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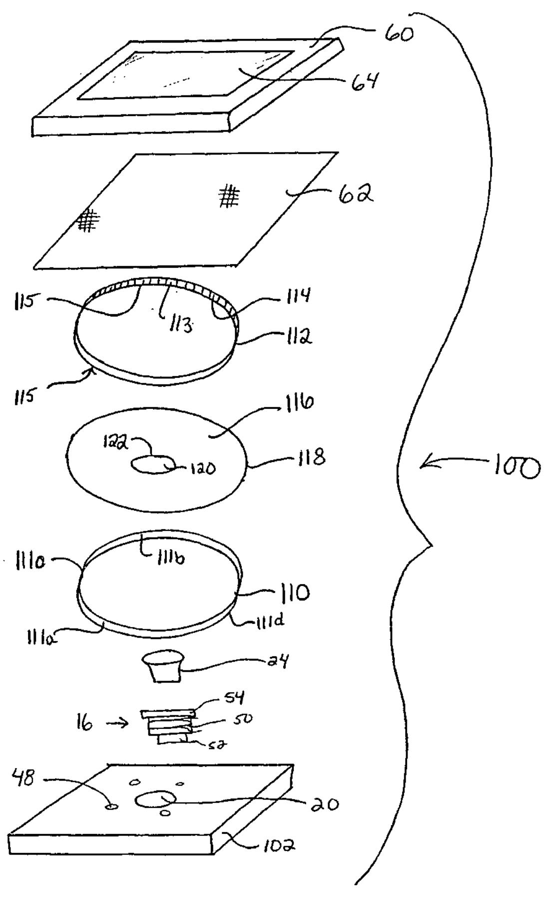

(57) Abstract: A loudspeaker is disclosed having a back plate, a driver attached to the back plate, the driver being responsive to an electrical signal, an enhancer having a neck and a mouth, the neck attached to the driver and movable in accordance with the movement of the driver, a thin film membrane defining a hole, the membrane attached to the enhancer such that the hole corresponds in size and location with the mouth of the enhancer, a frame for supporting the membrane and maintaining it in a taut state, a rubber type adhesive for dampening the membrane resonances and for adhering the membrane to the frame, and a clamp ring for clamping the membrane to the frame. Clarity of sound can be further improved by including a plurality of sound breathers in the back plate of the speaker. For improved sound radiation capability, especially in the middle and high frequency sound ranges, the size and the shape of the enhancer can be modified in various ways, including a frustoconical, parabolic, or bell-shaped enhancer.

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FLAT PANEL SPEAKER

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application No. 60/145,368, filed July 23, 1999.

FIELD OF THE INVENTION

This invention relates to loudspeakers and more particularly to loudspeakers having a flat panel design.

BACKGROUND OF THE INVENTION

Dynamic loudspeakers typically include a relatively stiff diaphragm that is coupled to an electromagnetic driver assembly, which basically comprises a voice coil and a permanent magnet. Such loudspeakers are usually mounted so as to occupy an opening in an enclosure or baffle. The interaction of the magnetic field of the permanent magnet and the varying magnetic field of the voice coil that is produced when a changing current is passed through the voice coil causes the loudspeaker diaphragm to vibrate. Vibration of the diaphragm causes movement of air, which in turn produces sound.

The advantages of the moving-coil drive unit are that its operation and design are widely understood and used, the components parts are readily available and it is inexpensive to produce. One disadvantage is that this drive unit is very inefficient as a transducer, typically converting between 1 and 3% of the electrical energy into sound energy. Another disadvantage of moving-coil drive units is that the mechanical inertia resulting from the mass of the driver itself makes it impossible for the driving part to start and stop instantly. This sets a limit on the transducer's bandwidth and on its ability to reproduce transients clearly.

To overcome the disadvantages of the typical moving-coil drive units, there has been developments in the areas of "mass-less" drivers. One such driver is the piezoelectric type. A piezoelectric speaker utilizes crystalline materials that will twist or bend mechanically when a voltage is applied. The resulting movement is very small and in practice crystal transducers are generally matched to a horn to improve efficiency. The problem with the piezoelectric transducer is that it has a limited bandwidth and its application is therefore limited to reasonably flat frequency response and low coloration.

Another attempt at the "mass-less" drive unit has been the flat panel loudspeaker, which uses low mass sheets or film in place of a cone diaphragm. The operating principle of the traditional electrostatic flat speaker is that of a two plate capacitor. One plate is a fixed electrode, the other is a stretched conductive plastic film. Both the audio signal and a DC polarizing voltage are applied across the plates. The applied voltage is varied in accordance with the audio signal. The charge between the plates also varies. The size of the electrostatic charge determines the attractive force and thus the film diaphragm is set in motion.

The loudness of the sound produced by a loudspeaker is related to the volume of air moved in from the loudspeaker by vibration of the diaphragm. Generally, the greater the volume of air moved by the diaphragm as it vibrates, the greater the loudness. The loudness of sound produced relative to the electrical energy provided as an electric current through the voice coil is also used to measure the efficiency of the loudspeaker.

It is desirous to make speakers more compact and flat for easy installation in locations with restricted areas such as walls, panels and other flat surface areas. The disadvantage of the electrostatic flat speaker is that manufacturing is difficult. This speaker requires a DC voltage source and a step-up transformer for impedance matching, which creates additional expense. Also, the speaker would have to be large to create good bass.

A known flat panel loudspeaker has been developed which uses a very stiff panel whose characteristics must conform to a specific mathematical relationship. This panel can be excited by a transducer such as a moving-coil element or a piezoelectric crystal. If all the parameters are met, the panel has a complex bending behavior resulting in a large number of seemingly randomized vibrational modes distributed across the panel surface. The disadvantage of this device is that the complex bending behavior of the panel requires precise manufacturing which is costly and time consuming.

It is, therefore, desirable to have a compact, flat speaker that emits high quality sound over a wide bandwidth while maintaining low manufacturing costs.

SUMMARY OF THE INVENTION

A compact, flat speaker of the present invention emits high quality sound over a wide bandwidth. Further, the manufacturing costs for the speaker are minimized by providing a speaker that is easy and inexpensive to manufacture. In addition, the speaker configuration substantially reduces the likelihood of membrane tearing or having a distorted membrane surface.

The loudspeaker of the present invention has a driver attached to a back plate and a sound enhancer. The driver is responsive to an electrical signal. A frame is attached to the back plate. A thin film membrane is supported by the frame. Preferably, the membrane has a hole. The enhancer has a neck attached to the driver and a mouth attached to an edge of the hole of the membrane. The enhancer is movable in accordance with the movement of the driver. Preferably, the membrane is attached to the frame by a rubber type adhesive that dampens the membrane resonances. Preferably, a clamp ring clamps the membrane to the frame while keeping the membrane under tension.

