April 25, 1933. H. C. HARRISON 1,905,704

ACOUSTIC DEVICE

Filed May 14, 1930 3 Sheets-Sheet 1

FIG. 1

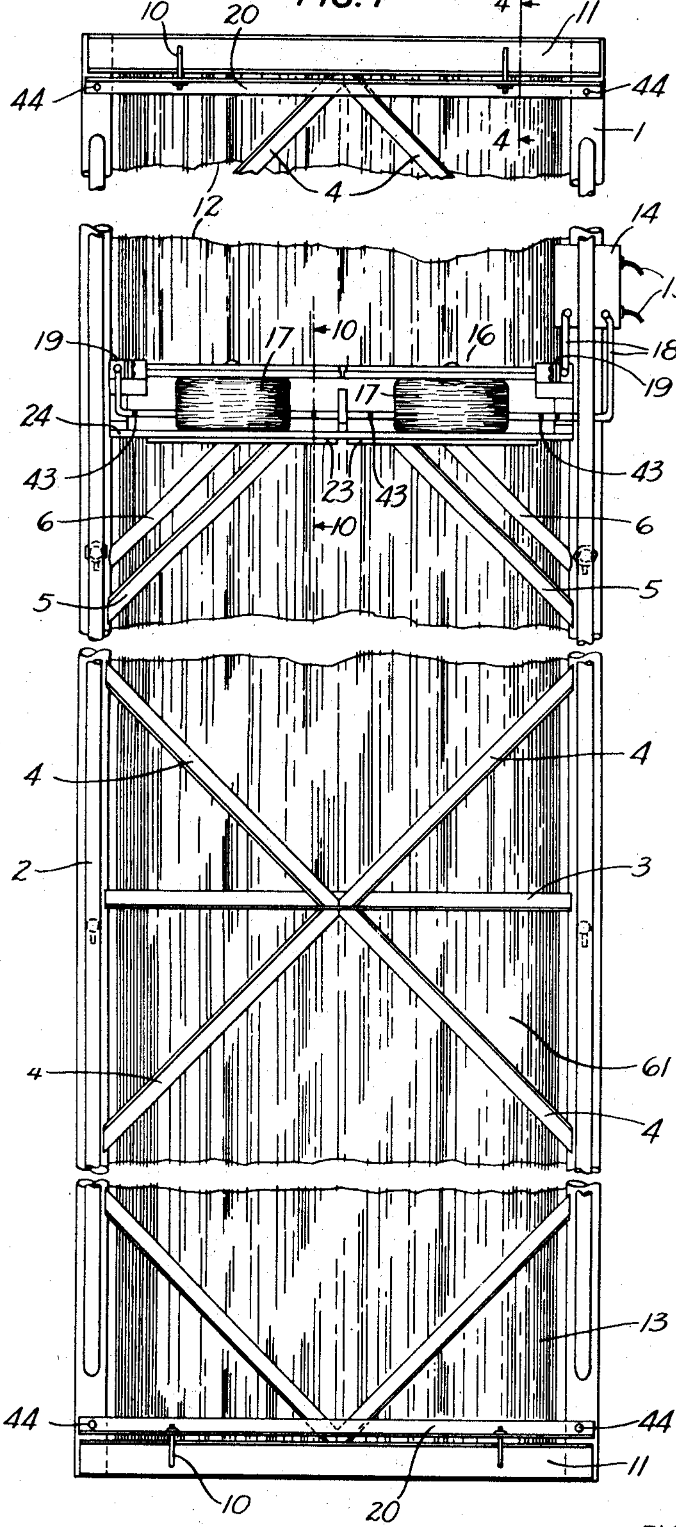
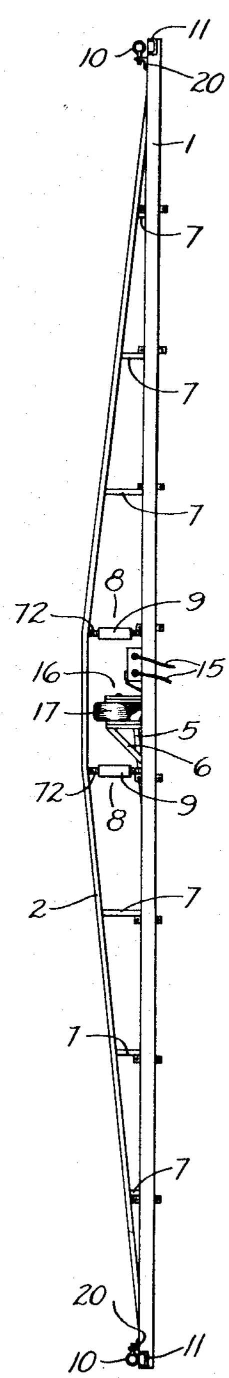


