Aug. 3, 1965 S. R. RICH 3,198,890

HIGH FIDELITY SOUND REPRODUCER

Filed June 14, 1961

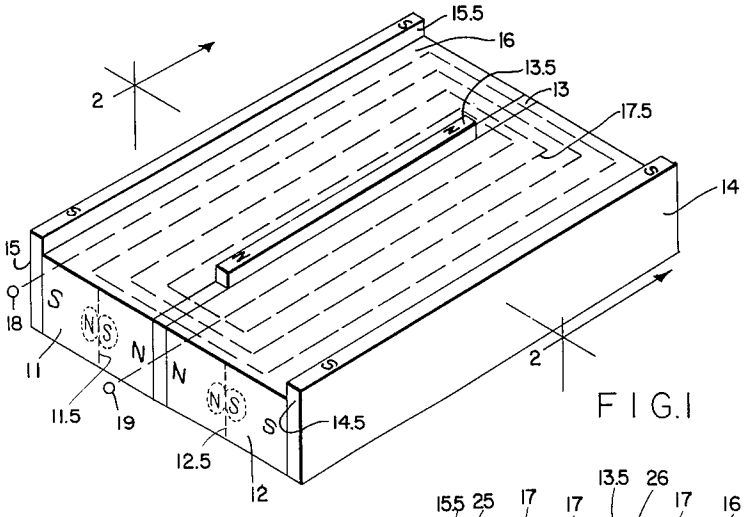


FIG. 1

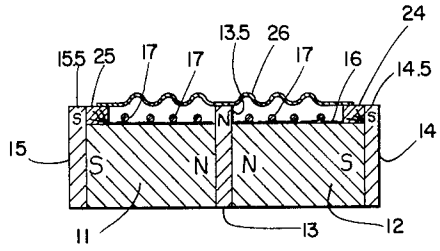


FIG. 2

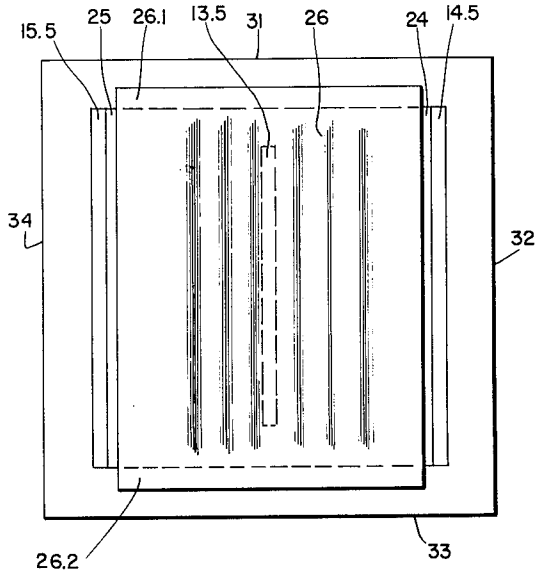


FIG. 5

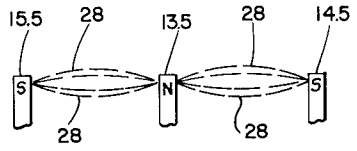


FIG. 3

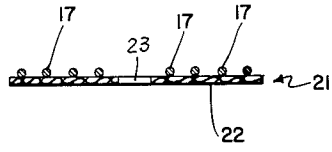


FIG. 4

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HIGH FIDELITY SOUND REPRODUCER

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This invention relates to electromechanical transducer devices for reproducing sound with high fidelity, and more particularly to loudspeakers for use in the high frequency portion of the audible sound spectrum.

It is an object of this invention to provide an improved loudspeaker for the upper audible frequencies. Another object is to provide such a loudspeaker which faithfully reproduces sounds without contributing distortions, or resonances, of its own. A further object is to provide such a loudspeaker in a structure which is compact, simple to construct, requires no unusual parts, and is readily adapted to cooperate with other loudspeaker units in a complete loudspeaker system.

