Aug. 26, 1930. C. E. LANE 1,773,910
SOUND RADIATOR
Filed Sept. 30, 1926 3 Sheets-Sheet 1

Fig. 1

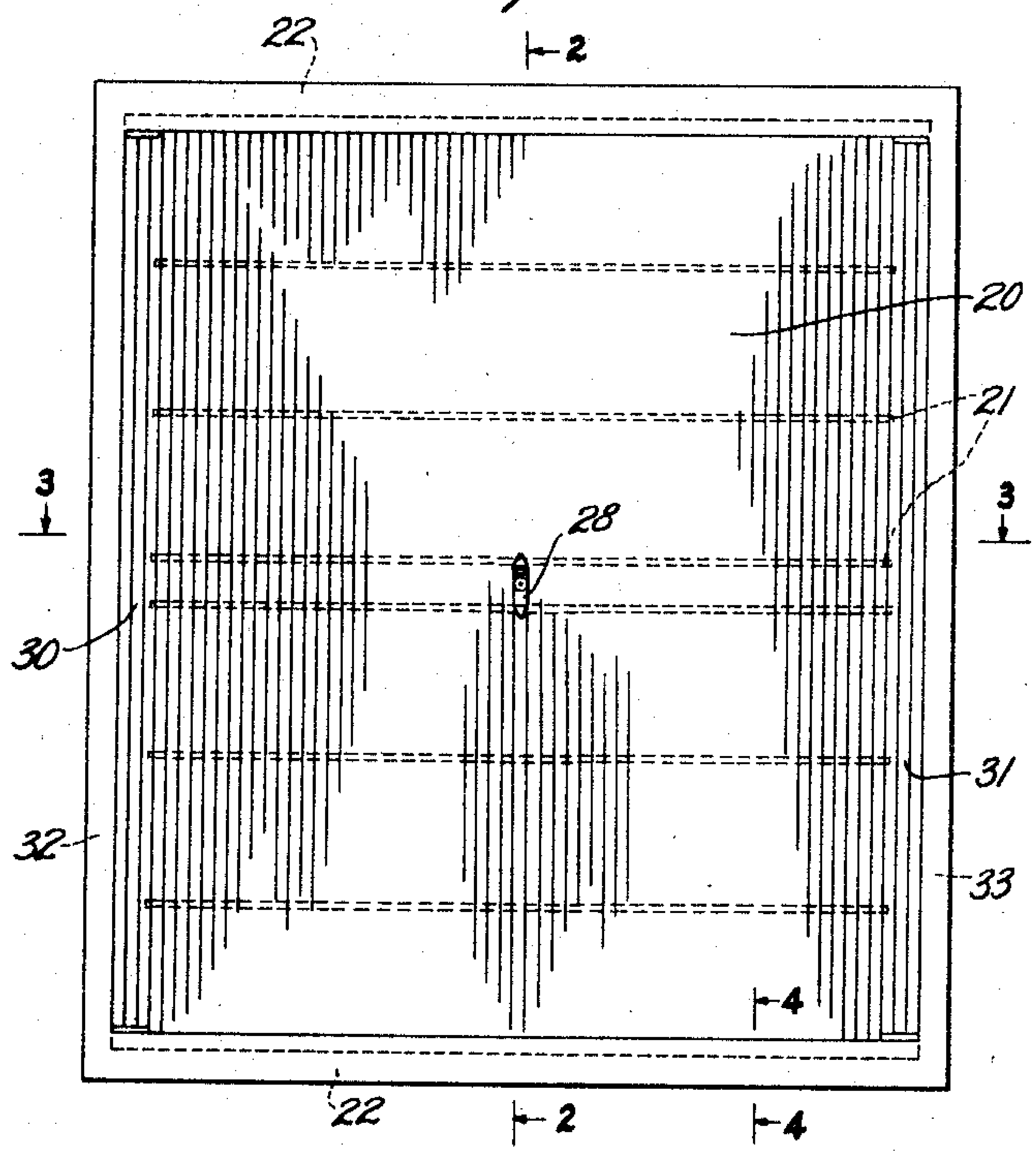


Fig. 2

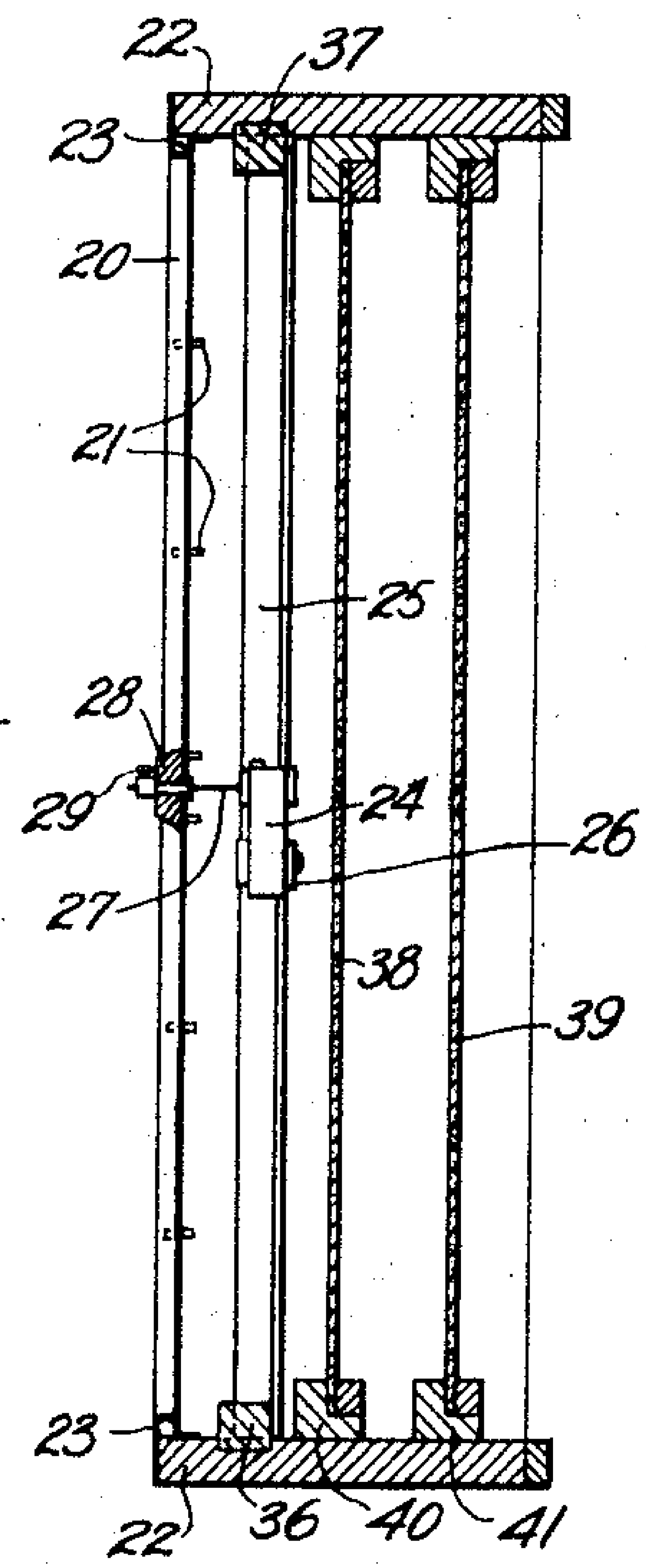


Fig. 3

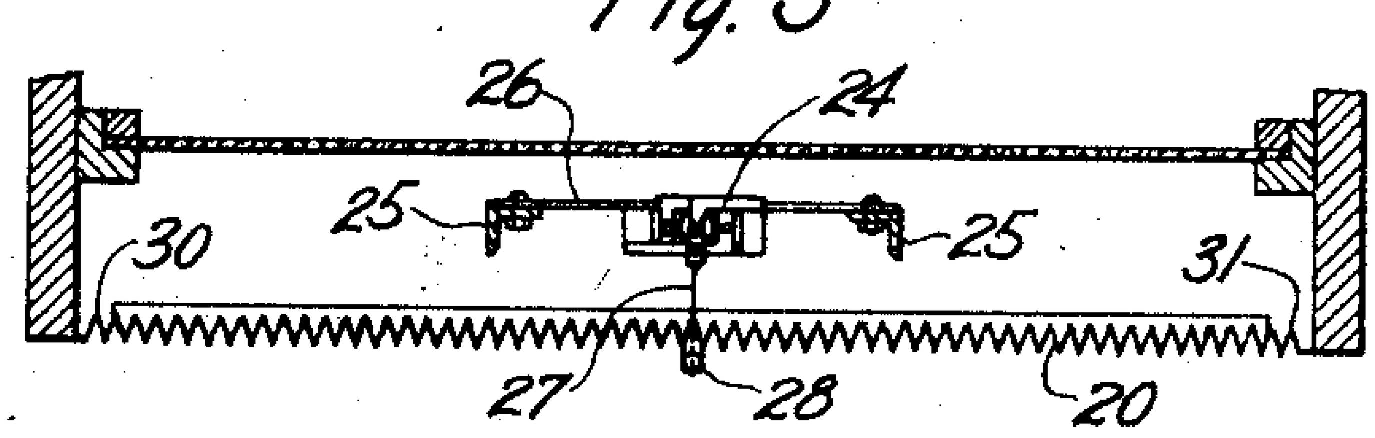