Clarity of sound can be further improved by including a plurality of sound breathers in the back plate of the speaker. For improved sound radiation capability, especially in the middle and high frequency sound ranges, the size and the shape of the enhancer can be modified in various ways, including a frustoconical, parabolic, or bell-shaped enhancer.

DESCRIPTION OF THE DRAWINGS

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 is an expanded view of the flat panel speaker of the present invention;

FIG. 2 is a side view of a bell-shaped enhancer utilized in an embodiment of the present invention;

FIG. 3 is a side view of a frustoconical enhancer utilized in an embodiment of the present invention;

FIG. 4 is a side view of a parabolic enhancer utilized in an embodiment of the present invention;

FIG. 5 is a side view of an enhancer utilized in an embodiment of the present invention;

FIG. 6 is a plan view of the enhancer of FIG. 5;

FIG. 7 is a plan view of an alternative embodiment of the frame member and the back plate with an off-center recess for a driver;

FIG. 8 is a side view of a driver utilized in an embodiment of the present invention;

FIG. 9 is an expanded view of another embodiment of the flat panel speaker;

FIG. 10 is a plan view of an embodiment of the flat panel speaker, but without a diaphragm, a clamp ring or a cover;

FIG. 11 is a cross-sectional view of the flat panel speaker through section c-c' of FIG. 10 with the diaphragm, the clamp ring and the cover;

FIG. 12 is a plan view of the assembled flat panel speaker of FIG. 10 with the cover;

FIG. 13 is a perspective view of an alternative embodiment of the base and the clamp ring of the present invention; and

FIG. 14a is a plan view of an alternative embodiment of the back plate of the present invention;

FIG. 14b is a cross-sectional view of the back plate through section D-D' of FIG. 14a;

FIG. 14c is a cross-sectional view of the back plate through section E-E' of FIG. 14a; and

FIG. 15 is a cross-sectional view of the clamp ring through section F-F' of FIG. 13.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates an expanded view of a first embodiment of a flat panel loudspeaker 10. The flat panel loudspeaker 10 has a back plate 12 with a driver 16, an open frame member 14 coupled with the back plate, a sound enhancer 24 coupled with the driver 16, and a membrane (or diaphragm) 18 attached to the sound enhancer and stretched across the frame member 14. The driver vibrates in response to an electrical signal which in turn vibrates the sound enhancer and membrane, thereby producing sound.

The back plate 12 and frame member 14 provide structural support for the speaker 10 and can be made of any rigid material that will maintain the structural integrity of the speaker while in use. The materials for the back plate and frame member may include a hard plastic, a metal, and/or wood.

In one embodiment, the thickness of the back plate 12 together with the attached and/or integral frame member 14 is equal to the sum of the thicknesses of the driver 16 and the enhancer 24. In a preferred embodiment, the thickness of the speaker, including the frame member and the back plate, is about ½ inch.

In one embodiment, the open frame member 14 has the same outer shape and size as the back plate 12, as shown in FIG.1. The back plate has a substantially solid flat rectangular shape. The frame member has a rectangular shape that is solid around the edges and open in the center. The outer edges of the frame member fits onto and aligns with the outer edges of the back plate when the frame member and back plate are coupled. In a preferred embodiment, the frame member and the back plate have an area of about 25 square inches, with lengths and widths of about 5 inches each.

The frame member is not limited to an open rectangular shape, however. For example, in another embodiment, the edges of the open frame member are rounded as discussed in the more detail below. In a preferred embodiment, the frame member is the same size and shape or smaller than the back plate. In another preferred embodiment the frame member is integral with the back plate regardless of the respective shapes.

The back plate 12 has a recess 20 provided for the driver 16. In one embodiment, the recess 20 in the back plate is centrally located with respect to the attached frame member. The driver is placed inside the recess 20 such that the bottom of the driver is aligned with and preferably attached to the bottom of the back plate 12. By placing the driver in the back plate, the thickness of the speaker 10 is thereby minimized. The driver 16 is discussed in more detail below.

For further improvement of sound clarity, a plurality of openings or sound breathers 48 are disposed in the back plate 12. The sound breathers are provided in the back plate to release the air that is trapped between the back plate 12 and the membrane 18. Without the sound breathers 48, the air trapped between the back plate and the membrane has an undesirable dampening effect on the vibratory motion of the membrane 18. The number and size of the sound breathers are design choices that affect the sound quality. Generally, the more sound breathers, the better the sound quality. However, the number of sound breathers are limited so as to not compromise the structural integrity of the back plate. The size, number and location of the sound breathers 48 shown in the Figures are for illustrative purposes only.

The frequency response characteristics of the loudspeaker can be changed by altering the shape, thickness or material of the sound enhancer 24. FIG. 1 depicts an enhancer 24 having a neck 26, a mouth 28, and a surface that increases in circumference between the neck 26 and the mouth 28, flaring out at the mouth. The sound enhancer 24 improves the sound radiation capability of the speaker.

Depending on the desired frequency response of the loudspeaker, the enhancer can be modified to have any shape. FIG. 2 depicts a bell-shaped enhancer 30 with an outer surface 32 that flares out at the mouth, similar to the enhancer shown in FIG. 1. FIG. 3 depicts another alternative enhancer 38 having a frustoconical shape. Enhancer 38 has a neck, a mouth, and a surface 40 that forms a straight surface between the neck and the mouth. FIG. 4 depicts an alternative parabolic enhancer 34 having a neck, a mouth and a surface 36 that forms a convex parabolic shape between the neck and the mouth.

FIGs. 5 and 6 depict a preferred embodiment for the enhancer 24. The enhancer has a neck 26, a mouth 28, and a surface that increases in circumference between the neck 26 and the mouth 28, flaring out at the mouth. Along the edge of the mouth is a rim 46. The rim of the enhancer is substantially flat and extends out horizontally from the mouth. The circular rim extends out in a flat manner 1 to 2 mm from the edge of the mouth. The diameter of the enhancer at the neck ranges from about 15mm to 30 mm, but preferably is about 25 mm. The diameter of the enhancer at the mouth ranges from about 25mm to 40 mm, but preferably is about 33 mm. The vertical distance from the neck to the mouth ranges from about 2mm to 8mm, but preferably is about 3 mm. The neck 26 is attached to the driver 16, while the rim 46 is attached to the membrane 18 as discussed below, such that the vibrations from the driver 16 are transmitted through the enhancer 24 to the membrane 18. These shapes are shown only as examples and can be used with the speakers disclosed in any of the embodiments of the present invention.