According to the present invention, a diaphragm made of a sheet of electrically conductive material disposed in a flattened magnetic field having lines of force generally parallel to the surfaces of the sheet, and a preferably flat coil of wire, serving as a voice coil, is disposed parallel to and sufficiently close to the diaphragm to induce eddy currents into the conductive material thereof from currents traversing the voice coil. The voice coil is fixed on a platform which is of substantial mass compared to the diaphragm, and the diaphragm is highly compliant, of light weight, and, within prescribed limits, free to move in either direction normal to the magnetic field. The platform may be part of a permanent magnet structure, and the space enclosed between the platform surface and the diaphragm, containing the voice coil, may be hermetically sealed.

An eddy current-type sound reproducer is shown in U.S. Patent No. 1,577,254 granted March 16, 1926 to Hayes. In this reproducer the magnetic field is perpendicular to the surface of a stiff conical diaphragm, and the only communication between the diaphragm and a listener is through a hole in the apex of a conical gap in the magnet structure. The hole is very small compared to the total area of the diaphragm, so that most of the energy available to make sound is dissipated between the magnet poles, as friction. Further, the eddy current driving the force at every point in the diaphragm is resolved into two components, one radial to the axis of the cone and the other parallel to the cone axis, and only the latter component is useful to generate sound waves. The Hayes device is, therefore, quite inefficient.

Another eddy current-type loudspeaker is shown in U.S. Patent No. 1,643,791 granted September 27, 1927 to Slepian. Here a sheet of conducting material rests on a flat voice coil, which is connected to a battery to produce a magnetic field. This field, like that of Hayes, has its lines of force normal to the diaphragm. Voice currents superposed upon the battery current are stated to cause changes in this field which induce eddy currents into the conductive sheet, and thereby to cause the sheet to be moved away from and toward the coil. Gravity enters into the forces tending to move the diaphragm toward the coil. It is not explained how the diaphragm is prevented from rattling when it falls back on the coil, or how it is made to move in a direction parallel to the magnetic field.

The reproducer of the present invention differs drastically from the prior art structures. For example, the diaphragm moves in directions normal to the magnetic field; the field is non-varying and is concentrated largely in the diaphragm, so that a most efficient combination results. The diaphragm is free to move, within adequate limits, in either direction without bumping into other

parts of the structure; it can be hydraulically as well as eddy-current damped and presents its entire movable surface to a listener. Other and further advantages and features of the invention will become apparent from the following description of an embodiment thereof. This description refers to the accompanying drawings, wherein:

FIG. 1 is an isometric view of the magnetic field structure of this embodiment of the invention, showing in dotted line the disposition of a voice coil thereon;

FIG. 2 is a section along line 2—2 in FIG. 1, of a completely assembled loudspeaker;

FIG. 3 illustrates the magnetic field pattern;

FIG. 4 is a detail showing the construction of the voice coil; and

FIG. 5 is a front view of the transducer as it appears fully assembled.

Referring to FIG. 1, first and second permanent bar magnets **11** and **12**, having poles on opposite long faces thereof, are disposed with like poles, here north poles, confronting each other. A spacer bar **13**, of cold-rolled steel, for example, is disposed between the confronting north poles. End plates **14** and **15**, also of cold-rolled steel, for example, are disposed one at each south pole. These parts are all held together by a suitable cement, such as an epoxy cement. It is also possible to hold them together with one or more bolts (not shown) passing through the structure from one end plate **14** to the other **15**; the end plates provide suitable bearing surfaces for such bolts. Obviously, each magnet **11** or **12** could be made of a series of smaller magnets, as is indicated at the dotted lines **11.5** and **12.5**, respectively.

The spacer bar and end plates **13**, **14** and **15** have edge portions **13.5**, **14.5** and **15.5** projecting above a platform **16** constituted by the surface at the top (in FIG. 1) of the magnets **11** and **12**. The projecting edge portion **13.5** of the spacer bar is shorter than the others, the end portions of the spacer bar **13** being flush with the platform **16**. A voice coil **17** (FIG. 2) omitted from FIG. 1 to permit a clear illustration of the magnetic field structure, occupies a position on platform **16** which is indicated by a flat spiral dotted line **17.5**. Terminals for the voice coil are indicated at **18** and **19**.