Fig. 4

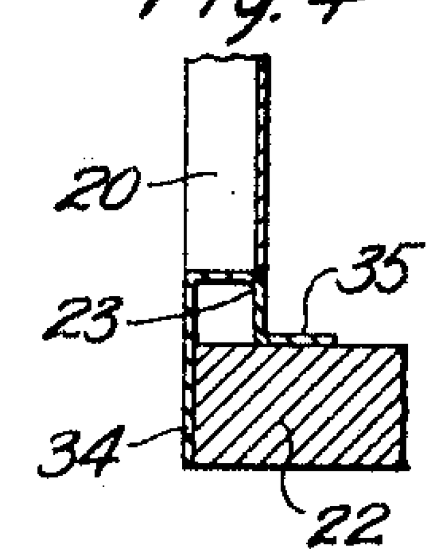


Fig. 5

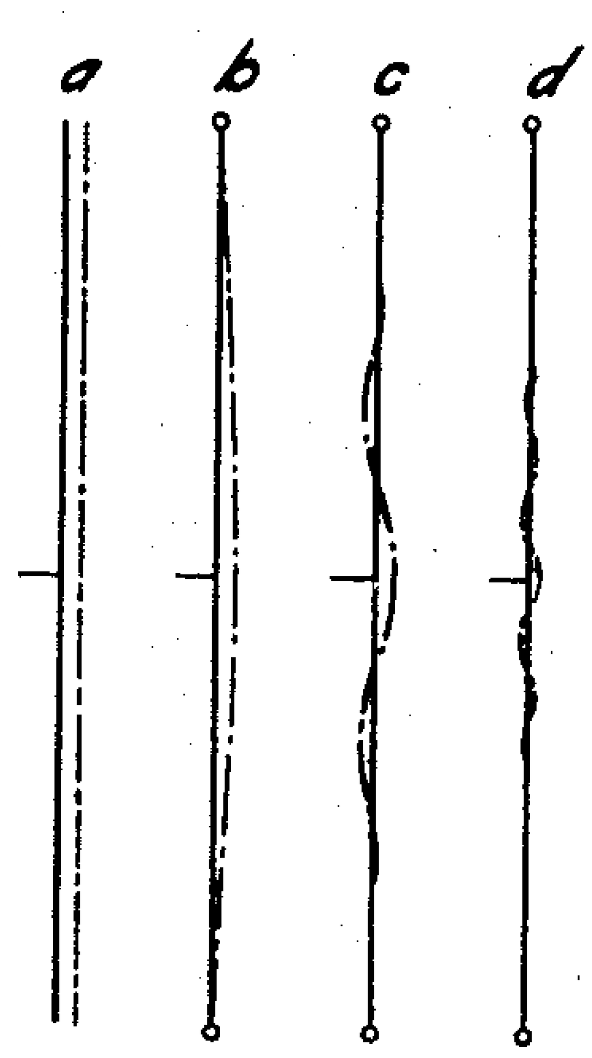
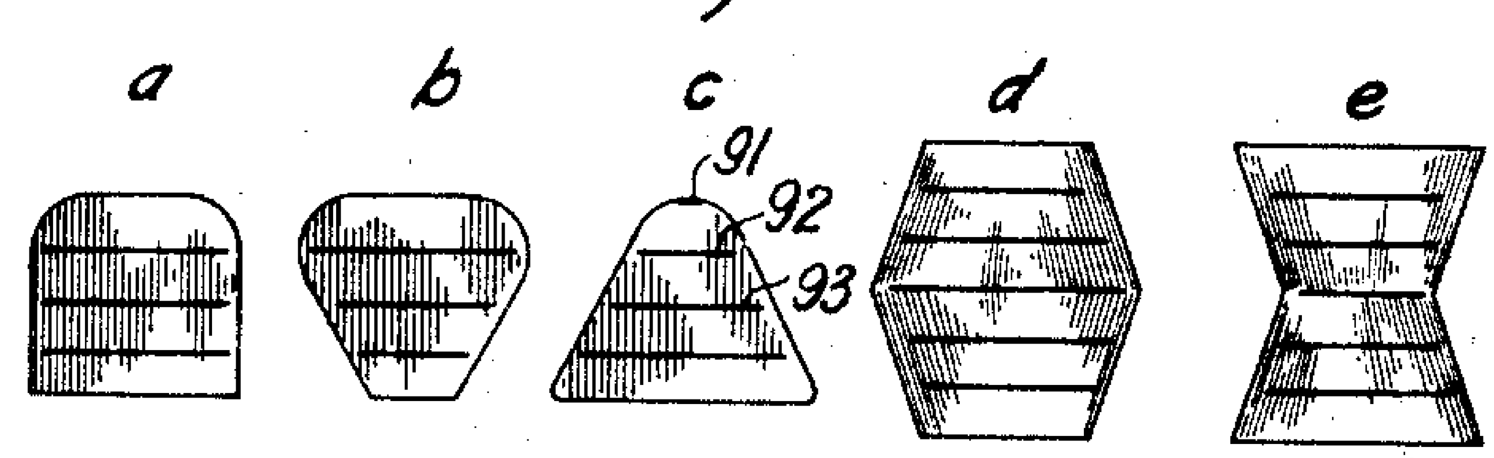


Fig. 6



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Aug. 26, 1930. C. E. LANE 1,773,910

