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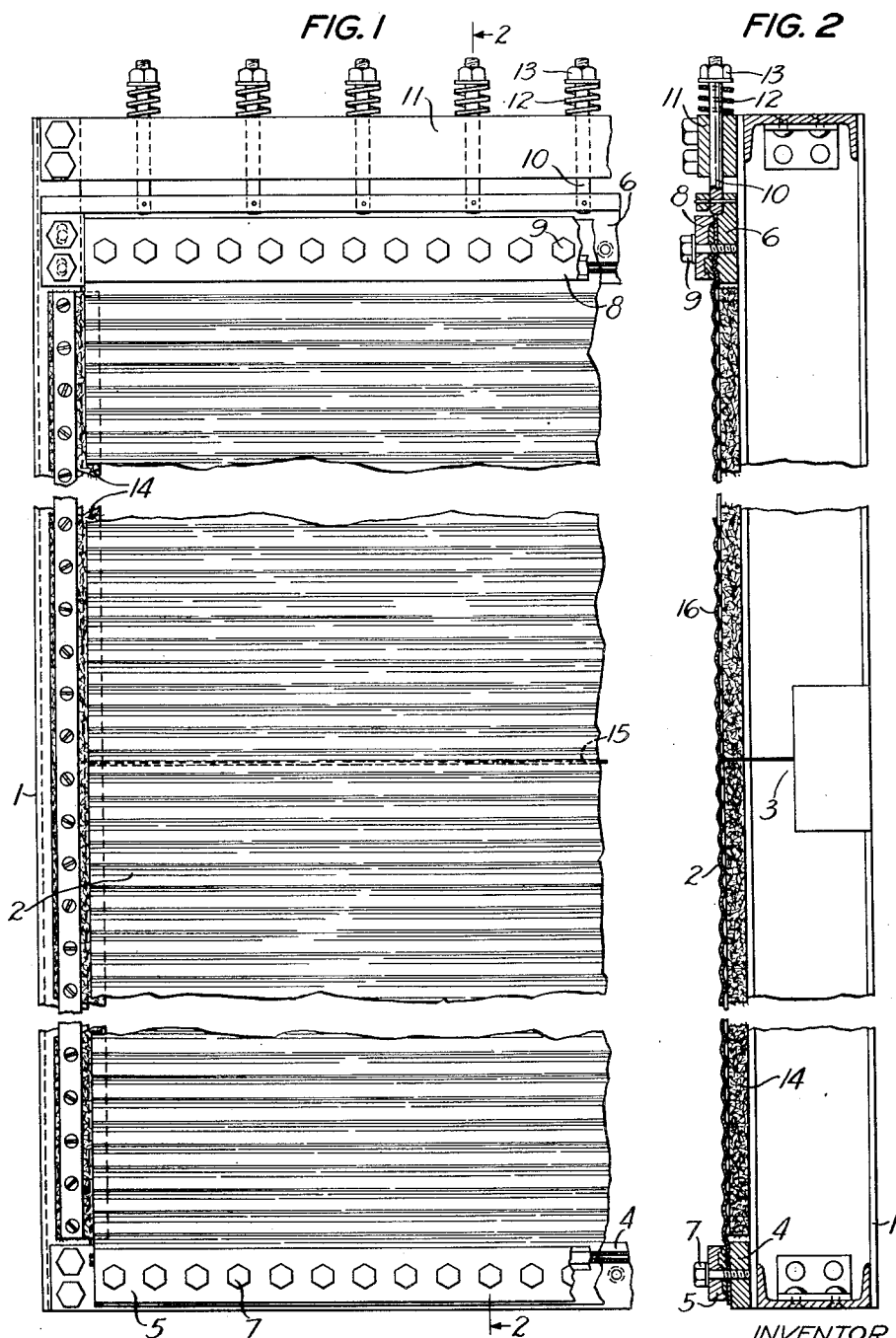
E. H. SMYTHE