The enhancer is preferably made from a fiber-reinforced paper composite. For example, the enhancer is a composite made from paper and fibers, such as fiberglass. In a more preferred embodiment, the enhancer is made from paper and an aramid fiber, such as Kevlar® by duPont. The composite is made of about 20-30% by weight Kevlar fibers. Altering the amount of fibers that are used in the composite alters the frequency response of the speaker, in particular, the frequency response in the high frequency range.

In a preferred embodiment, an oil with magnetic particles in colloidal suspension is placed inside the enhancer at a location near the neck to dampen the diaphragm resonances (not shown). In the preferred embodiment, the magnetic oil used is a colloidal suspension of nanoscopic magnetic particles, such as Ferrofluid® which is manufactured by Ferrofluidics Corporation of Nashua, NH. The amount of oil placed in the enhancer has a thickness of a range of about 1/4 mm to 1 mm ribbon around the inside and outside surfaces of the neck of the enhancer, but preferably about ½ mm ribbon. The magnetic oil has a viscosity in the range of viscosities generally used for woofers. When the viscosity is altered, the frequency response of the speaker is affected.

To further improve the sound radiation capabilities, especially in the high frequency sound region, a hole 42 is provided in the membrane 18 as shown in FIG. 1. The hole 42 is defined by an inner substantially circular edge 44 of the membrane 18. The hole 42 drastically improves the medium and high frequency sound emissions of the membrane 18 by clearing the path of the movement of air. The hole 42 is preferably about the same size as the mouth 28 of the enhancer 24. The inner edge 44 defining the hole 42 is attached to the rim 46 of the enhancer 24 that surrounds the mouth as described below.

The membrane 18 of FIG. 1 further has outer edges 22 which are attached to the frame member 14. The membrane is uniformly stretched to a desired tension across the frame member. The membrane is stretched and tensioned to lie flat on top of the frame member and the enhancer. The tension eliminates sagging of the membrane, and thus the need for cross members to support the membrane to maintain its flatness, and resonances caused by wrinkles.

The membrane 18 can be attached to the frame member 14, as well as to the enhancer 24, in various ways. One manner of attaching the membrane 18 is by utilizing an epoxy. There are numerous types of epoxy that can be used including rubber type adhesives, acrylic adhesives, silicone-type adhesives or epoxy cement. The adhesive used does not need to be limited to those listed herein. Any type of adhesive that does not contain solvents that deteriorate the speaker material and that form a reliable (and preferably permanent) bond can be used. The type of adhesive used is determined by the kind of material to be adhered. In a preferred embodiment, Scotch Brand VHB F-9469PC Adhesive Transfer in the 5 mil (or 0.127 mm) thickness is used to adhere the membrane to the frame member and/or to the enhancer. The thickness of the adhesive is in the range of about 1 mil (or 0.0254 mm). The width of the adhesive is in the range of about 3 mm. By varying the thickness and width of the adhesive, the energy absorption of the adhesive is adjusted as described in more detail below.

In one embodiment, the rubber type adhesive is deposited on a tape surface which has a release coating. The adhesive side of the tape is placed on an outer surface of the frame member. The adhesive adheres to the frame member. The tape is then peeled from the adhesive leaving only the adhesive gum. The membrane is pulled over the frame member edges to the outer surface to adhere to the adhesive. The adhesive makes the attachment of the membrane to the frame member substantially permanent.

The rubber type adhesive coupling the membrane to the frame member also dampens the resonances, in that the rubber type adhesive softens the vibrational energy of the diaphragm and acts as an energy absorbing cushion. The frame member provides a hard reflective termination which reflects the vibrational energy back into the diaphragm or membrane which increases the distortion content, and causes destructive cancellations in the acoustical output response of the membrane. The soft rubber type adhesive provides a soft termination which absorbs a portion of the vibrational energy and reduces reflections and distortion. In the preferred embodiment, the attached membrane is uniformly tensioned. In one embodiment, the membrane is under 5 to 30 pounds of tension. The surface of the membrane is substantially wrinkle-free, and the membrane behaves substantially as a rigid membrane.

The membrane generally will not be able to maintain the tensile strength of about 5 to 30 pounds using the rubber type adhesive alone to attach the membrane to the frame member.

Accordingly, additionally or alternatively to the adhesive, the membrane can be attached by press fit into the frame member. For example, the membrane can be clamped into the frame member as described in more detail below with respect to FIG. 9.

In an alternative embodiment shown in FIG. 7, the recess 20 in the back plate 12 for the driver is off-center with respect to the frame member 14. In this embodiment, the frame member can be either centrally located or not centrally located with respect to the back plate, but the recess 20 is not centrally located with respect to the frame member. The off-center recess 20 with respect to the frame member (and subsequently the membrane) provides for improved sound quality by minimizing resonances.

The driver 16 for each of the described embodiments is an electromagnetic driver assembly that is well known in the art. As shown in a detailed view of the driver in FIG. 8, and in the cross-sectional view of FIG. 11, the driver has a voice coil 50 wrapped about a pole piece, a permanent magnet 52 partially disposed within one end of the pole piece, a thin plate 54 attached to the other end of the pole piece, and a spider 51 that is used to center the voice coil with respect to the pole piece without appreciably hindering the in-and-out motion of the voice coil.

In order to vibrate the driver, a changing current is passed through the voice coil 50. The interaction of the magnetic field of the permanent magnet 52 and the magnetic field of the voice coil 50 that is produced from the changing current causes the coil and consequently, the attached thin plate to vibrate with respect to the permanent magnet. The driver 16 acts as a piston to vibrate in a substantially vertical direction. The thin plate 54 is attached to the enhancer 24 at the neck 26 thereof. Because the rim 46 of the enhancer is attached to the membrane 18, as the thin plate vibrates, the enhancer and the membrane consequently vibrate, thereby producing sound.

The driver could be any known electromagnetic driver assembly, including a piezoelectric assembly (not shown). In the piezoelectric assembly, the crystalline material will twist or bend in response to an applied voltage, causing the membrane 18 to vibrate and thus producing sound.

One embodiment with a circular-shaped clamp means, or clamp ring, is shown in FIG. 9. FIG. 9 illustrates an expanded view of a second embodiment of a flat panel loudspeaker 100. The flat panel loudspeaker 100 has a back plate 102 with the driver 16, an open frame member (or base) 110 coupled with the back plate, the sound enhancer 24 coupled with the driver 16, a membrane (or diaphragm) 116 attached to the sound enhancer and stretched across the base 110, a clamp ring 112 to press fit over the membrane and base, a cover 60 with a wire mesh 62 to protect the membrane, and cloth 64 over the wire mesh.