SOUND RADIATOR

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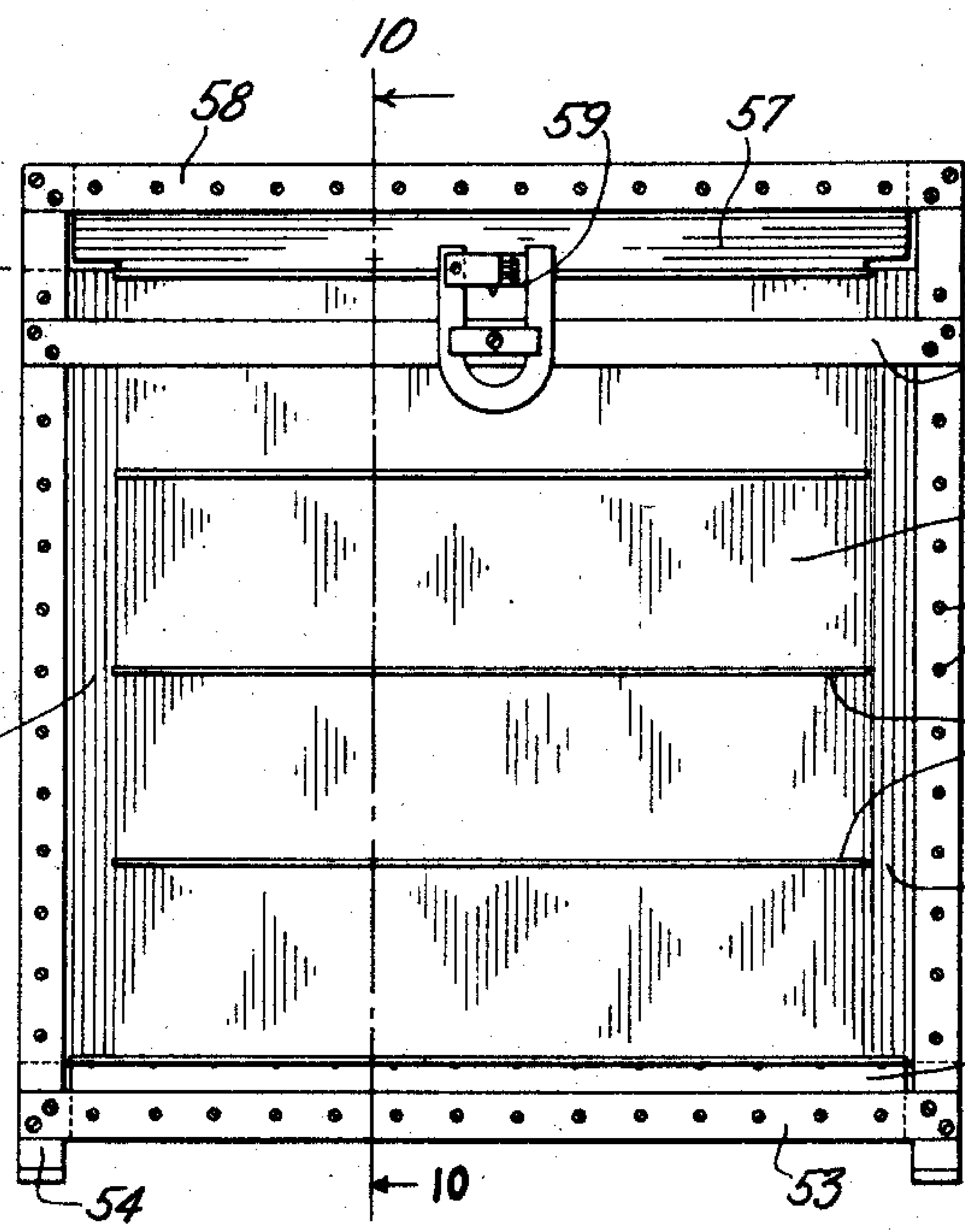