1,821,586

ACOUSTIC DEVICE

Filed April 20, 1929

4 Sheets-Sheet 1



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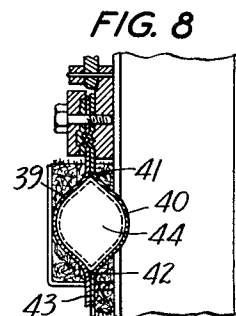
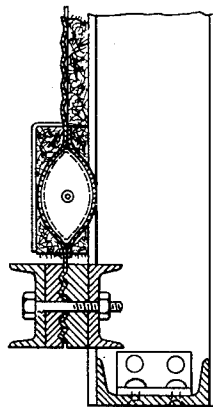
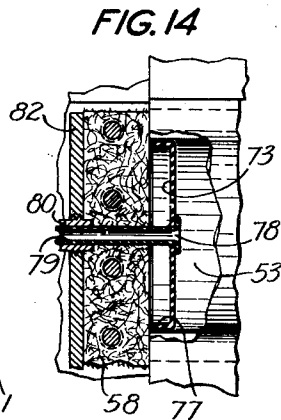
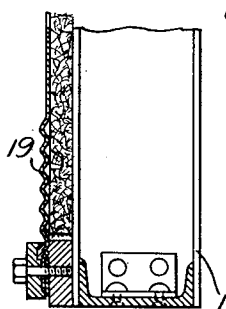
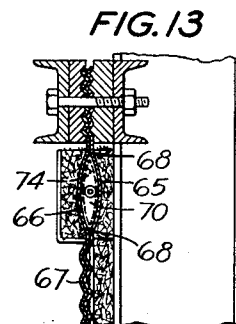
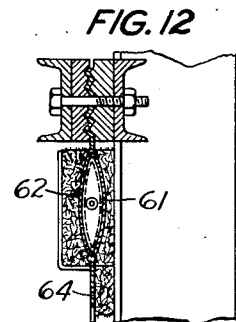
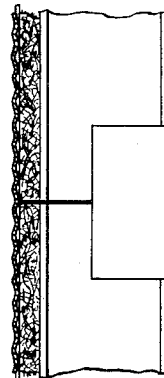
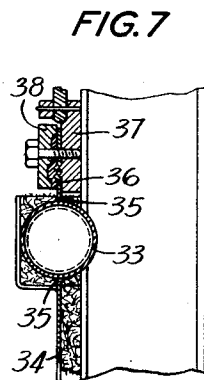
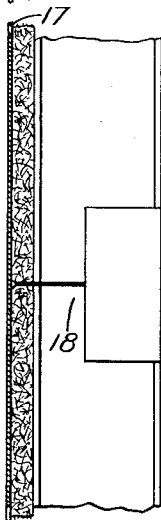
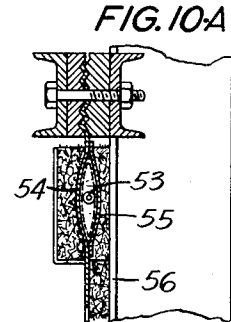
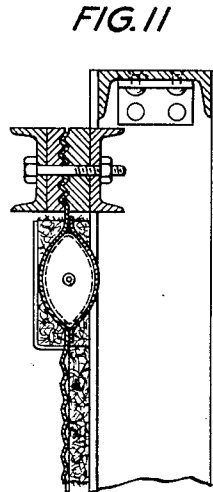
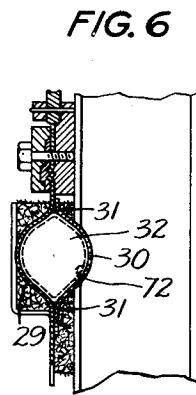
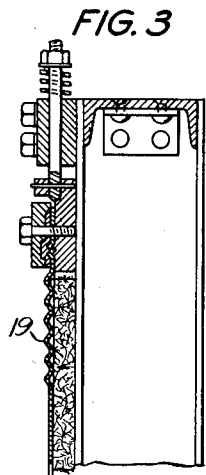
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ACOUSTIC DEVICE