The flat panel loudspeaker 100 operates similarly to the flat panel loudspeaker 10, for example, the driver vibrates in response to an electrical signal which in turn vibrates the sound enhancer and membrane, thereby producing sound. FIG. 10 illustrates a plan view of the speaker 100 with the back plate 102, the driver 16, the enhancer 24, and the base 110. FIG. 11 shows a cross-sectional view of the speaker 100 shown in FIG. 10 and additionally illustrating the clamp ring 112 and the cover 60.

In one embodiment, the base 110 has an open circular shape. The base has an outer surface 111a and an inner surface 111b. In between the outer surface 111a and the inner surface 111b are top and bottom surfaces, 111c and 111d, respectively. The bottom surface 111d of the base is attached to the back plate 102.

In one embodiment, the base 110 upon which the membrane is attached has rounded edges along the top surface 111c (not shown). The rounded edges render tearing of the membrane, when the membrane is stretched over them during attachment, less likely to occur.

The clamp ring 112 is circular-shaped and has an inner circular surface 113, and a bottom surface 115. A diameter of the inner circular surface 113 of the clamp ring closely corresponds to a diameter of the outer surface 111a of the base.

The membrane 116 has outer edges 118 which are attached to and stretched across the outer surface 111a and/or the top surface 111c of the base 110. In a preferred embodiment, the membrane is adhered to the base 110 by the rubber type adhesive. After adhering the membrane to the base, the bottom surface 115 of the clamp ring is placed over and around the base 110. In one embodiment, the membrane is positioned in between the outer surface 111a of the base and the inner surface 113 of the clamp ring. Alternatively or additionally, the membrane is positioned in between the top surface 111c of the base and the bottom surface 115 of the clamp ring. The surfaces of clamp ring 112 pressed together with the surfaces of the base, tightly hold the membrane in a taut state.

In one embodiment, the clamp ring 112 has teeth 114 on the inside surface 113 of the clamp ring. Measured from top of the tooth to top of the neighboring tooth, the teeth are spaced apart in the range of about 2 mm to 8 mm, but preferably about 4 mm apart. Each tooth has a tooth edge at one end and a base at another end which is adjacent the inner surface of the clamp ring. The tooth base has a thickness of about 2 to 3 mm and the edge has a thickness of about 1 mm. Preferably the tooth edge is flat. In an alternative embodiment, the tooth base has a thickness of about 1 mm.

The clamp ring and teeth are preferably made of an elastic material, such as molded plastic. In the preferred embodiment, the inner diameter of the clamp ring at edges of the teeth 114 is slightly smaller than the diameter of the outer surface 111a of the base. However, the inner diameter of the clamp ring at a base of the teeth is slightly larger than the diameter of the outer surface 111a of the base. In this embodiment, when the clamp ring is tightly fit over the base, the teeth 114 deform slightly to capture and uniformly pull the membrane. Because the teeth deform upon application of the clamp ring, the teeth grip the membrane with a high gripping strength.

As shown in FIG. 9, the teeth 114 are tapered along the bottom surface 115 of the clamp ring. The edges of the teeth along the bottom surface are sanded down or tapered to allow assembly of the membrane. The tapered teeth allow the clamp ring to grip the membrane, and to slide the membrane down the outer surface 111a without tearing the membrane with the sharp edges.

The clamp ring 112 is used to achieve the desired uniform tensile strength of about 5 to 30 lbs. of force in the membrane surface. For mass production of the speaker, attaching and stretching the membrane to the frame member is generally the most difficult part of the assembly procedure. Using the clamp ring to effect the attaching and stretching makes this assembly procedure more consistent, and thus, easier. Through the gripping and holding strength of the clamp ring, the membrane can be uniformly stretched and held. Furthermore, tearing of the membrane during the stretching process is less likely to occur with the substantially even circumferential gripping of the teeth. Through the adhesive, stretching of the membrane, and press fitting the clamp over the base, the tension of the membrane can be adjusted.

Through desirable tolerances in the differences in sizes between the clamp ring and the base, the size and spacing of the teeth in the clamp ring, and the characteristics of the plastic teeth material, the membrane can be uniformly tensioned, and the membrane tensioning amount can be adjusted.

If the press fit is used in addition to using an adhesive as described above, the adhesive between the membrane and the frame member can be placed on either before or after the clamp ring is secured onto the frame member. The benefit of using the adhesive is that, again, the adhesive absorbs the vibrational energy from the membrane and substantially permanently attaches the membrane, and reduces distortion.

As shown in FIG. 9, the back plate 102 is a rectangular shape with dimensions greater than the diameter of the base 110, but is not so limited. The back plate can have any shape and size. However, in the preferred embodiment, edges of the base do not extend from the surface of the back plate. Similar to the embodiment described with respect to FIG. 1, the back plate 102 and the base 110 provide structural support for the speaker 100 and can be made of any rigid material that will maintain the structural integrity of the speaker while in use.

Similar to the embodiment of FIG. 1, the back plate 102 in FIG. 9 has a recess 20 provided for the driver 16, and a plurality of sound breathers 48 to release the air that is trapped between the back plate 102 and the membrane 116. The recess 20 in the back plate can either be centrally located with respect to the attached base or off-center. The sound breathers may vary in size, number and location in the back plate 102.

The sound enhancer 24 of this embodiment has the same function and possible shapes as the embodiment of FIG. 1. Further, the membrane 116 has a hole 120 defined by edge 122. Edge 122 of the hole 120 is attached to the rim 46 of the enhancer 24.

The cover 60 is preferably the same shape as and attached to the back plate 102. In a preferred embodiment, and as shown in the embodiment of FIG. 9 and the embodiment of FIGs. 10-12, the cover and the back plate are rectangular. As shown in the cross-sectional view of FIG.

11 and the plan view of FIG. 12, the cover 60 is a protective and aesthetic frame that is placed over the membrane. The cover has a wire mesh 62 and a cloth 64 that is placed over the wire mesh. As shown in FIG. 11, when the cover is attached to the back plate, the wire mesh is spaced from the membrane so as not to interfere with the vibration thereof. As previously disclosed, the placement of the sound breathers 48 in the back plate may vary as shown by the different back plate embodiments of FIGs. 1, 7, 9, and 10, respectively.

Another embodiment is shown in FIG. 13, and the cross-sectional view of the clamp ring of FIG. 13 illustrated in FIG. 15. The base 110 has the bottom surface 111d with an outside edge 120, the top surface 111c with a smaller diameter than that of the bottom surface 111d, and the outer surface 111a which is defined between the top surface and the outside edge of the bottom surface and is therefore tapered. The clamp ring has the inner surface 113 that corresponds to the tapered outer surface 111a of the frame. The tapered angle α is about 1 to 5 degrees. As a result of the taper, the clamp ring and the base are able to fit together in a tight manner. The clamp ring 12 has a bottom surface 125 with interior edges being rounded. When the clamp ring is placed over the base, there is less likely to be a tear in the membrane due to the rounded edges. The clamp stays on the base because there is no more than about 1 mil (0.0254 mm) of tolerance between the base and the clamp. In a preferred embodiment, the adhesive bonds the clamp to the base substantially instantaneously. In another preferred embodiment, the clamp ring has teeth on the tapered inner surface to keep the clamp ring from sliding off of the base.