FIG. 2



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ACOUSTIC DEVICE

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FIG. 3

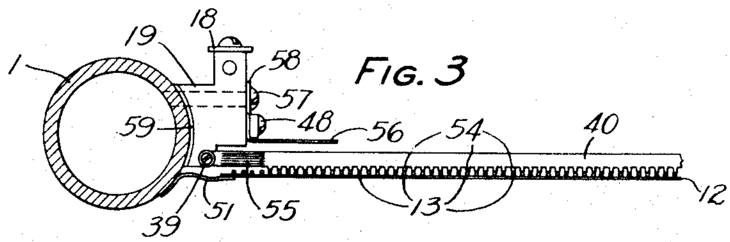


FIG. 4

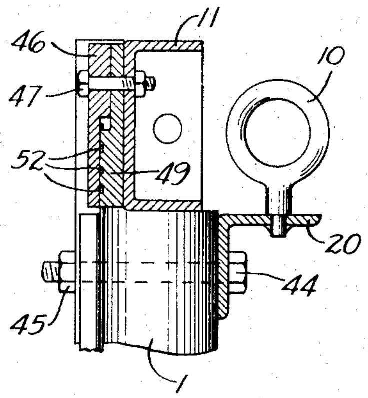


FIG. 5

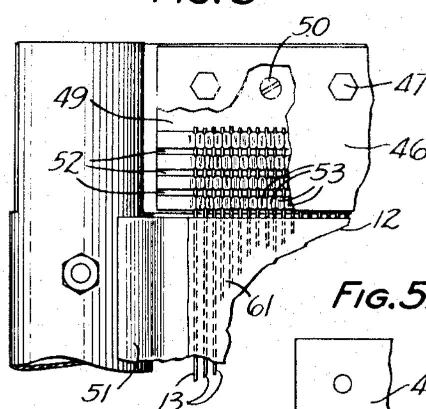


FIG. 5A

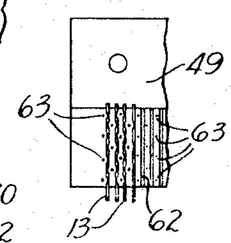


FIG. 6

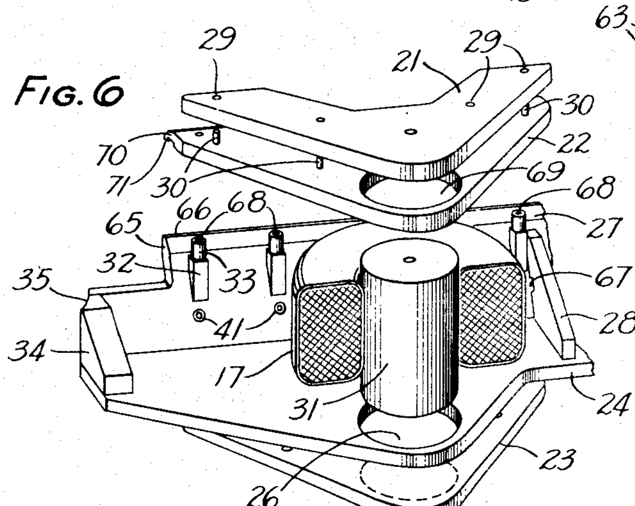
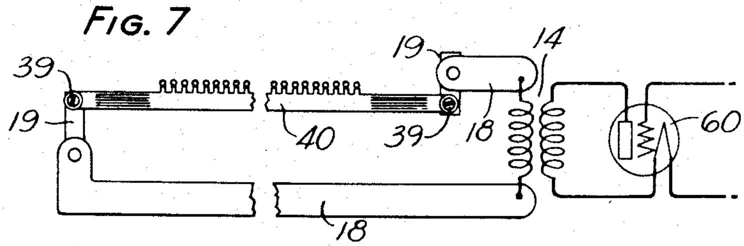