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4 Sheets-Sheet 2



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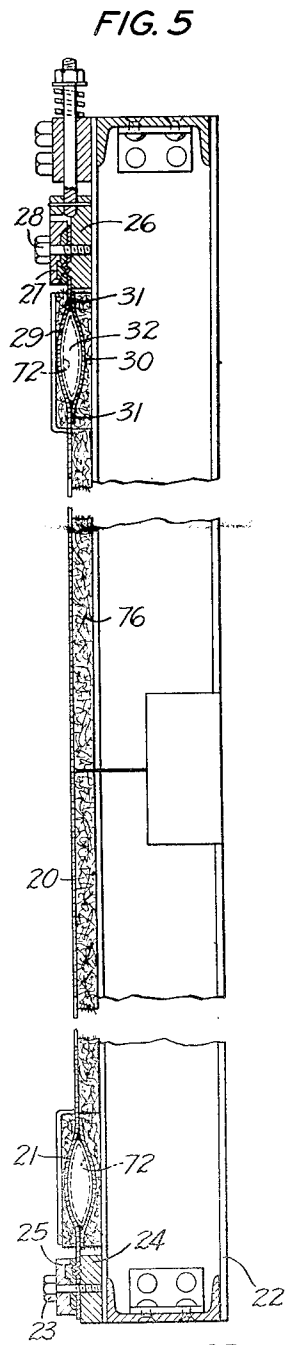
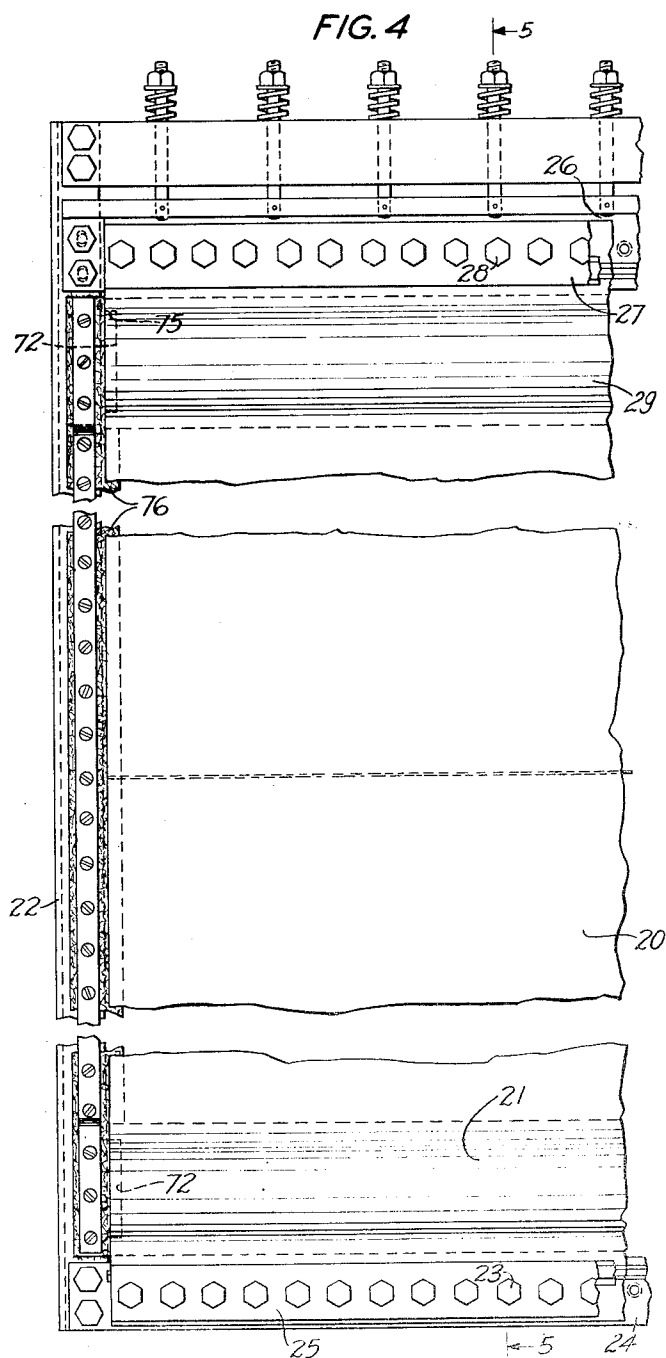
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ACOUSTIC DEVICE