FIG. 2 shows the wires of the voice coil **17** in cross-section, resting directly on the platform **16**. FIG. 4 shows a voice coil subassembly **21**, which may be used to prefabricate the voice coil. The wires of the voice coil are cemented to a support **22** of paper, as with an epoxy cement. A flat spiral coil of about 40 turns of No. 28 phenolic enamel insulated copper magnet wire, all in one layer, has been used in an area about 2 inches by 2½–3 inches. The paper support **22** has an aperture **23** in it, so that it will slip over the edge projection **13.5** of the spacer bar **13**. In an embodiment built according to the drawings, the dimensions of the magnet structure shown in FIG. 1 were about 3″ x 3″ x ¾″, and the length and width dimensions of the voice coil support **22** were about 3″ long parallel to the end plates **14** and **15** and about 2½″ wide between them. The voice coil **17** is mounted on the platform **16** by cementing the subassembly **21** thereto, using for example, an epoxy cement.

Referring again to FIG. 2, two diaphragm mount bars **24** and **25**, which may be made of wood, are cemented, respectively, one on each edge of the platform **16** closely adjacent the edge projection **14.5** or **15.5** of the adjoining end plate **14** or **15**. A diaphragm **26** is cemented at its edges to these mount bars, and at a strip along its center to the top edge of the edge projection **13.5** of the spacer bar **13**. The diaphragm is made of aluminum foil, ½ to 2 mil. inches thick, and is corrugated as shown, to assure high compliance to motion to and from the platform **16**, with no difficulty from stretching between the lineal re-

gions where it is mounted to the mount bars **24** and **25** and the spacer bar projection **13.5**. An epoxy cement is useful to assemble the diaphragm, mount bars and magnet structure.

Referring to FIG. 3, it will be seen that the edge projection **13.5** of the spacer bar **13** constitutes an elongated north magnetic pole and the edge projections **14.5** and **15.5** of the end plates **14** and **15**, respectively, each constitute an elongated south magnetic pole. Dotted lines **28** represent the magnetic field configuration between the north and each south pole. This is a field which is symmetrical and essentially rectangular to both sides of the north pole, and the diaphragm **26** is disposed essentially entirely within this field. The voice coil **17** is approximately 1/16 inch away from the diaphragm, the mount bars being about 1/16 inch thick, so that an electromagnetic field set up around the voice coil due to voice modulated currents therein can induce eddy currents into the aluminum diaphragm **26**. The latter being in the strongest part of the permanent magnetic field **28**, these eddy currents will react powerfully with the permanent magnetic field, causing motion of the diaphragm perpendicular to the permanent field **28** fluctuating according to the modulation, and faithful reproduction of sound.

FIG. 5 shows a completed loudspeaker in which a wood frame is provided, comprising members **31, 32, 33** and **34** at the edges of the magnet structure, surrounding this entire structure. This frame facilitates mounting the loudspeaker in a wood cabinet, for example. The diaphragm **26** is shown covering the spacer bar projection **13.5** (shown in dotted line) and partially covering the mount bars **24** and **25**, as illustrated in FIG. 2. The free edges of the end plate projections **14.5** and **15.5** can be seen exposed in FIG. 5.

The diaphragm **26** extends at its ends **26.1** and **26.2** to cover the adjoining frame members **31** and **33**, respectively. In this way the diaphragm hermetically seals the space between the diaphragm and the platform **16**. It will be understood that this space is entirely surrounded by wooden members, namely the diaphragm mount bars **24** and **25** and the frame members **31** and **33** perpendicular thereto, the joints between which are all sealed with cement, such as an epoxy cement. The rear surface of the diaphragm is thus provided with a sealed chamber. The aluminum foil of the diaphragm **26** is so thin that the corrugations, as seen in FIG. 2, can easily be made without interfering with the ability to preserve sufficient smoothness of the ends **26.1** and **26.2** for the purpose of cementing them down. Alternatively, the corrugations can be carried to the ends and filled with cement; they are very small—less than 1/16 inch deep, being exaggerated in FIG. 2 for the purpose of illustration.