FIG. 7



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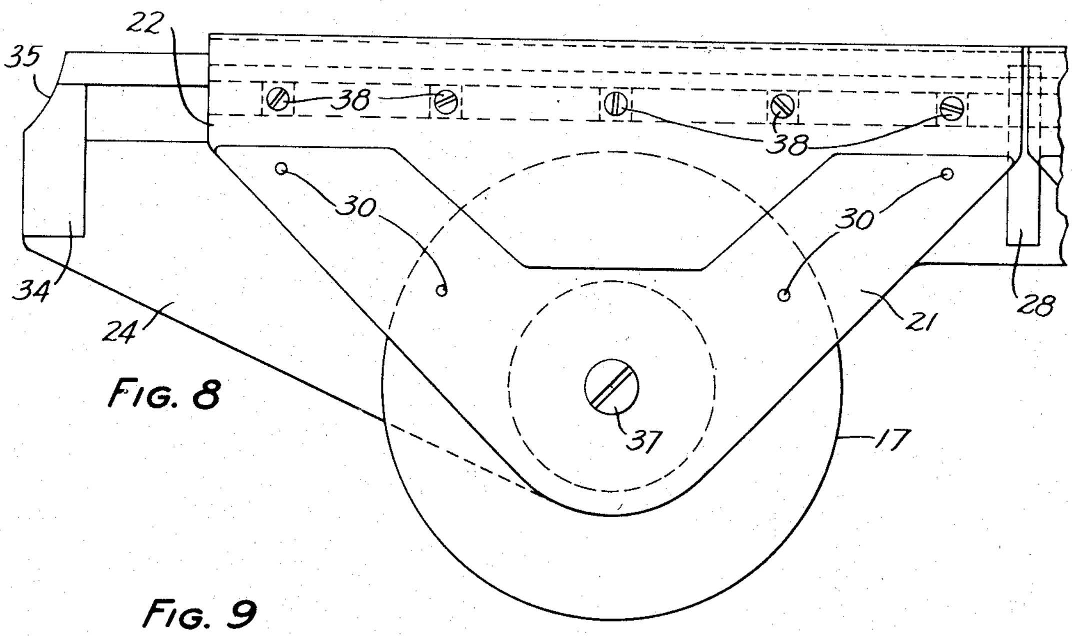