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4 Sheets-Sheet 3



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ACOUSTIC DEVICE

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FIG. 9

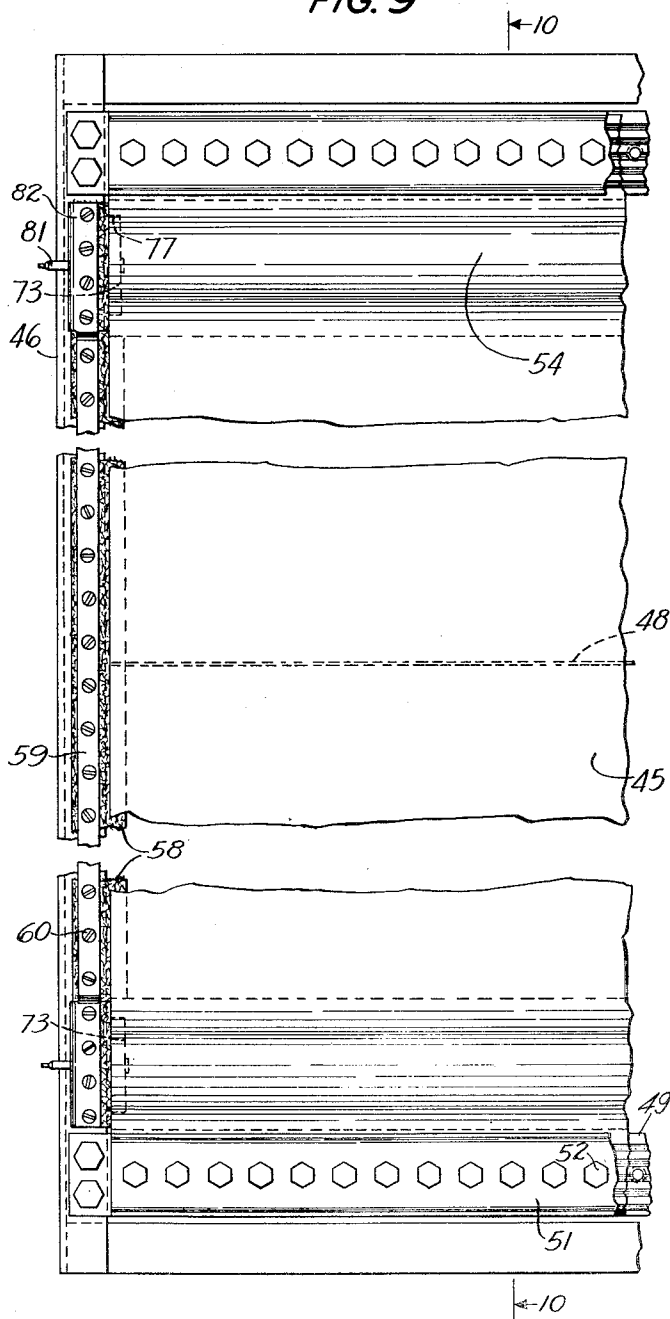
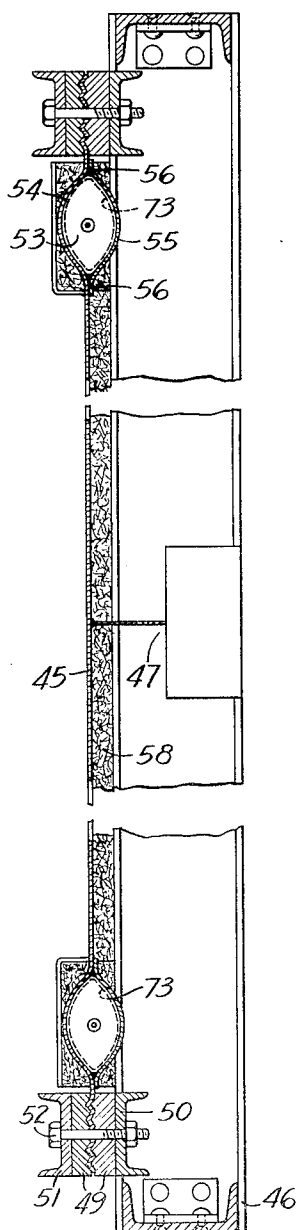


FIG. 10



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UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

Application filed April 20, 1929. Serial No. 356,632.

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

An object of this invention is to radiate sound energy with substantially uniform efficiency over at least a large portion of the entire frequency range of speech and music.

In accordance with this invention, there is provided an elongated, direct-acting diaphragm, tensioned to a degree approaching the elastic limit of the material of the diaphragm and provided with regions of special extensibility to ensure the maintenance of uniform tension under all conditions. In one embodiment of the invention there is provided a diaphragm of thin light material, such as aluminum or duralumin, having regions of special extensibility in the form of corrugations transverse to its length preferably over its entire surface. Means are provided at each end of the diaphragm for stretching it to a degree approaching the elastic limit of the aluminum or duralumin. This means may be similar to that shown in H. C. Harrison Patent 1,726,105 issued August 17, 1929. Means are also provided to impart acoustic vibrations to the diaphragm. This means may be of any suitable structure and may be secured to the diaphragm at any position intermediate its ends.

In another embodiment there is provided a diaphragm having means similar to that in the above embodiment for tensioning the diaphragm to a high degree. This diaphragm also has regions of special extensibility in the form of fluid enclosing means, at or near its ends. In the untensioned condition of the diaphragm, these regions are enclosures round or oval in cross-section and contain sealed therein fluid at any desired pressure, preferably atmospheric. When the diaphragm is stretched under the tensioning forces, these tubular members, for so they may be called, extending as they do the width of the diaphragm, tend to flatten out or to elongate. The decrease in volume occurs at the expense of an increase in pressure of the fluid contained within the tubular member. This fluid pressure, in acting to restore the tubular member to its original shape causes

a uniformly distributed tension lengthwise of the diaphragm and, when vibrations are imparted to the diaphragm, acts as a spring termination to maintain the uniformity of tension of said diaphragm.

In another embodiment there is provided a sheet or corrugated diaphragm having rigid supports and provided with tensioning means which are fluid distended portions of the diaphragm itself or fluid distended members secured to and intermediate the ends of the diaphragm and its supports. These distended portions operate to keep the diaphragm under more uniform tension under all conditions of amplitude and frequency variations of vibration and to increase the longitudinal extensibility at the end of the diaphragm proper over what it would be if it were directly attached to the supports. They also act as a means for introducing tension of a high degree into the diaphragm and may be equipped with means for varying the degree of fluid pressure and to thus vary the degree of tension in the diaphragm.