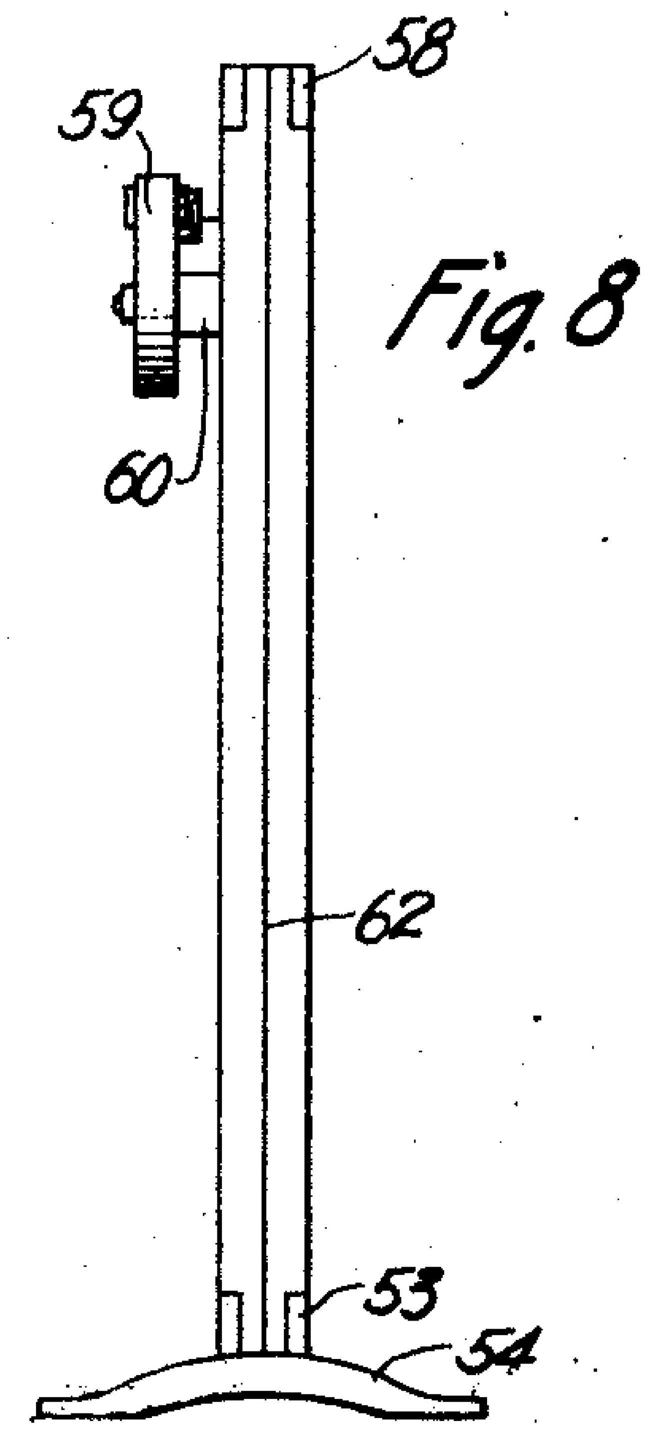

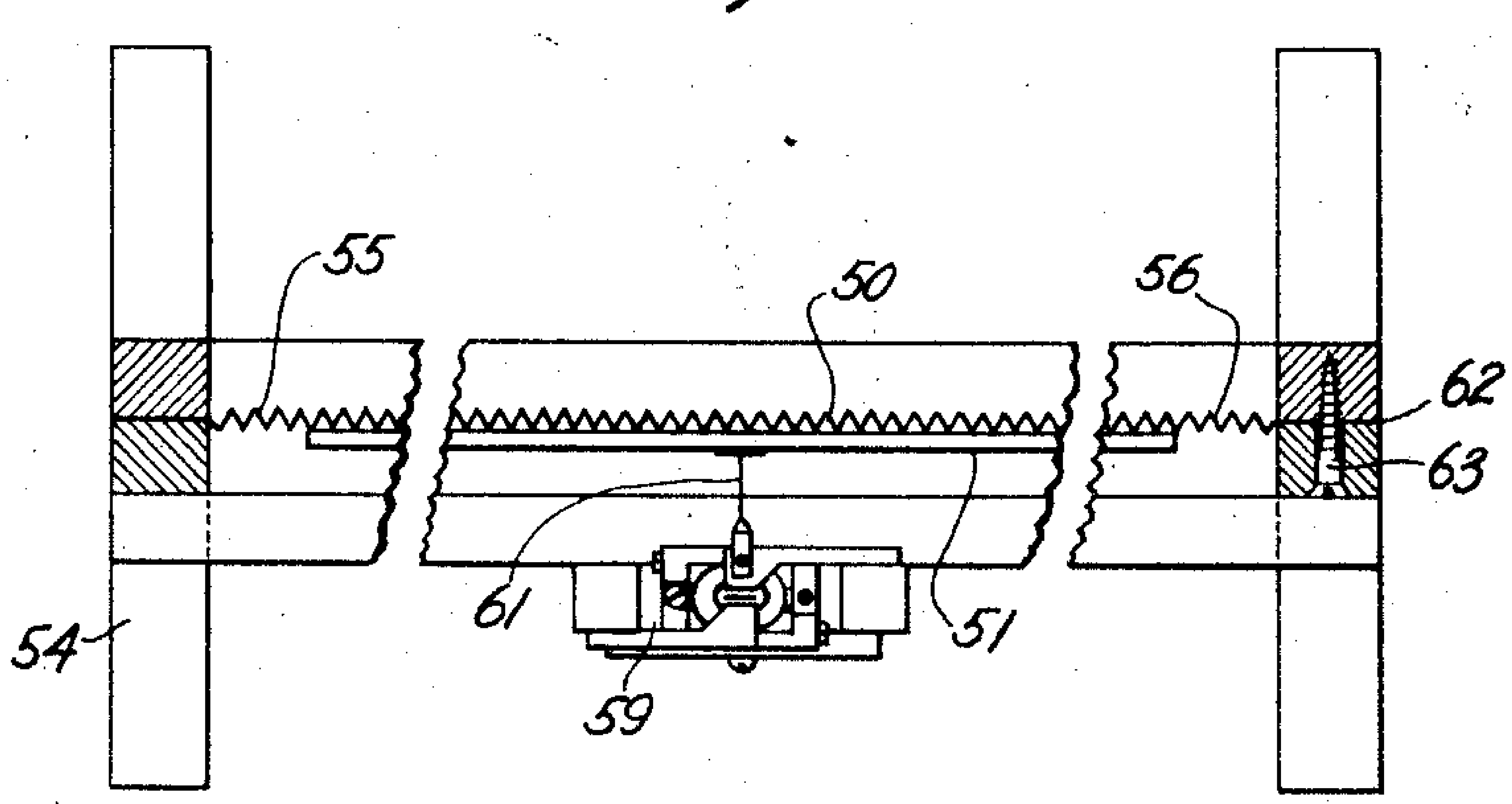

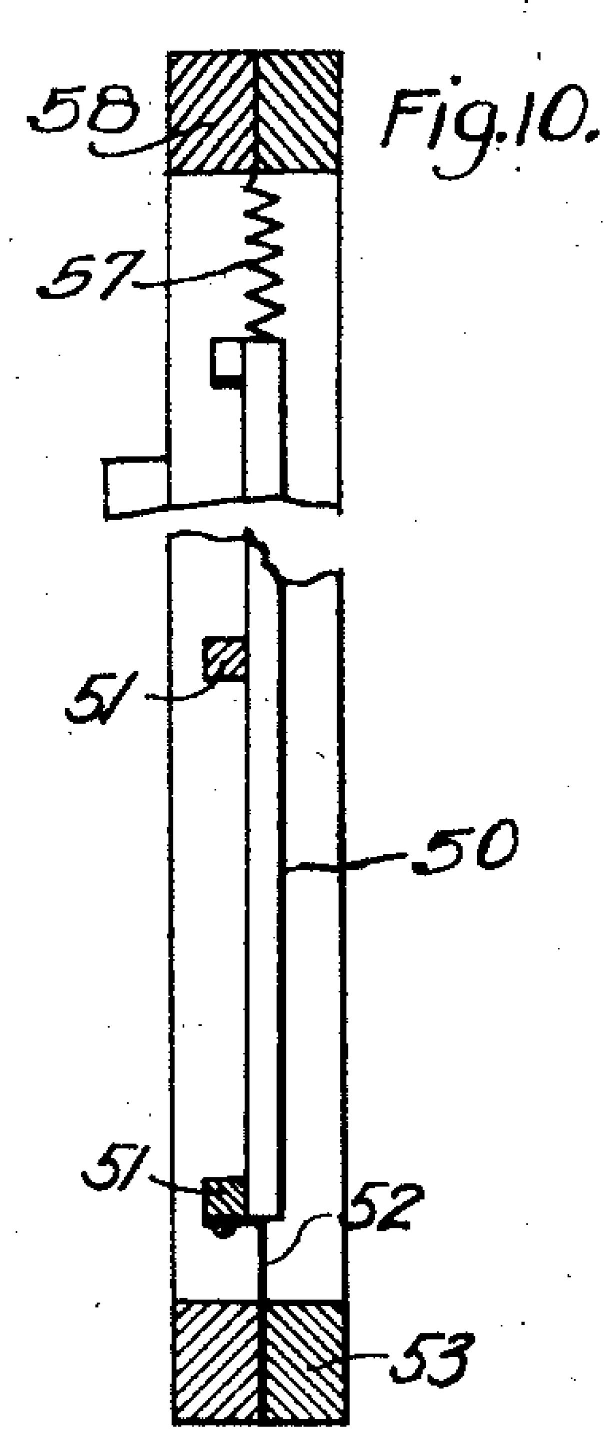

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SOUND RADIATOR