FIG. 8

FIG. 9

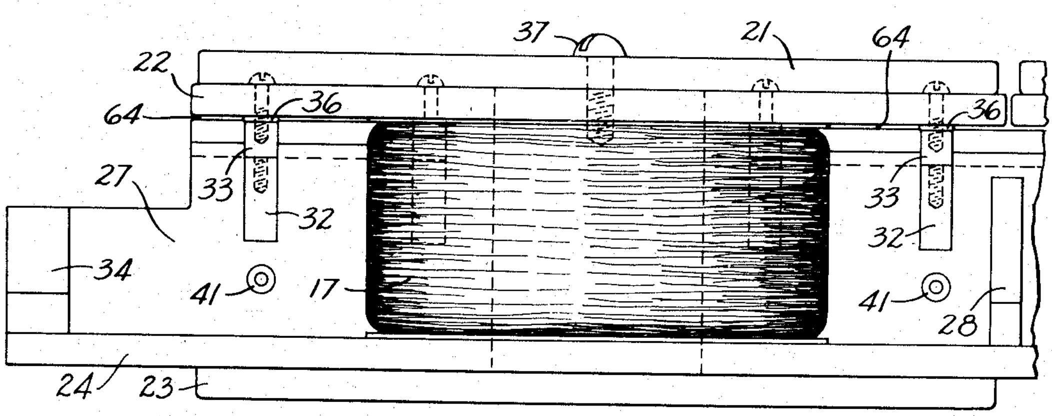
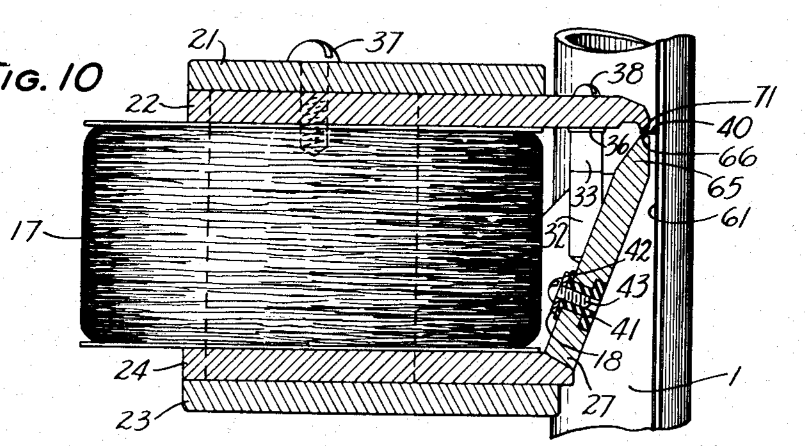


FIG. 10



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Patented Apr. 25, 1933

1,905,704

UNITED STATES PATENT OFFICE

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ACOUSTIC DEVICE

Application filed May 14, 1930. Serial No. 452,154.

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

The 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.

One feature of this invention resides in the sound radiator employed to translate the vibrations impressed thereon into sound disturbances.

Another feature of this invention resides in the driving means employed to impart acoustic vibrations to said sound radiator.

Still another feature resides in the magnetic structure forming a part of said driving means.

In accordance with this invention there is provided a direct acting sound radiator comprising a plurality of tensioned members to which is secured some thin material to prevent acoustic short circuit between opposite surfaces thereof and driving means therefor comprising a current carrying member of a material having a high ratio of conductivity to mass, said strip being secured to and across one face thereof and intermediate its ends. This current carrying member is disposed in an elongated magnetic air-gap formed by a pair of parallel pole pieces which are elements in a magnetic structure which allows a maximum and uniform distribution of magnetic flux with the use of a comparatively small amount of copper in the energizing coils of the magnet.

A more complete understanding of this invention will be obtained by reference to the appended drawings wherein:

Fig. 1 shows fragmentarily an embodiment of this invention incorporating the features thereof;

Fig. 2 is a side elevation to a reduced scale of the embodiment shown fragmentarily in Fig. 1;

Fig. 3 shows a portion of the strip drive forming a feature of this invention;

Fig. 4 is a fragmentary section of a portion of the frame of the structure shown in Fig. 1 along line 4—4;

Fig. 5 is a front elevational view of Fig. 4 showing in detail the means employed for securing the extremities of the tensioned elements employed in the sound radiator;

Fig. 5—A shows a variation in the tensioned member securing means shown in Fig. 5;

Fig. 6 is an exploded view of a portion of the magnetic structure comprising a feature of this invention;

Fig. 7 is a schematic of the circuit provided for the electrical impulses which are to be reproduced by the sound radiator;

Figs. 8 and 9 are plan and rear elevational views of a portion of the magnet structures shown in Figs. 1 and 2; and

Fig. 10 is a section of the magnetic structure shown in Fig. 1 along the line 10—10.