A more complete understanding of my invention may be obtained from the following detailed description and the appended drawings wherein:

Fig. 1 shows one embodiment of my invention in which a large direct-acting uniformly tensioned diaphragm having transverse corrugations is employed;

Fig. 2 is a sectional view of Fig. 1 along the line 2-2;

Fig. 3 is a partial section of another embodiment of my invention which shows a plane diaphragm having corrugations at its terminations;

Fig. 4 is a partial view of another embodiment of my invention wherein a large direct-acting diaphragm is held under uniform tension by means of fluid enclosing portions in the diaphragm;

Fig. 5 is a section of Fig. 4 along the line 5-5 and illustrates a preferable structure of the fluid enclosing portion;

Fig. 6 shows a section of the fluid enclosing portions in Figs. 4 and 5 when in a relatively untensioned condition;

Fig. 7 shows said fluid enclosing portion

in the untensioned condition as a separate member secured by suitable means intermediate the diaphragm and suitable supports for the tensioning means;

5 Fig. 8 shows an untensioned fluid enclosing portion of a double membrane diaphragm;

10 Fig. 9 shows a partial view of a large plane diaphragm uniformly tensioned by fluid distensible portions;

Fig. 10 is a sectional view of the embodiment of my invention shown in Fig. 9 with the fluid enclosing members in a distended condition;

15 Fig. 11 illustrates this tensioning means employed to uniformly tension a corrugated diaphragm;

20 Figs. 10—A, 12 and 13 illustrate the fluid distensible portions in various embodiments in an undistended condition.

Fig. 14 is an enlarged sectional view of a means to introduce fluid into the fluid distensible portions of the diaphragm.

Referring now to Figs. 1 and 2, a frame 1 serves to support an actuating means 3 (shown schematically) and a diaphragm 2 preferably made of a light-weight high strength material, such as aluminum or duralumin about 2 mils in thickness. The diaphragm is preferably provided with corrugations 16, shown in exaggerated form by Fig. 2 across its face in a direction transverse to its length. The lower edge of the diaphragm 2 is clamped between the serrated surfaces of a projecting portion 4 of the frame 1 and a member 5 by means of the screws 7. The upper edge of the diaphragm is similarly clamped between the serrated surfaces of the members 6 and 8 and held by screws 9. The rods 10 secured to the member 6 pass through openings in a projecting portion 11 of the frame 1. For the purpose of tensioning the diaphragm there are provided springs 12 encircling the upper portions of the rods 10 and disposed between the projecting portion 11 and adjustable nuts 13 engaging the threaded end portions of the rods 10. Strips 14 of damping material are provided to damp vibrations reaching the side edges of the diaphragm. One edge of the strip 14 is secured to the diaphragm 2 and the opposite edge to the frame 1.

A driving means 3 of suitable character may be supported by a cross bar (not shown) attached to the frame 1. The drive is preferably along a line 15 across one face of the diaphragm and might take the form shown in H. C. Harrison Patent 1,726,105 issued August 17, 1929, or my Patent 1,778,871 granted October 21, 1930.

60 The diaphragm 2, formed with closely spaced corrugations of small radius of curvature is mounted in a relatively untensioned condition or with such tension as may unavoidably occur in the mounting of the dia-

phragm between the serrated clamping members and also with that caused by its own weight. The diaphragm is then tensioned to a high degree and preferably to a degree approaching the elastic limit of the diaphragm material. As the diaphragm is tensioned the corrugations are flattened and their radius of curvature is increased so that they become more like a ripple of the surface of the diaphragm. The presence of these closely spaced corrugations of large radius of curvature transverse to the direction of the tensioning forces lengthwise of the diaphragm results in a more uniform distribution of tension therein. Furthermore, the resiliency of the corrugations adds resiliency to the diaphragm and enables it to maintain a more nearly uniform tension under all conditions than would be possible with a plane diaphragm. In an untensioned plane diaphragm there will be present areas of varying stiffness resulting from the uneven working of the material into its sheet form. When under tension these unbalances are accentuated and any slip in the tensioning means results in a still further unbalance inasmuch as the percentage slip of the diaphragm will be large as the total elongation before the elastic limit is reached, is small, probably in the neighborhood of one-half of one per cent.

However, if a plane diaphragm is corrugated, which aids considerably in smoothing out any unbalanced stiffness in the diaphragm itself, and then tensioned to the desired degree, one advantage is that the overall percentage elongation permissible will be greater than with a plane diaphragm of the same dimensions. There will also be a more even distribution of longitudinal tension along the breadth of the diaphragm, and a slip in the clamping or tensioning means of a given amount after the diaphragm has been adjusted to the desired degree, consequently works through a greater elongation and causes a much smaller tensional unbalance in the diaphragm as a whole than in the case of the plane diaphragm. An additional advantageous feature of this embodiment is that the diaphragm may be tensioned closer to its elastic limit without danger of the limit being exceeded by vibrations of excessive amplitude due to resonance or to over-driving.