In yet another embodiment, the inner surface of the clamp or clamp ring is smooth, and the outer surface of the base or frame member has gripping teeth. In this embodiment, the adhesive tape is placed on the clamp or clamp ring and the clamp is placed over the membrane and frame member and pressed fit with the frame member. FIGs. 14a to 14c illustrate an alternative embodiment of a back plate 102 with a base 110. In a preferred embodiment, the base is integral with the back plate. The back plate has a driver support 127 defining an opening 20 for the driver 16, and spokes (or ribs) 125 connecting the driver support 127 and the base 110. The membrane is stretched across the base 110, thereby placing the circular base 110 in compression. The ribs 125 provide the base with structural strength, making the base more rigid to sufficiently withstand the compression forces. The ribs are tapered, wherein the cross-sectional area of the rib increases from the driver support 127 to the base 110, as illustrated in FIG. 14b. In the preferred embodiment, there are 8 ribs.

For each of the embodiments, the membrane is preferably made of a thin flexible material that is durable enough to endure the vibrational forces of the driver, and yet flexible enough to vibrate in response to the driver. The membrane is generally not porous, is tensioned to a uniform force of about 5 to 30 lbs, and does not stretch even under the constant tensile load of about 5 to 30 lbs. Any thin film material could be used that is flexible enough to emanate sound waves while being strong enough to survive harsh environmental conditions. For instance, it is desired that the membrane is able to tolerate inclement temperatures such as extreme heat in a car or severe coldness in wintry conditions. It is believed that a material from the polyimide group would satisfy these requirements. In one embodiment, the materials is dielectric. In another embodiment, the membrane material is a silicone based, thermosetting adhesive system. The material has high puncture resistance, is conformable, and has good high temperature performance. In the preferred embodiment, the membrane is made of thin, flexible materials, for example, Kapton® of duPont. Kapton® is an especially desirable material because it is strong enough to endure physical constraints, as well as being resistant to chemical and environmental corrosion. Other material, such as thin aluminum tin foil or other similar metal film, could also be used.

It is desirable to minimize the thickness and the weight of the membrane to minimize inertia due to the vibrations and approach the goal of having a "mass-less" membrane. The membrane thickness is in the range of about ½ mil (or 0.0127 mm) to 1½ mil (or 0.038 mm). If the thickness is greater than 1½ mil (or 0.038 mm), the sound quality is not as desired. In the preferred embodiment the membrane thickness is about 1 mil (or 0.0254 mm).

The sound quality of the speaker can also be altered by changing the contour of the membrane. For example, the membrane may have varying thicknesses and/or materials throughout the surface. However, in the preferred embodiment, the membrane has a homogeneous surface, i.e. the same thickness and the same material throughout the membrane surface.

While the invention is disclosed in conjunction with the specific embodiments thereof, it is to be evident that many alternatives, modifications, and variations will be apparent to those skilled in the art in light of the foregoing description. For example, the membrane described above can be used in microphones and telephone type receivers, as well as loudspeakers. Accordingly, it is intended to embrace all such alternatives, modifications and variations as falling within the spirit and broad scope of the appended claims.

IN THE CLAIMS:

1. A loudspeaker, comprising:

a back plate;

a driver attached to the back plate, the driver being responsive to an electrical signal;

an enhancer having a neck and a mouth, the neck attached to the driver, the enhancer being movable in accordance with the movement of the driver;

a thin film membrane having a hole, the membrane attached to the enhancer such that the hole corresponds in size and location with the mouth of the enhancer; and

a frame attached to the back plate and having a surface supporting and maintaining the membrane in a taut state.

2. The loudspeaker in accordance with claim 2 wherein the back plate has a recess that is off-center with respect to the attached frame member, wherein the driver is disposed in the recess in the back plate.

3. The loudspeaker in accordance with claim 1 wherein the enhancer has a frustoconical shape.

4. The loudspeaker in accordance with claim 1 wherein the enhancer has a parabolic shape.

5. The loudspeaker in accordance with claim 1 wherein the enhancer has a bell shape.

6. The loudspeaker in accordance with claim 1 wherein a sum of a thickness of the backplate and a thickness of the frame is equal to a sum of a thickness of the driver and a thickness of the enhancer.

7. The loudspeaker in accordance with claim 6 wherein the thickness of the speaker, including the frame member and the back plate, is about ½ inch.

8. The loudspeaker in accordance with claim 1 wherein the membrane is made of Kapton®.

9. The loudspeaker in accordance with claim 1 wherein the membrane is made of a polyimide material.

10. The loudspeaker in accordance with claim 1 wherein the membrane is made of a metal foil material.

11. The loudspeaker in accordance with claim 1 wherein the membrane is uniformly tensioned, wherein the tensile force is about 5 to 30 pounds.

12. The loudspeaker in accordance with claim 1 wherein the membrane has a thickness in the range of ½ mil (or 0.0127 mm) to 1½ mil (or 0.038 mm).

13. The loudspeaker in accordance with claim 12 wherein the membrane has a thickness of about 1 mil (or 0.0254 mm).

14. The loudspeaker in accordance with claim 1 wherein the membrane has a thickness such that the membrane that is attached to the frame is flexible and durable to endure vibrational forces of the driver without stretching.

15. The loudspeaker in accordance with claim 1 wherein the membrane has a surface in between edges of the frame, wherein the surface is homogeneous in thickness and material.

16. The loudspeaker in accordance with claim 1 wherein magnetic oil is used in the driver to dampen the membrane resonances, wherein the magnetic oil used has a viscosity that is in a range of viscosities generally used for woofers.

17. The loudspeaker in accordance with claim 1 wherein the frame has at least one rounded top edge.

18. The loudspeaker in accordance with claim 1 wherein the enhancer has a rim along an edge of the mouth, wherein an edge of the hole of the membrane is attached to the enhancer at the rim.

19. The loudspeaker in accordance with claim 18 wherein the rim is a flat circular surface having a width of 1 to 2 mm.

20. The loudspeaker in accordance with claim 1 wherein a diameter of the neck of the enhancer ranges from about 15mm to 25 mm.

21. The loudspeaker in accordance with claim 1 wherein a diameter of the mouth of the enhancer ranges from about 25mm to 40 mm.