Referring now to the drawings, Figs. 1 and 2 show a sound reproducer incorporating the features of this invention. There is provided a frame which supports a diaphragm 61, a magnet structure 16 and a transformer 14 which latter is provided with input leads 15. This frame comprises vertical supports 1 which may be of iron pipe or other suitable material and horizontal channel members 11 which extend between the extremities of the vertical supports and may be secured thereto in any desired manner preferably by welding. The frame is strengthened by angle irons 3 extending between the vertical supports and by angle irons 4 which extend angularly between said members 3 and supports 1. Members 3 and 4 are welded preferably to one another and to the supports. To give the frame greater rigidity, bracing members 2, which may be of iron pipe, are secured at their extremities to the vertical supports 1, preferably, by welding, and are maintained spaced therefrom by spacer members 7 and 8. The spacer members 8 comprise studs secured to the bracing member 2 and the support 1 and are coupled together by a turn buckle element 9.

This sound reproducer may be placed on any flat surface resting on either its longer or shorter dimension, or may be supported from a ceiling, wall or frame by means of the eye bolts 10 which are secured to channel members 20, in turn secured to the supports 1 by bolts 44 and nuts 45. Intermediate the extremities of the frame, and in operative relation to the diaphragm 61, is the magnet structure 16 which is secured at its opposite ends to the supports 1 preferably by welding and supported by the members 5 and 6 which extend angularly between the lower portion thereof and the supports 1. The magnet structure will be more fully described hereinafter with reference to Figs. 6, 8, 9 and 10.

Figs. 1 and 2 show, further, the energizing coils 17 therefor and the terminals 19 for the strip member 40 (Fig. 3) whose movements are communicated to the diaphragm and cause it to vibrate and radiate sound. Connected to the terminal blocks 19 are conductors 18 of highly conductive material and of large cross section which provide the return path to the transformer 14 for the currents passing therefrom to the conducting strip 40. Conductors 18 may be of aluminum or of copper or of any other material having preferably a low impedance and may be secured conveniently to, but conductively insulated from, a portion of the magnet structure. As shown in Fig. 10, this may be accomplished at definite intervals along its length by spacing the conductor 18 from the portion 27 of the magnet structure by a washer 42 of insulating material and securing it against the latter by screw 43 which threads into a T-sectioned block of insulation 41 which fits into a recess in the portion 27.

The diaphragm 61 comprises a plurality of parallel tensioned members 13 spaced very short distances apart and extending between the extremities of the frame, and a thin material 12 preferably, imperforate to air, which is secured to said tensioned members to prevent acoustic short circuit between the opposite surfaces thereof. The length of the diaphragm is preferably greater than twice its width and also greater preferably than one-half the wave length of the lowest frequency to be radiated. Such a diaphragm has been found highly satisfactory as a sound radiator which may be tensioned to a desired degree in the direction of its long dimension only, if desired, and having substantially no tenssion therein in a direction transverse to its length. The diaphragm is preferably tensioned to such a degree that the sound vibrations are propagated therein at a velocity greater than one-quarter that of sound in air. It may be desirable to introduce a slight lateral tension in the diaphragm to maintain the desired velocity of propagation in the diaphragm and to counteract the effect of the mass of air into which it is working which has a tendency to reduce the attenuation. Such a diaphragm is disclosed in R. L. Wegel Patent 1,870,271, patented August 9, 1932. As here employed, tensioned members 13 may be wires of duralumin and the thin material secured to them may be of paper.

A means for securing these wires in spaced relation and maintaining them in that condition is shown in Figs. 4 and 5. Secured by bolts 50 to the channel member 11 extending between the supports 1 is a member 49 which is preferably of a material similar to that employed for the tensioned elements 13. This member 49 has parallel saw cuts 52 and at right angles thereto a series of saw cuts in which the extremities of the elements 13 are positioned and clamped against movement by forcing the portions 53 between the vertical saw cuts about the portions of the tensioned elements in each saw cut. It will be understood that one of these members is employed at each extremity of the tensioned elements and that one extremity of each wire may be initially secured in such means, then the other extremity subjected to the tensioning force necessary to produce the desired condition of strain therein and thereafter clamped in a like securing means. As a protection to the wire securing member 49, an elongated member 46 is positioned over it and maintained in place by bolts 47 which project through the members 46 and 49 and the channel cross member 11. Fig. 5 shows also a strip 51 of thin flexible material, such as leather, which is secured to the support 1 and to the lateral edge of the diaphragm. Such a flexible strip is employed along each lateral edge of the diaphragm extending in the direction of its longer dimension to prevent acoustic short circuit between opposing surfaces of the sound radiator in the area between the lateral edges thereof and the vertical supports 1 of the frame.

