.

22. In combination, a diaphragm, means for maintaining said diaphragm under tension, actuating means for setting up vibrations in said diaphragm, and damping means associated with a small area on said dia-

phragm for dissipating reflected vibrational waves traveling therein.

23. An acoustic device comprising a diaphragm of thin flat material and means for tensioning said diaphragm to a degree below the elastic limit and to an extent such as to allow vibrations to be propagated therein at a rate greater than 275 feet per second, said diaphragm being sufficiently large so that tensioned it has a fundamental natural frequency below 250 cycles per second.

24. In a radio apparatus including a cabinet, a baffle-board mounted in said cabinet at an oblique angle with the walls thereof, and a sound producer mounted on said baffle-board.

25. In combination, a sound producer, a cabinet adapted to provide a common housing for a radio receiving apparatus and said sound producer, a baffle-board for and associated with the sound producer, said baffle-board being mounted in the cabinet and secured along two of its edges to the walls thereof at an oblique angle to said walls whereby compartment resonance and the transmission of sound vibrations to such receiving apparatus are prevented.

In witness whereof, I hereunto subscribe my name this 10th day of May, A. D., 1927.

VESPER A. SCHLENKER.