22. The loudspeaker in accordance with claim 1 wherein a distance from the neck to the mouth of the enhancer is about 3 mm.

23. The loudspeaker in accordance with claim 1 wherein the back plate has a driver support defining a recess in which the driver is disposed, and a plurality of spokes that extend from the driver support to the frame to provide structural support for the frame which is under compression from the membrane.

24. The loudspeaker in accordance with claim 1 wherein the enhancer is made of a fiber-reinforced paper composite.

25. The loudspeaker in accordance with claim 23 wherein 20 to 30% of the enhancer is made of Kevlar®.

26. The loudspeaker in accordance with claim 1 wherein the membrane is adhered to at least one of the enhancer and the frame by using a rubber type adhesive that is capable of dampening resonances.

27. The loudspeaker in accordance with claim 26 wherein the rubber type adhesive is Scotch Brand VHB F-9469PC adhesive transfer tape.

28. The loudspeaker in accordance with claim 27 wherein the adhesive tape has a thickness of 5 mil (or 0.127 mm).

29. The loudspeaker in accordance with claim 1 further comprising a clamp, wherein the clamp captures the membrane in between the clamp and the frame.

30. The loudspeaker in accordance with claim 29 wherein the membrane is adhered to the frame by a rubber type adhesive.

31. The loudspeaker in accordance with claim 29 wherein the clamp has an inner surface and the frame has an outer surface, wherein the membrane is positioned in between the outer surface of the frame and the inner surface of the clamp.

32. The loudspeaker in accordance with claim 29 wherein the membrane is positioned in between a top surface of the frame and a bottom surface of the clamp.

33. The loudspeaker in accordance with claim 29 wherein the clamp is a clamp ring and corresponds in shape to the frame.

34. The loudspeaker in accordance with claim 33 wherein the clamp ring has an inner surface with teeth.

35. The loudspeaker in accordance with claim 34 wherein the teeth are spaced apart in the range of about 2 mm to 8 mm, wherein each tooth has a tooth edge at one end and a base at another end which is adjacent an inner surface of the frame, the base having a thickness of about 2 to 3 mm and the edge having a thickness of about 1 mm.

36. The loudspeaker in accordance with claim 29 wherein the clamp is made of an elastic material.

37. The loudspeaker in accordance with claim 34 wherein the teeth have edges with a diameter and a base with a diameter that is larger than the teeth edges diameter, wherein a diameter of an outer surface of the frame is in between the teeth edges diameter and the teeth base diameter, wherein the teeth are made of molded plastic, wherein the teeth deform when the clamp ring captures the membrane in between the teeth and the frame.

38. The loudspeaker in accordance with claim 36 wherein the clamp ring has a membrane contacting surface that has tapered teeth such that the sharpness of the teeth are decreased and likelihood of tearing of the membrane is reduced.

39. The loudspeaker in accordance with claim 35 wherein the frame has a bottom surface with an outside edge, a top surface that has a smaller diameter than that of the bottom surface, and an outer surface defined between the top surface and the outside edge of the bottom surface, wherein the outer surface of the frame is tapered, wherein the clamp ring has an inner surface that corresponds to the tapered outer surface of the frame.