Substantially the result obtained with the tensioned element holding means of Fig. 5 may be secured by the modification thereof shown in Fig. 5—A. Cross cuts 52 are omitted and continuous parallel vertical slots 62 are provided in which the extremities of the elements 13 are placed. They are secured therein by causing the material between the slots 62 to overlap the elements 13 therein as shown. This may be accomplished by using a punching tool and striking the member 49 at the staggered points 63 with sufficient force to cause the desired displacement of the material between said slots thereby clamping the wires therein.

The diaphragm or sound radiator comprising tensioned elements 13 and thin material secured thereto is driven by a current conducting strip which is secured intermediate the ends thereof to and across the face of the diaphragm at substantially right angles thereto. This strip is of a material having a high ratio of conductivity to mass and is disposed in an elongated magnetic air-gap formed by the parallel pole pieces of an electromagnetically energized magnet structure 16.

Referring to Fig. 3, a portion of this conducting strip 40 is shown and is, preferably, of aluminum or copper. As shown it is thin, flat and ribbon-like in structure, altho a plurality of such strips forming a portion of the winding of an elongated coil could be employed. It is provided with a plurality of feet 54 each of which is secured to one of the tensioned elements 13 providing what is virtually an individual drive for each tensioned element. Near each extremity of this elongated strip is a portion 55 which is shredded or slotted to give it flexibility in that region. This flexibility could also be obtained by having that portion of the strip of thin foil but of appropriate cross section. Each end of the strip may be secured directly to the terminal block 19 by soldering it thereto, if desired, or, as shown, by means of a screw 39. Terminal block 19 which may be of a material such as brass is fastened to the support 1 by a screw 57 which is surrounded by a sleeve 58 of insulating material to avoid a metallic circuit between the terminal block and support. The terminal block is electrically insulated therefrom further by a plate of insulating material 59, such as hard rubber. Guard member 56 secured to the terminal block by a screw 48 is provided to protect each extremity of the conducting strip.

It will be understood, of course, that the strip or conductor 40 may be homogeneous in section at all points therealong or that it may consist of a ribbon-like strip of material having non-integral feet portions which are secured to one edge thereof and providing means for positioning the conductor wholly within the field of the magnet structure and for securing it to the diaphragm. As a further modification, feet portions 54 may be omitted altogether and the conductor secured directly along one edge thereof to and across the face of the diaphragm, substantially at right angles thereto.

Fig. 7 is a schematic of the circuit for the electrical impulses which are to be reproduced by the sound reproducer incorporating the features of this invention. The conducting strip 40 is shown connected at its extremities to the terminal blocks 19 as are also the return conductors 18 to the secondary of the transformer 14 whose primary is shown connected in the output circuit of the last stage 60 of an amplifier. The return conductors 18 are of a material of high conductivity, for instance, of copper, and are of large cross section to reduce to a minimum dissipation of energy therein. Preferably the impedance of the strip 40 is substantially equal to the combined impedances of the secondary of the transformer 14 and the low impedance return conductors 18 which are shown in Figs. 1, 3 and 7 as connected to the terminal blocks 19. It will be apparent that a negligible percentage only of the currents flowing through the strip 40 will pass through the feet portions 54 and that these portions may be connected directly to the tensioned elements 13. In the normal position of the strip 40 in the elongated air-gap of the magnetic structure, these feet portions need not be therewithin. This provides the necessary clearance between the diaphragm and the magnet structure without any appreciable portion of the currents passing through the strip 40 traversing the portion thereof without the magnetic air-gap. If the feet portions 54 were of non-conductive material, the current flow in the strip or conductor 40 would be wholly in that portion thereof within the magnetic air-gap. The normal position of the conducting portion 40 is shown clearly in Fig. 10.