Fig. 3 shows a modification of the embodiment of my invention illustrated in Figs. 1 and 2. As in the embodiment previously described, a frame 1 supports a diaphragm 17 and an actuating means 18. The diaphragm 17 comprises a plane diaphragm having initially closely spaced and small radius corrugations 19 at the terminations of its main vibrating portion. These corrugations extend across the face of the diaphragm. The diaphragm is clamped at its upper and lower edges between serrated surfaces and tensioned with means similar to that shown in

Figs. 1 and 2, the corrugations being flattened to a curvature of large radius in the tensioning process.

Another embodiment of my invention, whereby a diaphragm can be uniformly tensioned along one or both of its edges, is illustrated by Figs. 4 and 5. A partial view of a large direct-acting acoustic device is shown and comprises a plane diaphragm 20 having tubular portions enclosing fluid under greater than atmospheric pressure. The diaphragm is mounted in a relatively untensioned state on the frame 22 and at its lower edge is clamped and held by screws 23 between the serrated surfaces of the portion 24 of the frame 22 and the member 25. The diaphragm is clamped similarly at its upper edge between the serrated surfaces of the members 26 and 27 and held therein by screws 28. Tensioning means similar to that above described with reference to Fig. 1 is also employed.

The form taken by the tubular portion 21 in the untensioned condition, of the diaphragm is illustrated more clearly in Fig. 6. A suitable depression 29 is formed across the face of a plane diaphragm at the termination of its main vibrating portion and a like shaped strip 30 having suitable edge portions 31 is secured to the diaphragm in an air-tight manner, in the position shown by soldering, cementing, spot-welding, or brazing. The tubular portion thus formed, which may be varnished or impregnated if the material is porous, is preferably circular in section although it may take any desired geometrical form and still be within the scope of my invention. Each end of said tubular portion, preferably coincident with the side edge of the diaphragm is suitably sealed by a light membrane 72, preferably of thin rubber, to enclose a fluid such as air within the chamber 32 under preferably atmospheric pressure.

In the untensioned condition of the diaphragm, illustrated by Fig. 6, this membrane 72 in the form of a disc, would be secured at its upturned peripheral edge 75 (Fig. 4) by cement, or similar material, to the inner surface of the tubular portion. Such a seal at each end of the tubular portion would serve as an air-tight seal to the chamber 32 but would be useless if the chamber 32 were not perfectly air-tight. If this latter were the case it would be preferable to provide an enclosed tube (not shown) preferably of very light rubber membrane, capable of being placed snugly within the tubular portion and containing fluid under a pressure just sufficient to hold the membrane tube in contact with the inner walls of the tubular portion. When the diaphragm is placed under tension the tubular member will be distorted as also will the inner tube. In each type of sealing means employed to enclose

the volume of the tubular portion, there will be distention of the end membranes when the diaphragm is under tension. Such distention however, will be limited by the frame 22 and the damping material 76. It would be possible, of course, when the sealing membranes are employed, to introduce fluid under greater than atmospheric pressure through a suitable valve (not shown) in one of the membranes.

Referring again to Figs. 4 and 5, placing the diaphragm under tension results in the tubular portion becoming distorted, reducing the volume of the fluid enclosed, and increasing the fluid pressure within the tubular portion. In acting to restore the tubular portion to its original shape, as illustrated by Fig. 6, the increased pressure above the initial pressure acts to place the diaphragm under a uniform lengthwise tension along its breadth.

Figs. 7 and 8 show other forms which the fluid enclosing portions may take.

In Fig. 7, a hollow member 33, preferably circular in section independent of the diaphragm 34 is secured at 35 to the edge of the diaphragm and also to a strip 36, preferably, but not necessarily, of the same material as the diaphragm, which is secured between the serrated surfaces of the portion 37 and the member 38. The fluid enclosing means extends across the face of the diaphragm of which Fig. 7 shows a partial section, and is suitably sealed preferably in the manner previously described. It flattens out when under tension and acts in the same way as the previously described embodiment of this means.

Fig. 8 shows still another form in which a double membrane diaphragm 43 is employed having depressions 39 and 40 which are sealed in an air-tight manner at 41 and 42 across the face of each membrane and at their side edges in the manner above described with reference to Figs. 4, 5, 6 to form an air-tight enclosure 44. As in the previous embodiments the diaphragm may be suitably clamped and provided with means for providing tensional force or forces along its extremities.

The diaphragm 20 of Fig. 4 is tensioned preferably to a high degree and to a degree approaching the elastic limit of the material comprising the diaphragm. Vibrations are propagated in the direction of the diaphragm's length. Although a considerable portion of the energy imparted to the diaphragm will be radiated, ordinarily, before reaching the terminations of the diaphragm, the latter must be very long, or suitable damping material must be provided at the edges to prevent wave reflection which seriously impairs the efficiency of the acoustic device. Instead of making the diaphragm

cumbersomely long or providing damping material, the use of the fluid enclosing portions in, or attached to the diaphragm, simulates an additional length of diaphragm and acts to reduce the wave reflection at the terminations of the diaphragm. In this way the means which I employ to permit of a uniform distribution of tension in the diaphragm, also, when suitably proportioned acts to reduce disturbing wave reflections from the end edges of the diaphragm. This tends to improve the frequency characteristic of the vibrating system.