A loudspeaker built as described above, using two magnets on each side of the spacer bar **13**, each about 3" long and 5/8" square, is an excellent and most efficient reproducer in the frequency range from 5,000 to 30,000 c.p.s. The exciting coil **17** being an inductor, the reactance falls off at lower frequencies. A loudspeaker employing the same principles can, however, be designed for use in a lower frequency range.

With the diaphragm **26** sealed at all of its edges, and provided at its rear surface with a sealed chamber, as in FIG. 5, only the front surface is acoustically exposed to a listener, so that no radiation is present from the back surface, and distortion from that source does not exist. In addition, the sealed back chamber provides the diaphragm with the hydraulic damping, in addition to the eddy current damping which is to be expected from the presence of the aluminum sheet in a magnetic field. Furthermore, the sealed back chamber can be used to move the resonance of the diaphragm **26** to a frequency range higher than audible.

The embodiments of the invention which have been illustrated and described herein are but a few illustrations of the invention. Other embodiments and modifications will occur to those skilled in the art. No attempt has been made to illustrate all possible embodiments of the invention, but rather only to illustrate its principles and the best manner presently known to practice it. Therefore, while certain specific embodiments have been described as illustrative of the invention, such other forms as would occur to one skilled in this art on a reading of the foregoing specification are also within the spirit and scope of the invention, and it is intended that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

What is claimed is:

1. Loudspeaker comprising an electrically conductive diaphragm, means providing a magnetic field having lines of force directed substantially parallel to said diaphragm, said diaphragm being disposed within said field, voice coil means disposed adjacent one side only of said diaphragm adapted to induce eddy currents therein in responce to modulated currents flowing in said voice coil means, said voice coil means being spaced from said diaphragm so that within prescribed limits said diaphragm may move toward and away from said voice coil means without contacting the same, and means including said diaphragm as a wall member thereof for providing a chamber at said one side of said diaphragm.

2. Loudspeaker comprising an electrically conductive diaphragm, means providing a magnetic field having lines of force directed substantially parallel to said diaphragm, said diaphragm being disposed within said field, a flat spiral voice coil parallel and adjacent one side only of said diaphragm, said voice coil means being spaced from said diaphragm a distance such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulated currents flowing in said voice coil will induce eddy currents in said diaphragm, and means including said diaphragm as a wall member thereof for providing a chamber at said one side of said diaphragm.

3. Loudspeaker comprising an electrically conductive diaphragm, means providing a magnetic field having lines of force directed substantially parallel to said diaphragm, said diaphragm being disposed within said field, a platform parallel to and spaced a distance from said diaphragm confronting one side of said diaphragm, a flat spiral voice coil fixedly mounted on said platform, means supporting said diaphragm relative to said platform, said distance being such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulated currents flowing in said voice coil will induce eddy currents in said diaphragm, and means including said diaphragm as a wall member thereof for providing a chamber at said one side of said diaphragm.

4. Loudspeaker comprising an electrically conductive diaphragm, a permanent magnet having magnetically permeable members respectively one at each pole, said members having projections extending beyond a side of said magnet, means mounting said diaphragm to said magnet between said projections, said diaphragm being thereby disposed parallel to said side with one side of said diaphragm confronting the same and spaced a distance therefrom, voice coil means fixedly mounted on said side of said magnet, said distance being such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulated currents flowing in said voice coil will induce eddy currents in said diaphragm, and means including said diaphragm and said magnet as wall members thereof for providing a chamber at said one side of said diaphragm enclosing said voice coil.