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Fig. 11

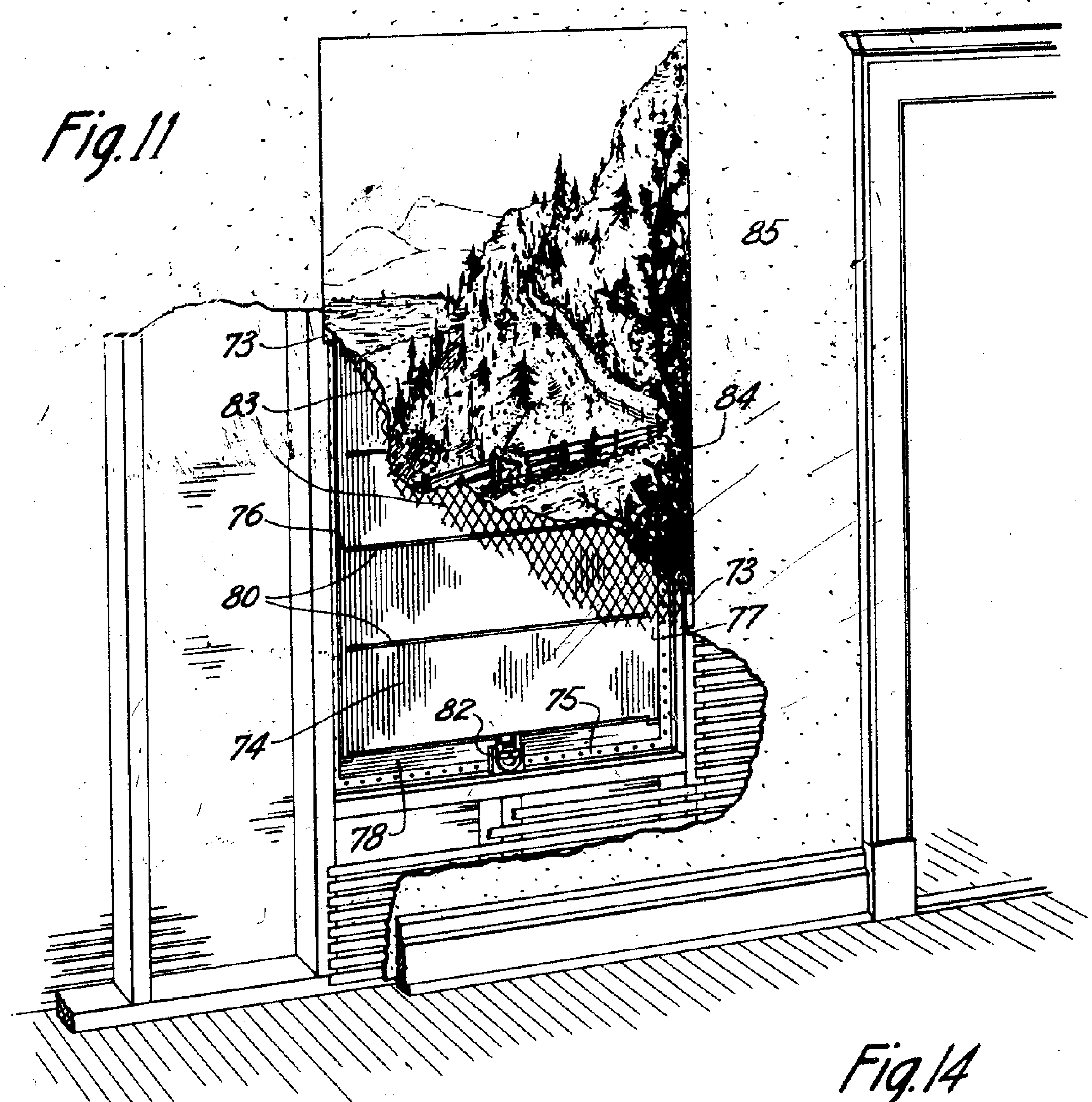


Fig. 12

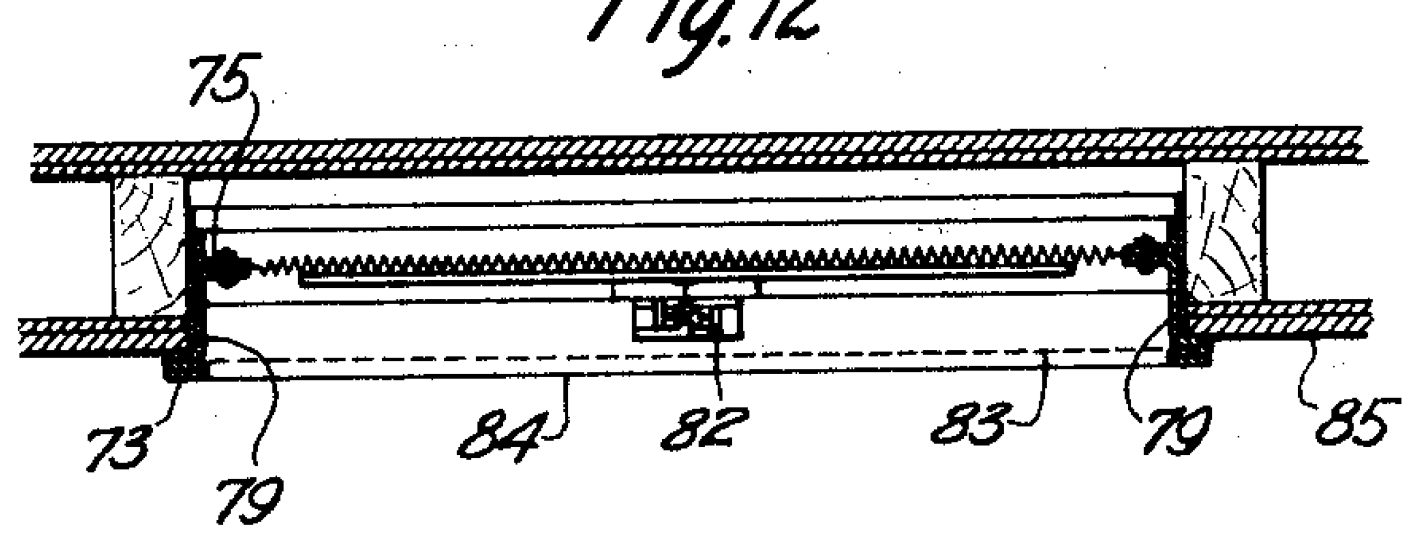


Fig. 13

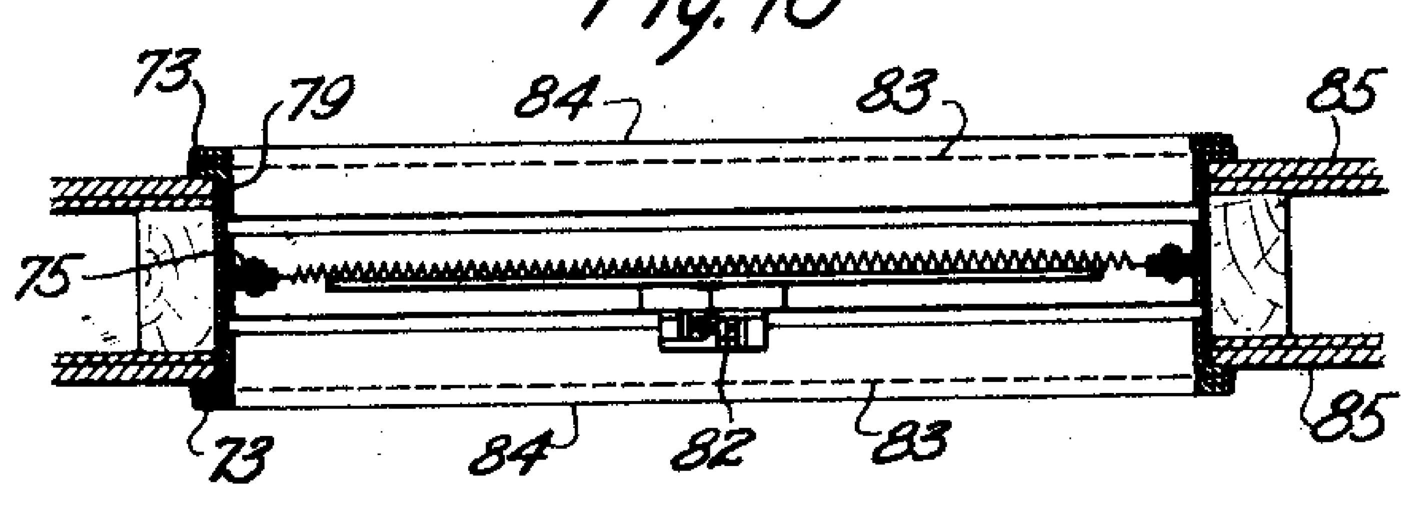
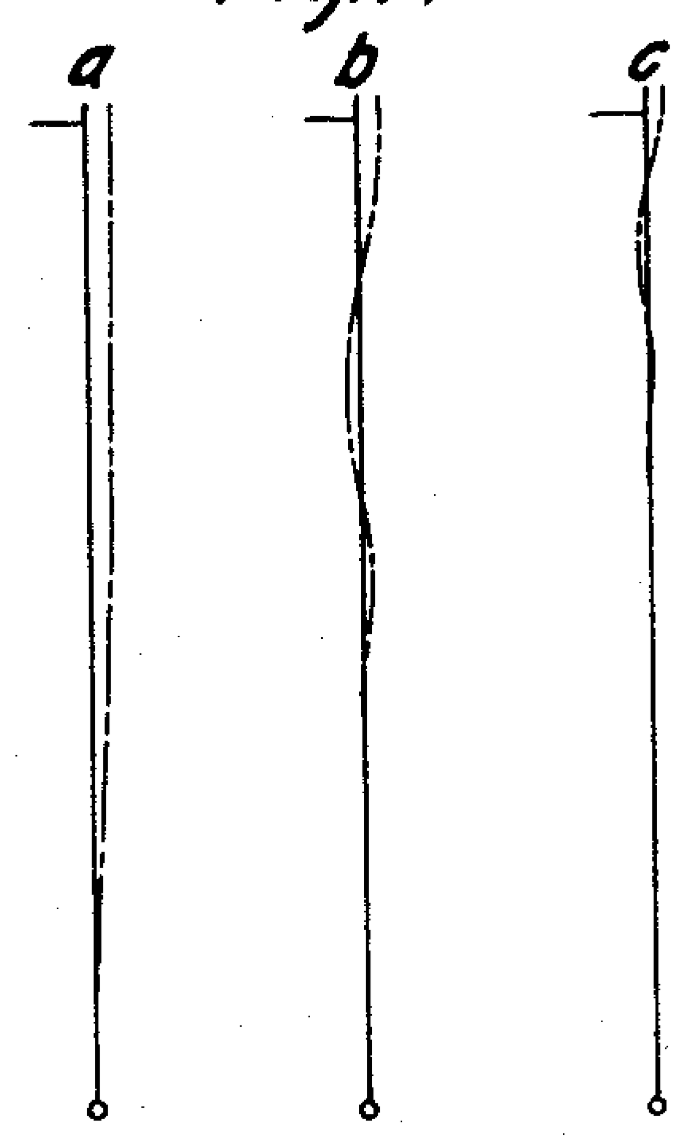