Referring now to Figs. 9 and 10 there is shown a diaphragm 45, of a material such as duralumin or aluminum, mounted upon frame 46 and provided with driving means 47, (shown schematically) preferably of the line type, which drives the diaphragm along the line 48. The diaphragm may be mounted so that it is initially under a slight tension other than that caused by its own weight. The lower edge is clamped between serrated members 49 which are held tightly in position by a portion 50 of the frame 46, a member 51 and the bolts 52. The upper edge of the diaphragm is secured in a similar way, the serrations produced in that portion of the diaphragm held between the clamps causing an initial tension in the diaphragm. The degree of initial tension may be controlled by the number and amplitude of the serrations. It is preferable, however, only to lightly tension the diaphragm by this means as it is designed more to overcome the uneven tension condition resulting from the weight of the diaphragm itself. The desired degree of uniformly distributed tension is obtained by means hereinafter described. This means takes the form of fluid under pressure in a completely enclosed chamber formed by a depressed portion 54 of the diaphragm 45 and a strip 55 of similar material secured at its edges 56 to the diaphragm by means of solder, cement, spot-welding, or brazing, positioned as shown in Fig. 10, and suitably sealed for instance by membranes 73, preferably of thin rubber, at each end, in a way similar to that described above with reference to Figs. 4, 5 and 6. At least one membrane of each tubular portion is provided with means through which fluid to the desired degree of pressure may be introduced into the tubular portion. In an enlarged section, Fig. 14 shows a preferable arrangement of such means. The sealing membrane 73 is cemented, or otherwise secured on its upturned edge 77 to the inner surface of the tubular portion. To the inner edge surface of an opening 78 in the membrane 73 there is secured the upturned end portion of a tubing 79, of membrane material which extends through the damping material 58, the angle

portion 82 of the member 59 and is then sealed to the inner surface of the valve stem 80 secured to said portion 82 preferably as shown. Adjustments in fluid pressure within the chamber 53 may be made through a suitable valve 81 (see Fig. 9) forming part of said valve stem 80. Instead of using the end membranes, an inner tube of membrane material, preferably of thin rubber, supplied with the pressure adjusting means described above, could be employed to act as distending means within the tubular portion of the diaphragm. As illustrated by Fig. 10, the tubular portions are held distended under fluid pressure which may be varied as desired through the valve 81. The uniform lengthwise tension introduced in the diaphragm along its breadth by the tubular portions, when in the distended condition is preferably of an order approaching the elastic limit of the diaphragm material. As in previously described embodiments the diaphragm 45 is damped along its edges by strips 58 of damping material, one portion of which is secured to the diaphragm and the remaining portion between the frame 40 and a member 59 by means of screws 60. Another function served by these fluid distended portions has been explained with reference to Fig. 4 in which the fluid enclosing member attached to or forming an integral part of the diaphragm is designed to act as a region of special extensibility so as to reduce wave reflection at the end edges of the diaphragm.

Fig. 10—A illustrates the condition of the fluid distendable tensioning means shown in Figs. 9 and 10 when in an undistended state. Portions 54 and 55 are flattened out and the volume of chamber 53 is very small. In fact, in the condition wherein atmospheric pressure exists both within and without the chamber 53, the walls 54 and 55 will be practically adjacent. Modifications of the disclosure in Figs. 9, 10 and 10—A are shown in Figs. 12, 13 and 14.

In Fig. 12 the tensioning means is in the form of a fluid enclosing member, neither of the walls 61 and 62 of which are integral with the diaphragm 64, but are secured along its edge by solder, cement, or the like and also secured to that portion of the structure clamped between serrated members above described. Means for introducing fluid under pressure to the chamber formed and to control said fluid pressure may be similar to that described with reference to Figs. 9, 10 and 14.

In Fig. 13 the walls 65 and 66 of the tensioning means are formed by spaced portions of a corrugated double membrane diaphragm 67 mounted on the frame as previously described with reference to Fig. 10. The two membranes are sealed in an air-tight man-

ner at 68 across the face of the diaphragm and the tubular chamber 70 thus formed is suitably sealed at each end by a membrane 74, the degree of fluid pressure within the chamber 70 being controlled as above described.

In the embodiment of my invention shown in Fig. 11 I employ both the corrugated diaphragm and the means for uniformly tensioning the diaphragm which I have particularly described with reference to Figs. 9 and 10 thus combining the advantageous features of each in one structure.