The detailed description above has been with reference to a diaphragm comprising a plurality of tensioned elements closely spaced together and with a thin material imperforate to air secured thereto to prevent acoustic short circuit between opposite surfaces thereof. Although this sound radiator is preferred, it will be understood that a uniformly tensioned sheet diaphragm such as is shown in my Patent 1,726,105, issued August 27, 1929, may be employed or a transversely corrugated sheet diaphragm such as is disclosed in E. H. Smythe Patent 1,821,586, issued Sept. 1, 1931. Furthermore instead of using a diaphragm of a single large sheet as disclosed in the patents referred to above, one made up of a plurality of elongated strips of uniformly tensioned diaphragm material may be employed.

The magnet structure forming a feature of this invention will now be described with reference to Figs. 1, 6, 8, 9 and 10. As shown in Fig. 1, magnet structure 16 extends between the vertical supports 1. It provides an elongated air-gap 64 in which is positioned a conducting strip 40 secured across the face of the diaphragm 61. An elongated permanent magnet with oppositely disposed pole portions might be employed to provide the desired uni-directional magnetic field across said air-gap but for the purpose of this disclosure electromagnetic means are preferred. It is understood of course that a conductor disposed in a uni-directional magnetic field and carrying an electric current will be acted upon by forces whose direction and magnitude depend upon the character and amplitude of the currents flowing therein, the strength of the magnetic field in which it is positioned, and the direction in which the latter is acting. Further, to have the conductor acted upon along its length with the same force at all points thereon with a given current flowing therethrough, the strength of the uni-directional magnetic field should be uniform at all points there along. This condition has been attained with the structure now to be described, said structure being compact and requiring a minimum of copper in its energizing coils.

Figs. 6, 8 and 9 are exploded, plan and rear elevation views of slightly more than one-half of the magnet structure, it being understood that the structure is symmetrical in outline. A metallic plate 24 of a magnetic material, such as soft iron, is secured to an angularly disposed metallic plate 27, which may be of soft iron also, which forms one pole piece of the electromagnet. The member 27 has a tapered edge portion 65 converging to form a long narrow edge 66, so that when magnetic flux is produced in said pole piece, it is concentrated in an elongated rectangular area. To give rigidity to this assembly, blocks 34 and 28 are fastened, for instance, by welding, to their inner surfaces. Surface 35 of block 34 is curved to fit the curvature of supports 1. An opening 67 is provided in strengthening member 28 for the conductor 18 which is secured to but electrically insulated from member 27. To insure a uniform distribution of magnetic flux to the member 27, members 23 of magnetic material and triangular in shape are positioned on the under surface of the member 24 and may be secured thereto in any suitable way, for instance by welding. Supported by the member 27 are blocks 32 whose upper portions 33 are of a non-magnetic material such as brass and are provided with tapped drillings 68 into which screws 38 may be threaded. Supported by the member 24 are cores 31 of magnetic material which are surrounded by energizing coils 17 which may be connected to a source of current when it is desired to magnetically energize the cores. The core is secured to the triangular member 23, preferably by welding it thereto but a screw projecting through said member and into the core would be satisfactory. The other pole of the electromagnet comprises members 22 which are also triangular in shape. Each member 22 has an opening 69 therein into which the core 31 projects and dowel pins 30 with which the openings 29 in the V-shaped members 21 register. Members 21 and 22 are of magnetic material and may be fastened to one another by any suitable means. A screw 37, passing through member 29 and threading into the core 31, and screws 38, passing through the member 22 and threading into the portions 33 of the blocks 32, hold these members firmly in place. The portion 70 of the member 22 projecting out beyond this support by the blocks 32 is so shaped as to concentrate the magnetic flux which may be present therein and terminates in an elongated surface 71 oppositely disposed with reference to the surface 66 forming the other pole face of the electromagnet.