Fig. 14



Inventor:
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by Joel R. Palmer Atty.

Patented Aug. 26, 1930 **1,773,910**

UNITED STATES PATENT OFFICE

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SOUND RADIATOR

Application filed September 30, 1926. Serial No. 138,620.

This invention relates to sound radiators and particularly to the type in which a large vibrating structure radiates directly into the air.

An object of the 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.

The ideal sound radiator is one which emits sounds with uniform efficiency over the entire audible frequency range. The higher frequencies are especially important in reproducing speech since some of the consonant sounds have a large portion of their energy at the higher frequencies, for instance the sounds z, th, and s have a substantial portion of their energy at a frequency range above 5,000 cycles per second. The low frequencies on the other hand, are necessary for the faithful reproduction of music. The sound radiator of the present invention responds to the higher speech frequencies as well as the lower frequencies of the audible range, and has a fairly uniform frequency response characteristic.

In accordance with the invention, in a broad aspect, there is provided a large diaphragm which is hinged to a support at a peripheral portion and is driven at a portion remote from said hinged portion. In one embodiment of the invention, the diaphragm, which is preferably made of paper or other light material corrugated vertically and reinforced by horizontal stiffening ribs of wood or other light material, is hinged to a support at two opposite ends and driven by an electromagnetic element secured to stiffening ribs positioned remotely from the hinged portion of the diaphragm. The material, of which the diaphragm is made, extends, at each side edge, beyond the stiffening ribs to form flexible members which are attached to the upright portions of the stand or frame. The diaphragm may form a side of an enclosed air chamber, which may be one of a plurality of such air chambers, serving to effectively increase the mass of the diaphragm at low frequencies while at higher frequencies these enclosed spaces may serve as resonant chambers. The structure occupies very little space in the direction perpendicular to the plane of the diaphragm and may, therefore, be easily fitted into a wall or cabinet.

The invention may be more clearly understood by referring to the accompanying drawing in which:

Fig. 1 is a front view of one embodiment of the invention,

Figs. 2, 3 and 4 are sectional views taken along the lines 2—2, 3—3 and 4—4 of Fig. 1,

Fig. 5 is a diagrammatic showing of the wave propagation along a diaphragm of the type shown in Fig. 1,

Fig. 6 shows variously shaped diaphragms which may be employed in connection with this invention,

Figs. 7 and 8 are front and side views, respectively, of a modified form of the structure shown in Fig. 1,

Figs. 9 and 10 are sectional views taken along the lines 9—9 and 10—10, respectively of Fig. 7,

Figs. 11 to 13 show the invention in a form which is adapted to be set into a wall of a room, Fig. 11 being a perspective view partly in section and Figs. 12 and 13 being sectional views showing two different embodiments of the invention of the general form shown in Fig. 11, and

Fig. 14 is a diagrammatic showing of the wave propagation along a diaphragm of the type shown in Figs. 7 and 11.

Referring particularly to Figs. 1 to 4, inclusive, of the drawing, the rectangular shaped diaphragm 20 in a preferred form is made of crimped, pleated or corrugated flexible material and is preferably at least a square foot in area although it may be smaller. The diaphragm is reinforced by the stiffening ribs 21 and is connected to the frame 22 by the hinge-like members 23 which are preferably more flexible than the diaphragm. The stiffening ribs 21 in a preferred form are made of flat strips of wood or other light material having an edge formed to fit into the corrugations of the diaphragm to which the strip may be glued or otherwise secured. The driving element 24 is secured to the frame 22 by means of the upright angular bars 25 and the cross bar 26. The bars 25 are secured to the blocks 36 and 37 which are secured to the lower and upper portions, respectively, of the frame 22. The driving element 24 is preferably secured to the diaphragm so that the driving force is applied to one or more of the stiffening ribs 21 in order to actuate a relatively large portion of the diaphragm. This is accomplished by securing a wedge shaped member 28 to the side of the diaphragm opposite that to which the stiffening ribs are secured, this member extending between and slightly beyond two of these stiffening ribs. The vibrating member of the driving element is connected to the wedge-shaped member 28 by means of the rod 27, which is secured by means of the set screw 29. The diaphragm is supported at the edges by flexible members 30 and 31 which may be made of paper or other flexible material, preferably crimped, corrugated or the like, and may be glued or otherwise attached to the upright members 32 and 33 of the frame 22 along one edge, while the other edge is secured to a side edge of the diaphragm 20. In a preferred form the diaphragm 20 and the flexible members 30 and 31 are formed out of a continuous sheet of material. In a rectangular shaped structure, such as shown in Fig. 1, it is preferable to have the corrugations of both diaphragm 20 and of the flexible members 30 and 31 extend parallel to the sides of the diaphragm and the stiffening ribs 21 are preferably positioned substantially perpendicular to the direction of the corrugations.

The hinge member 23 has a substantially U-shaped cross-section, the projecting portions 34 and 35 being preferably glued to the base of the frame 22 as shown in Fig. 4 and the upper and lower edges of the pleated diaphragm may be glued to the U-shaped hinge members 23. The actuating means 24 may be of any desired form, a suitable electromagnetic driving means being that described in Patent 1,365,898 of January 18, 1921 to H. C. Egerton, modified as described in Patent No. 1,704,354 to R. L. Wegel, granted March 5, 1929. The member 38, which is preferably of flexible sound absorbing material such as felt, forms one side of an enclosed air chamber, the other sides of which are formed by the diaphragm 20 and the frame 22. The member 39 similar to member 38 encloses one side of a second air space between the members 38 and 39. The members 38 and 39 are secured to the rectangular frames 40 and 41 which are attached to the frame 22.