What is claimed is:

1. An acoustic device comprising a direct-acting diaphragm uniformly tensioned to a high degree and having means therein providing regions of special extensibility.

2. An acoustic device comprising a uniformly and highly tensioned diaphragm having regions of special extensibility, said regions comprising corrugations in said diaphragm intermediate its ends.

3. An acoustic device comprising a uniformly and highly tensioned diaphragm having regions of special extensibility, said regions comprising fluid enclosing portions in said diaphragm.

4. In an acoustic device, a diaphragm having fluid enclosing terminations.

5. In an acoustic device, a corrugated diaphragm having fluid enclosing terminations.

6. An acoustic device comprising a corrugated diaphragm, and means for tensioning said diaphragm uniformly to a high degree.

7. In an acoustic device, a corrugated diaphragm stretched uniformly to a high degree, and means extending across one face of the diaphragm for imparting vibrations thereto.

8. In an acoustic device, a stretched diaphragm, and means for tensioning said diaphragm, said means comprising fluid distended portions in said diaphragm.

9. An acoustic device comprising a diaphragm having corrugations transverse to one dimension thereof and stretched to a high degree.

10. An acoustic device comprising a corrugated diaphragm stretched to a high degree and approaching the elastic limit of the material constituting the diaphragm.

11. An acoustic device comprising a direct-acting diaphragm having rigid supports and fluid distended portions intermediate said supports and the ends of the diaphragm.

12. An acoustic device comprising an elongated direct-acting diaphragm, and means for tensioning said diaphragm to a high degree and approaching its elastic limit, said means comprising fluid distendable portions in said diaphragm.

13. An acoustic device comprising an elongated direct-acting diaphragm, rigid supports at the ends thereof, and means inter-

mediate the ends of said diaphragm and its supports for uniformly tensioning said diaphragm.

14. An acoustic device comprising a diaphragm having corrugations therein and means for stretching said diaphragm in a direction transverse to said corrugations to a high degree and approaching the elastic limit of the diaphragm material.

15. An acoustic device comprising a diaphragm having corrugations transverse to one dimension thereof and uniformly stretched to a high degree and approaching the elastic limit of the diaphragm material, and means extending across one face of the diaphragm for imparting vibrations thereto.

16. An acoustic device comprising a diaphragm having a greater length than width with corrugations transverse to its length, means for uniformly tensioning said diaphragm to a high degree, and means extending across one face of the diaphragm for imparting vibrations thereto.

17. An acoustic device comprising an elongated diaphragm having transverse corrugations intermediate its ends, and means for tensioning said diaphragm to a high degree.

18. An acoustic device comprising a direct-acting diaphragm having transverse corrugations intermediate its ends, and means for tensioning said diaphragm to approximately the elastic limit of the material constituting the diaphragm.

19. An acoustic device comprising a corrugated diaphragm, driving means therefor, said driving means including a member extending across and secured to one face of said diaphragm and means for tensioning said diaphragm in the direction of its length to a degree greater than one quarter its elastic limit and so that the velocity of vibrations propagated in the direction of its length will be greater than one half the velocity of sound waves in air.

20. In an acoustic device a direct-acting diaphragm provided with means which simulates an additional length of diaphragm, said means comprising fluid enclosing terminations to its main vibrating portion.

21. In an acoustic device, a diaphragm, an elastic member associated therewith, and means for exerting a force on said diaphragm to distort said elastic member and to maintain the extremity of said diaphragm fixed in position, said elastic member acting to maintain said diaphragm in a tensioned condition.

22. The method of maintaining a diaphragm under a condition of uniform tension which comprises associating with said diaphragm an elastic member, subjecting said diaphragm to a tensioning force whereby it is stretched and the elastic member associated therewith changed in shape, and rigidly securing the peripheral portion of said

diaphragm, whereby said elastic member in seeking to return to its original condition will tend to maintain said diaphragm in a condition of tension.

5 In witness whereof, I hereunto subscribe my name this 19th day of April, 1929.

EDWIN H. SMYTHE.

DISCLAIMER

1,821,586.—*Edwin H. Smythe, Evanston, Ill. ACOUSTIC DEVICE. Patent dated September 1, 1931. Disclaimer filed March 31, 1934, by the assignee, Bell Telephone Laboratories, Incorporated.*

Hereby enters this disclaimer to wit:

1. Your petitioner hereby disclaims the subject matter of claims 1 and 2 except acoustic devices described by said claims in which the diaphragm is tensioned to a degree approaching the elastic limit of the diaphragm material.

2. Your petitioner hereby disclaims the subject matter of claim 9, except acoustic devices described by said claim in which the diaphragm is stretched to a degree approaching the elastic limit of the diaphragm material.

[*Official Gazette May 1, 1934.*]

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