5. Loudspeaker comprising an electrically conductive diaphragm, first and second elongated permanent magnets of rectangular cross section, each magnet having a

north pole at one long face and a south pole at the opposite long face, a flat spacer bar of magnetically permeable material, said magnets disposed with one pair of like poles confronting and said spacer bar between them, first and second magnetically permeable end plates disposed respectively one at each of the remaining pair of like poles, side surfaces of said magnets between said poles of each lying in a common plane, said spacer bar and end plates having edge portions projecting beyond said plane, said diaphragm being supported at its edges between said edge portions of said end plates and at an intermediate region from said edge portion of said spacer bar, and a flat spiral voice coil fixedly mounted on said side surfaces of said magnets confronting a surface of said diaphragm, the distance between said diaphragm and said voice coil being such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulated currents flowing in said voice coil will induce eddy currents in said diaphragm.

6. Loudspeaker comprising an electrically conductive diaphragm, means providing a magnetic field having lines of force directed substantially parallel to said diaphragm, said diaphragm being disposed within said field, a flat platform parallel to and spaced from said diaphragm voice coil means fixedly mounted in said platform and disposed adjacent and confronting one side only of said diaphragm adapted to induce eddy currents therein in response to modulated currents flowing in said voice coil means, said voice coil means and platfrom being spaced from said diaphragm so that within prescribed limits said diaphragm may move toward and away from said voice coil means without contacting the same, and means including said diaphragm and the mounting means for said voice coil means for providing an acoustically sealed chamber around said side of said diaphragm.

7. Loudspeaker comprising an electrically conductive rectangular diaphragm, means providing a magnetic field having lines of force directed substantially parallel to said diaphragm, the direction of said lines of force being symmetrical between two parallel edges of said diaphragm and a line in said diaphragm parallel to and substantially between said two edges, said diaphragm being disposed within said field, a flat rectangular spiral voice coil lying in a plane parallel and adjacent one side only of said diaphragm, said coil having an elongated rectangular open portion in the center in register with said line, said voice coil being spaced from said diaphragm a distance such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulated currents flowing in said voice coil will induce eddy currents in said diaphragm, and means including said diaphragm as a wall member thereof for providing a chamber at said one side of said diaphragm.

8. Loudspeaker comprising an electrically conductive diaphragm, means providing a magnetic field having lines of force directed substantially parallel to said diaphragm, said diaphragm being disposed within said field, a platform parallel to and spaced a distance from said diaphragm confronting one side only of said diaphragm, a flat spiral voice coil fixedly supported on said platfrom, means supporting said diaphragm relative to said platform, said distance being such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulated currents flowing in said voice coil will induce eddy currents in said diaphragm, and means including said diaphragm and said platform as wall members thereof for providing substantially an acoustically sealed chamber at said one side of said diaphragm.

9. Loudspeaker comprising a substantially flat electrically conductive diaphragm, a permanent magnet having magnetically permeable members respectively one at each pole, said members having projections extending beyond a side of said magnet, means mounting said diaphragm to said magnet between said projections, said side being flat, a flat spiral voice coil fixedly mounted on said side, said diaphragm being disposed parallel to said side with one side of said diaphragm confronting the same and spaced a prescribed distance therefrom such that, within prescribed limits, said diaphragm can move toward and away from said voice coil without contacting the same, and simultaneously such that modulating currents flowing in said voice coil will induce eddy currents in said diaphragm.

10. Loudspeaker comprising an electrically conductive diaphragm, elongated permanent magnet means of rectangular cross-section and having a first pole at one long face and a second pole at the opposite long face, first and second magnetically permeable end plates disposed respectively one at each of said poles, said end plates having edge portions projecting beyond one side of said magnet means, said side lying in a plane between said long faces, said diaphragm being supported from said edge portions substantially parallel to said plane, and a flat voice coil fixedly mounted on said one side of said magnet means confronting a surface of said diaphragm, the distance between said diaphragm and said voice coil being such that, within prescribed limits, said diaphragm may move toward and away from said voice coil without contacting the same, and simultaneously such that modulating currents flowing in said voice coil will induce eddy currents in said diaphragm.

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