Another embodiment of the invention is shown in Figs. 7 to 10 inclusive, this embodiment differing in one respect from the structure shown in Fig. 1 in that the diaphragm in this case is hinged at only one edge and is driven along a stiffening rib positioned near the opposite edge. In this embodiment of the invention the diaphragm 50, preferably of corrugated paper, is reinforced by the stiffening ribs 51 and is hinged to the base 53 of frame 54 by means of the strip 52 of paper or other flexible material, the strip 52 being secured to the base 53 of the frame 54 and to the stiffening rib along the lower edge of the diaphragm. The flexible members 55 and 56 which are preferably formed by extending the diaphragm material beyond the ends of the stiffening ribs, are secured to the upright members of the stand 54. The flexible member 57 is attached to the stiffening rib near the upper edge of the diaphragm, and to the upper crosspiece 58 of the frame 54. The member 57 may also be pleated or corrugated, the direction of the corrugations preferably extending perpendicularly to the corrugations of the diaphragm 50. The actuating means 59 is attached to the cross piece 60 of the frame 54 and is connected to one of the ribs 51 by the rod 61. This rod is preferably attached to a stiffening rib near the upper edge of the diaphragm but it may be connected to other parts of the diaphragm, or a plurality of actuating means connected to several parts of the diaphragm may be employed. One way of securing the hinge member 52 and the flexible members 55, 56 and 57 to the frame 54 is indicated in Fig. 9. The edge of the flexible member 56 is shown inserted in the slot 62 in the upright member of the frame 54, where it is firmly clamped by tightening the screw 63.

Figs. 11, 12 and 13 show another embodiment of the invention in which the sound radiating structure is inserted in an opening in a wall. The diaphragm 74 which may be constructed similarly to the diaphragms 20 or 50 of Figs. 1 and 7, respectively, is shown connected to the frame 75 by the flexible members 76, 77 and 78 and by a hinge member, not shown. The stiffening ribs 80 are attached to the diaphragm 74 preferably perpendicularly to the direction of the corrugations. The wall 85 and flexible members 76, 77 and 78 together serve as a baffle to prevent sound waves radiated from one side of the diaphragm from reaching the opposite side. The frame 75, which is preferably adaptable to walls of various thickness, is set into a suitable opening in the wall 85 and is secured to the sides of the opening by wood screws, expansion bolts or other suitable means. The actuating means 82 is attached to the frame 75 and to the stiffening rib which is secured to the lower edge of the diaphragm 74.

A diaphragm of any size may be employed but it seems desirable for use in a living room or auditorium, to employ a structure about the size of a wall panel. The structure of this invention is particularly adapted for use as a wall type loud speaker, as shown in Fig. 11, because of its small dimension in the direction perpendicular to the plane of the diaphragm. Instead of having one large diaphragm about the size of the opening in the wall, two diaphragms of the same width but half the length of the opening may be employed. In this case one diaphragm is preferably hinged at the top of the opening and the other at the bottom, the edges opposite the hinged sides being adjacent near the midportion of the opening and being driven by a common actuating device or several actuating units preferably driven in synchronism. A single diaphragm of the type shown in Fig. 1 may also be employed, such a diaphragm being substantially equivalent to two diaphragms joined at their adjacent edges, hinged at the opposite edges, and driven along a stiffening rib positioned between the two hinged portions.

The embodiment of the invention shown in Fig. 11, aside from its practicability as an efficient and faithful reproducer of sound, is readily adaptable to the art of interior decoration. For this purpose a decorative screen of wire, sheet or molded metal, or carved wood may be used. Where desired, a screen of this sort may be used only for protecting the diaphragm and a hanging of silk, tapestry or other material may be used, over the screen, as a decoration. As shown in the drawing a protecting screen 83 and a decorative hanging 84, preferably of light material, are attached to the frame 73 which fits into the frame 75. When employing rather heavy hangings, it is preferable to have the upper portion of the frame 73 project slightly beyond the other edges of the frame and the front of the wall and to attach the hanging 84 to this projecting portion so as to avoid excessive damping of the radiated sound waves. Material of relatively light weight may, however, be stretched across the frame as shown.

In Fig. 13 the sound radiator is shown inserted in a wall between two adjoining rooms, in which case two frames 73 and their associated hangings 84 are employed, one on each side of the diaphragm. The sound radiator may also be employed in a wall which is closed up at its inner side as shown in Fig. 12. With this arrangement the enclosed space at the back of the frame may serve as a resonant chamber for accentuating certain frequencies.

While the exact mode of vibration of a diaphragm constructed in accordance with this invention has not been determined and while the invention is independent of the theory of operation, it seems very probable that the correct explanation of the operation of the improved diaphragm which accounts for the superior results obtained with it, is as follows: Considering first a low frequency force applied by the driving means to a diaphragm of the type shown in Fig. 7, the diaphragm will move substantially as a unit about the hinged portion as indicated at *a* of Fig. 14. At considerably higher frequencies the driving force sets up a wave motion in the diaphragm structure. This wave, which is initiated at all points along the upper edge of the diaphragm simultaneously, is propagated toward the hinged portion at a velocity dependent upon the elasticity and mass of the structure and is attenuated or damped as it progresses. The rate of damping, with respect to the distance traveled by the wave increases with frequency and at certain higher frequencies within the range employed in the reproduction of speech and music, the wave is attenuated to a very small amplitude, compared with its initial amplitude, before reaching the hinge and the energy radiated at this portion of the diaphragm becomes negligible. At still higher frequencies within this range, this point of negligible radiation is at a relatively short distance from the top of the structure. These conditions are diagrammatically represented at *b* and *c*, respectively, of Fig. 14. The diaphragm structure is given very great stiffness and small mass so that at the higher frequencies of the speech and music range the wave has greater amplitude and is propagated a greater distance and therefore involves a larger area of the diaphragm structure than would be the case if the stiffness were less or the mass greater. Furthermore, the driving force is applied not at a single point but simultaneously at all points along the upper edge of the diaphragm, which likewise increases the area of the diaphragm which is brought into active service at the higher frequencies, as compared with arrangements in which the driving force is applied at a single point or along a relatively short line.

As stated above the diaphragm of the type shown in Fig. 1 differs from the one shown in Fig. 7, essentially in that the former consists in effect of two diaphragms of the latter type joined and driven along the edge opposite the hinged portion, but these diaphragms also differ from each other in the type of hinge employed. The diaphragm of the structure shown in Fig. 1, because of the type of hinge employed and also because of the relatively large degree of stiffness at the driven portion of this diaphragm in the direction perpendicular to the stiffening ribs moves substantially as a unit at low frequencies, that is, all portions of the diaphragm are displaced equally as shown at *a* of Fig. 5. At higher frequencies, the diaphagm vibrates as indicated at *b*, *c* and *d* of Fig. 5, these diagrams being the same as those shown at *a*, *b* and *c* of Fig. 14 except that in Fig. 5 the waves are shown traveling in both directions from the driven portion toward the two hinged members.

One effect which the enclosed air chambers, shown in Fig. 2, have upon the frequency response characteristic of this sound radiator, is probably to increase the amplitude of the low frequency vibrations. At low frequencies the air spaces and the flexible members 38 and 39 move as a unit in synchronism with the diaphragm, and the mass of the air and the flexible members is thus effectively added to that of the diaphragm. Since a diaphragm having a relatively high ratio of mass to stiffness is resonant at a low frequency, the efficiency of the diaphragm at low frequencies is increased due to the addition of the air chamber mass to the mass of the diaphragm. At relatively higher frequencies the diaphragm does not move as a unit but breaks up into waves as shown at c and d of Fig. 5. For this condition there is no tendency for the diaphragm to move the mass of the enclosed air as a unit and, therefore, the mass of the diaphragm is not effectively increased as is the case at lower frequencies. These air chambers, however, may be of such size that they are resonant to waves of relatively high frequency. These two effects then, may serve to increase the efficiency of the diaphragm at both the upper and lower ends of the sound frequency range.