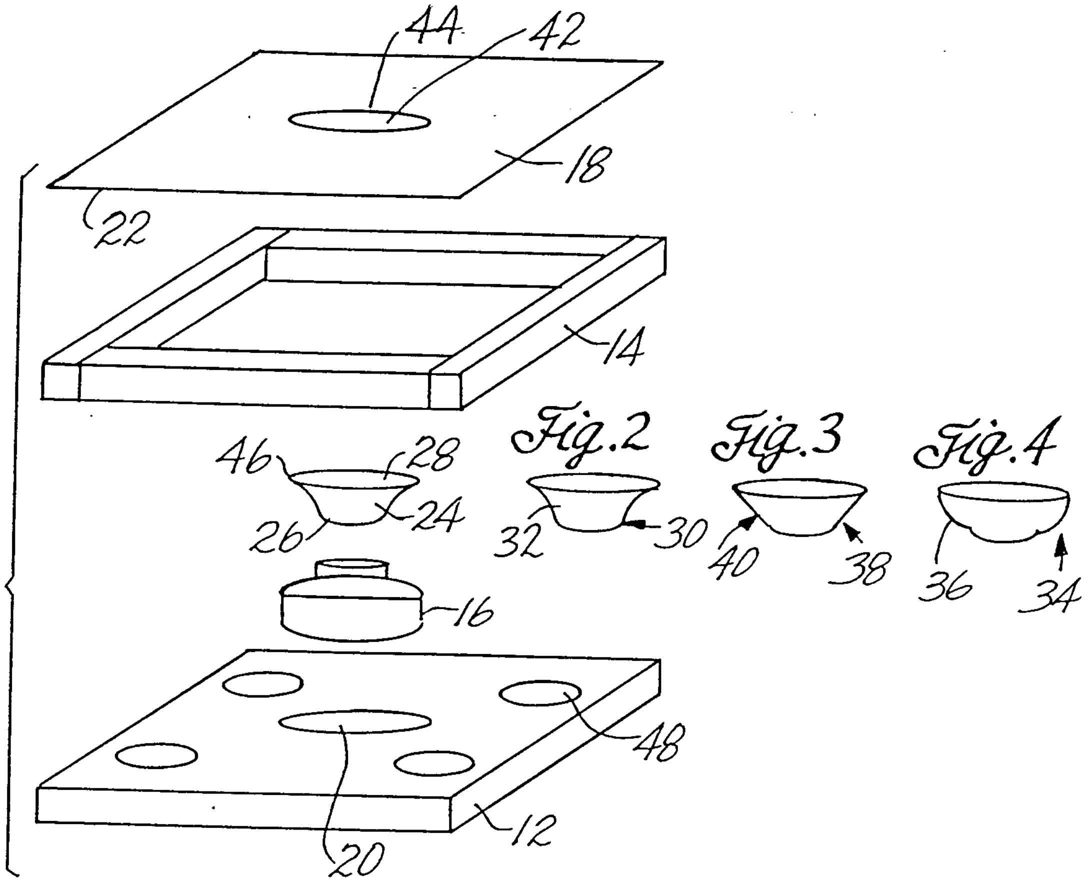

Fig.2 Fig.3 Fig.4

Fig.1

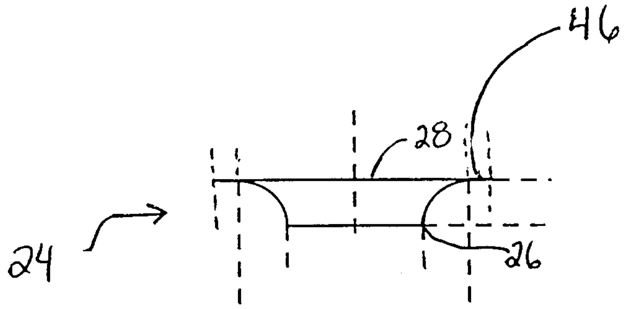

FIG. 5

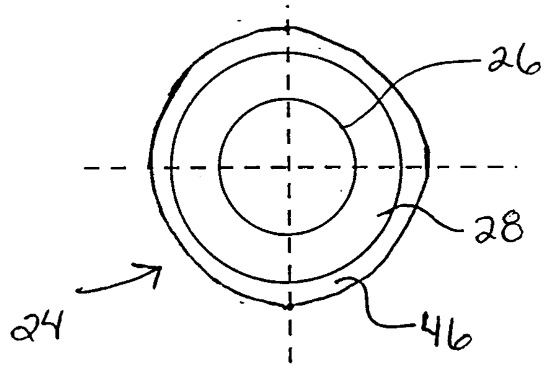

FIG. 6

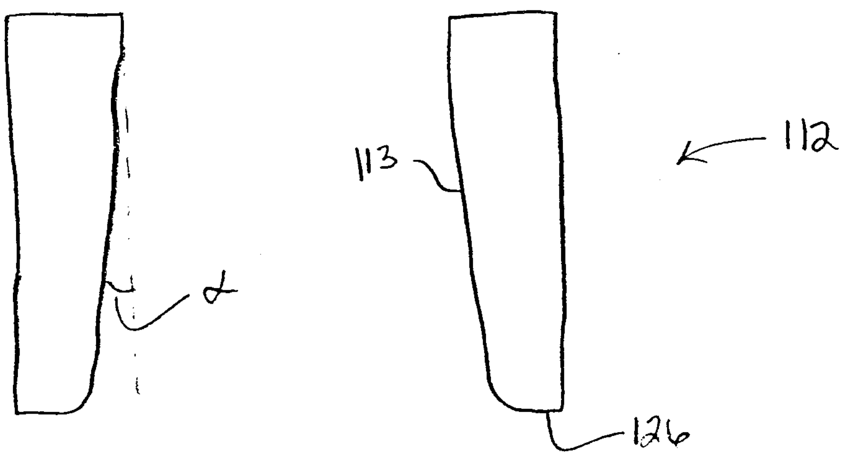

FIG. 15

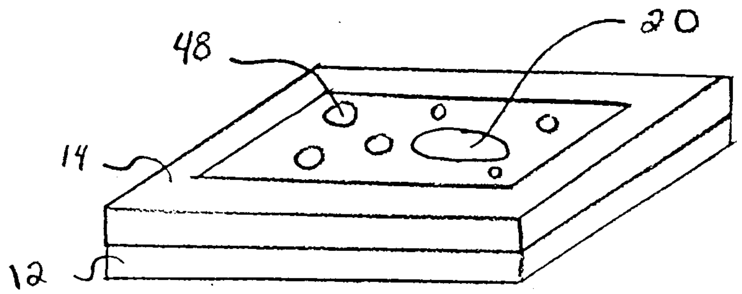

FIG. 7

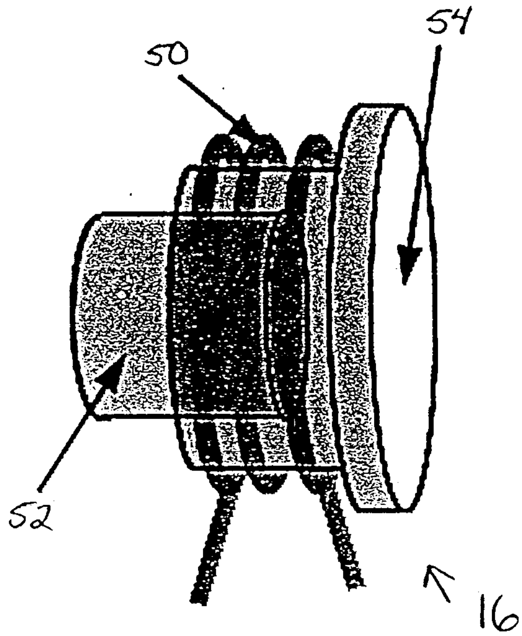