It will be apparent that the structure described permits of a uniform distribution for the magnetic flux produced in the core 31 when energizing currents are flowing in coils 17 and provides a long narrow air-gap within which a current conducting strip may be placed. The width of the air-gap may be varied by using different thicknesses of washers 36 between the under surface of the member 22 and the upper portion 33 of the block 32. It will be apparent, also, that, if desired, elements 21 and 22 may be formed as an integral unit as may, also, elements 23 and 24.

There has been described a sound reproducer of the electro-dynamic type in which the moving element comprises a conducting strip disposed in an elongated magnetic air-gap and secured to and across the face of an elongated diaphragm which is in a condition of uniform tension and which comprises preferably a plurality of tensioned elements securely held at their extremities. The conducting strip is preferably provided with a multiplicity of feet portions, one secured, preferably, to each tensioned element and is adapted for movement in accordance with the sounds to be reproduced, said movement resulting from motor action between the current conducting strip and the uni-directional magnetic field in which it is located; the movements being in the plane of the conductor. These movements are communicated to the diaphragm and sound energy is radiated therefrom to the atmosphere.

It is to be understood that the embodiment of this invention described above and shown on the appended drawings is illustrative of the invention and that its scope is to be limited only by the appended claims.

What is claimed is:

1. A sound reproducing device comprising an elongated direct acting diaphragm, means defining a magnetic air-gap, and a current conducting member disposed in said air-gap and secured to and across the face of said diaphragm along its short dimension, said member having integral flexible portions near its extremities.

2. In combination, a direct acting diaphragm comprising a plurality of elongated elements, means defining a magnetic air-gap, and a current conducting member disposed in said air-gap and secured to said diaphragm, said member having a plurality of projecting portions, each of which engages with at least one of said elongated elements.

3. In combination, a direct acting diaphragm comprising a plurality of elongated metallic elements, means defining a magnetic air-gap, and a current conducting member disposed in said air-gap and secured to said diaphragm, said member having a plurality of projecting portions, each of which is attached to at least one of said elements.

4. In combination, a diaphragm having a length substantially greater than twice its

width and more than one half the wave length of the lowest frequency to be reproduced, comprising a plurality of spaced elements and a thin material secured thereto, said diaphragm being tensioned substantially along its length only, means defining a magnetic air-gap, and a current conducting member attached to said diaphragm's spaced elements, said member being disposed in said magnetic air-gap.

5. In combination, a diaphragm comprising a plurality of spaced elongated elements, means for securing said elements at their extremities, said means comprising a member having depressions into which the extremities of said elements are placed and clamped therein by displacement of the material between said depressions, and means for actuating said diaphragm.

6. In a sound reproducing device, a frame, a diaphragm supported by said frame, and comprising a plurality of metallic elements to which is secured a thin material imperforate to air, thin flexible means intermediate the lateral edges of said diaphragm and frame to minimize acoustic short circuit between the surfaces of said diaphragm, means for actuating said diaphragm comprising a thin flat conductor secured to and across one surface of said diaphragm intermediate its ends, said conductor having flexible portions near its extremities, and a magnet structure providing an elongated magnetic air-gap in which a portion of said conductor is disposed.

7. In combination, a diaphragm and means for driving said diaphragm, said means comprising a conducting member secured to said diaphragm and a magnet structure including pole pieces disposed to form a magnetic air-gap, each of said pole pieces being so shaped as to insure a uniform distribution of magnetic flux at all points along said air-gap one of said pole pieces comprising a triangular shaped portion and a V-shaped portion.

8. In an acoustic device, a diaphragm comprising a plurality of elongated metallic elements, means defining a magnetic air gap, and a current conducting member disposed in said air gap and secured to said diaphragm, said member comprising a plurality of serrations each of which is attached to at least one of said elements.

9. In combination, a diaphragm and means for driving said diaphragm, said means comprising a conducting member secured to said diaphragm and a magnet structure including pole pieces disposed to form a magnetic air gap, one of said pole pieces comprising a triangular shaped portion and a V shaped portion, the apex of said V being farthest removed from the air gap, and the arms of the V extending toward the magnetic air gap.

In witness whereof, I hereunto subscribe my name this 12th day of May, 1930.

HENRY C. HARRISON.