In order to apply the driving force simultaneously to all points along the driven portion of the diaphragm it is necessary that the stiffening rib at this edge be inflexible. To make this stiffening rib substantially inflexible would necessitate its having a considerable mass, which would be particularly disadvantageous because of its location at the point of maximum amplitude of vibration. However, by providing a series of stiffening ribs parallel to the hinged edges of the diaphragm and distributed over the surface in a manner preferably to be determined by trial, the same result can be accomplished in a somewhat lesser degree. There is then, obviously, not the necessity for as great stiffness in each of a plurality of stiffening ribs as in a single rib used alone, and the total mass is distributed advantageously.

While it seems preferable to apply the driving force along a relatively long line on the diaphragm, the stiffening ribs may be employed to increase the vibrating area of the diaphragm even where the driving force is applied along a relatively short line on the diaphragm. If at e of Fig. 6 the driving force is applied to a very short rib 91 secured to the upper portion of the diaphragm, the movement of this rib will set into vibration at least the rectangular area enclosed by the ribs 91 and 92 and the projection lines of rib 91 extending to rib 92. The vibrations of this area will serve to actuate the rib 92, thereby setting up vibrations in at least the rectangular area enclosed between the ribs 92 and 93 and the projection lines of rib 92 on rib 93. In this way the vibrating area of the diaphragm is appreciably increased by the use of the stiffening ribs even though the diaphragm is driven along a relatively short line.

It will be clear from what has just been stated that an advantage may sometimes be gained by varying the shape of the diaphragm structure to eliminate the outermost portions adjacent the stiffening rib to which the driving force is applied. This is shown at a and e of Fig. 6. Furthermore, the relative efficiency at various frequencies throughout the range may be modified by otherwise varying the shape of the diaphragm as shown for instance at b, c and d of Fig. 6. The stiffening ribs may be variously positioned and shaped to assist in obtaining a desired transmission characteristic.

While the drawings show a substantially plane, corrugated diaphragm of a variety of shapes, it is to be understood that the scope of the invention includes diaphragms made in various other shapes and forms than shown in the drawing and various other means for stiffening the diaphragm. For example, the diaphragm may be curved rather than plane and the periphery may be circular or elliptical. The term "direct acting diaphragm" is used in the claims to signify a diaphragm which acts directly upon the unrestricted sound medium into which it radiates.

What is claimed is:

1. A sound radiator comprising a direct acting plane corrugated diaphragm hinged at a peripheral portion to a supporting means, and means to drive said diaphragm at a portion remote from said hinged portion.

2. A sound radiator comprising a direct acting plane diaphragm hinged at a peripheral portion to a supporting means, and means to drive said diaphragm at a portion remote from said hinged portion.

3. A sound radiator comprising a flat pleated diaphragm at least one square foot in area hinged at a peripheral portion to a supporting means, and actuating means to drive said diaphragm at a portion remote from said hinged portion.

4. A sound radiator comprising a plane diaphragm of flexible corrugated material hinged at a peripheral portion to a supporting means, stiffening ribs for said diaphragm transverse to the corrugations in said material, and actuating means to drive said diaphragm at a portion remote from said hinged portion.

5. A sound radiator comprising a direct acting diaphragm hinged at a peripheral portion to a supporting means, flexible members attached to said diaphragm and to said supporting means for, in part at least, closing the opening therebetween, and actuating means connected to said diaphragm to drive it at a portion remote from said hinged portion.

6. A sound radiator comprising a dia-

phragm of flexible corrugated material hinged at a peripheral portion to a supporting means, a plurality of stiffening ribs attached to the diaphragm and extending in an angular direction with respect to the direction of said corrugations, flexible members attached at one edge to said diaphragm and at the other edge to said supporting means, and actuating means connected to the diaphragm to drive it at a portion remote from said hinged portion.

7. A sound radiator comprising a diaphragm, a support, a hinge along at least one straight edge of said diaphragm between said diaphragm and said support, spaced stiffening ribs for said diaphragm parallel to said hinge, and driving means the vibrating element of which is attached to at least one of said ribs.

8. A sound radiator comprising a diaphragm, a support, a flexible hinge along at least one straight edge of said diaphragm connecting said diaphragm with said support, spaced stiffening ribs for said diaphragm parallel to said hinge, said ribs assisting in giving said diaphragm a fairly constant transmission characteristic over a wide range of frequencies, and driving means the vibrating element of which is attached to at least one of said ribs.

9. A sound radiator comprising a diaphragm of relatively light corrugated material, a support, a flexible hinge along at least one straight edge of said diaphragm connecting said diaphragm to said support, spaced stiffening ribs for said diaphragm parallel to said hinge, said ribs cooperating with the corrugations of said material to assist in giving said diaphragm a fairly constant transmission characteristic over a wide range of frequencies, and driving means the vibrating element of which is attached to at least one of said ribs.

10. A sound radiator comprising a diaphragm, a support, a flexible hinge along a straight edge of said diaphragm connecting said diaphragm with said support, a stiffening rib parallel to the hinge, and driving means the vibrating element of which is attached to said stiffening rib.

11. A sound radiator comprising a corrugated diaphragm, a plurality of stiffening ribs attached to said diaphragm and extending in an angular direction with respect to the direction of said corrugations, a supporting means near a peripherial portion of said diaphragm, and means attached to at least one of said stiffening ribs for actuating said diaphragm.

12. A sound radiator comprising a diaphragm of flexible corrugated material hinged to a support, stiffening ribs for said diaphragm shaped to fit into the corrugations of said diaphragm, and actuating means the vibrating element of which is attached to at least one of said stiffening ribs.

13. A sound radiator comprising a diaphragm of flexible corrugated material hinged to a support, parallel stiffening ribs attached to said diaphragm, an intersecting rib for connecting at least two of said parallel stiffening ribs, and means attached to said intersecting rib for driving said diaphragm along said parallel ribs.

14. A sound radiator comprising a diaphragm of flexible corrugated material having stiffening ribs attached thereto, substantially U-shaped hinged members, the bases of which are attached to an edge of said diaphragm substantially parallel to said stiffening ribs, projecting members forming a part of said U-shaped hinged member for securing said hinged member to a support, and actuating means for driving said diaphragm along one of said stiffening ribs.

15. A sound radiator comprising a diaphragm of flexible corrugated material, stiffening ribs attached to said diaphragm extending substantially perpendicular to the corrugations of said diaphragm, a substantially U-shaped hinged member extending substantially parallel to said stiffening ribs for connecting a peripheral portion of said diaphragm to a support, driving means secured to a portion of said diaphragm remote from said hinged member for moving said diaphragm substantially as a unit at low frequencies.

16. A sound radiator comprising a stiffened diaphragm, flexible hinge members for connecting a peripheral portion of said diaphragm to a support, means for driving said diaphragm at a portion remote from said hinged members, and enclosed air spaces, one side of which is formed by said diaphragm, for effectively increasing the mass of said diaphragm when driven at relatively low frequencies.

17. A sound radiator comprising a stiffened diaphragm, substantially U-shaped hinge members for connecting said diaphragm to a support, means for driving said diaphragm substantially as a unit at low frequencies and for setting up waves in said diaphragm at substantially higher frequencies, and adjacent air chambers at least partially enclosed by flexible material, one of said air chambers being partially enclosed by said diaphragm, said air chambers assisting in giving said diaphragm a fairly constant transmission characteristic over a wide range of frequencies.

In witness whereof, I hereunto subscribe my name this 28th day of September, A. D. 1926.

CLARENCE E. LANE.