FIG. 8

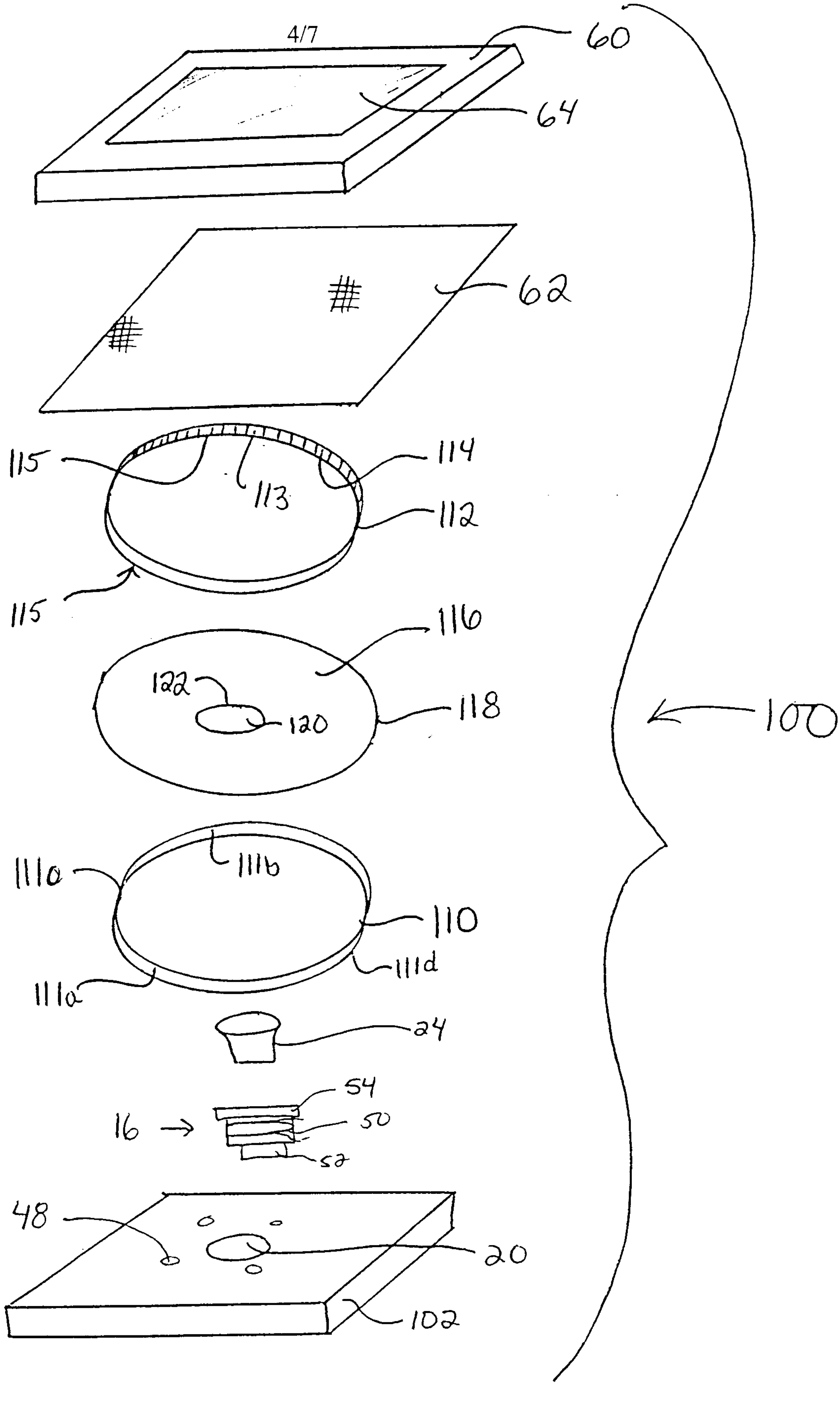
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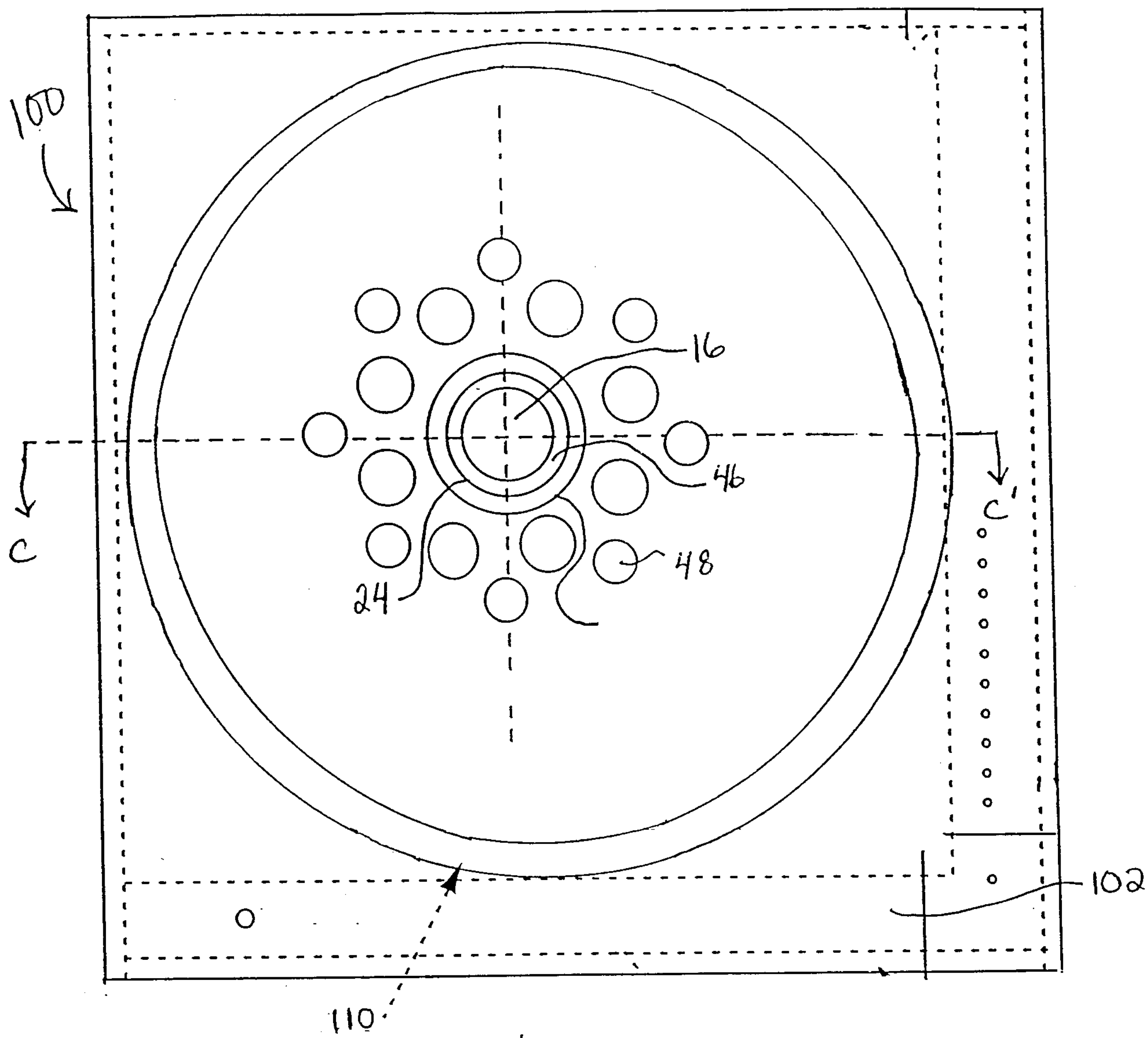
FIG. 9

FIG. 10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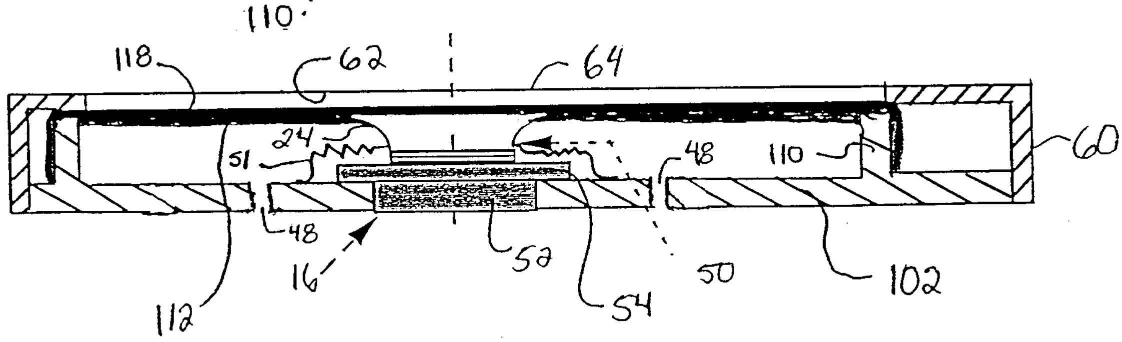
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FIG. 11

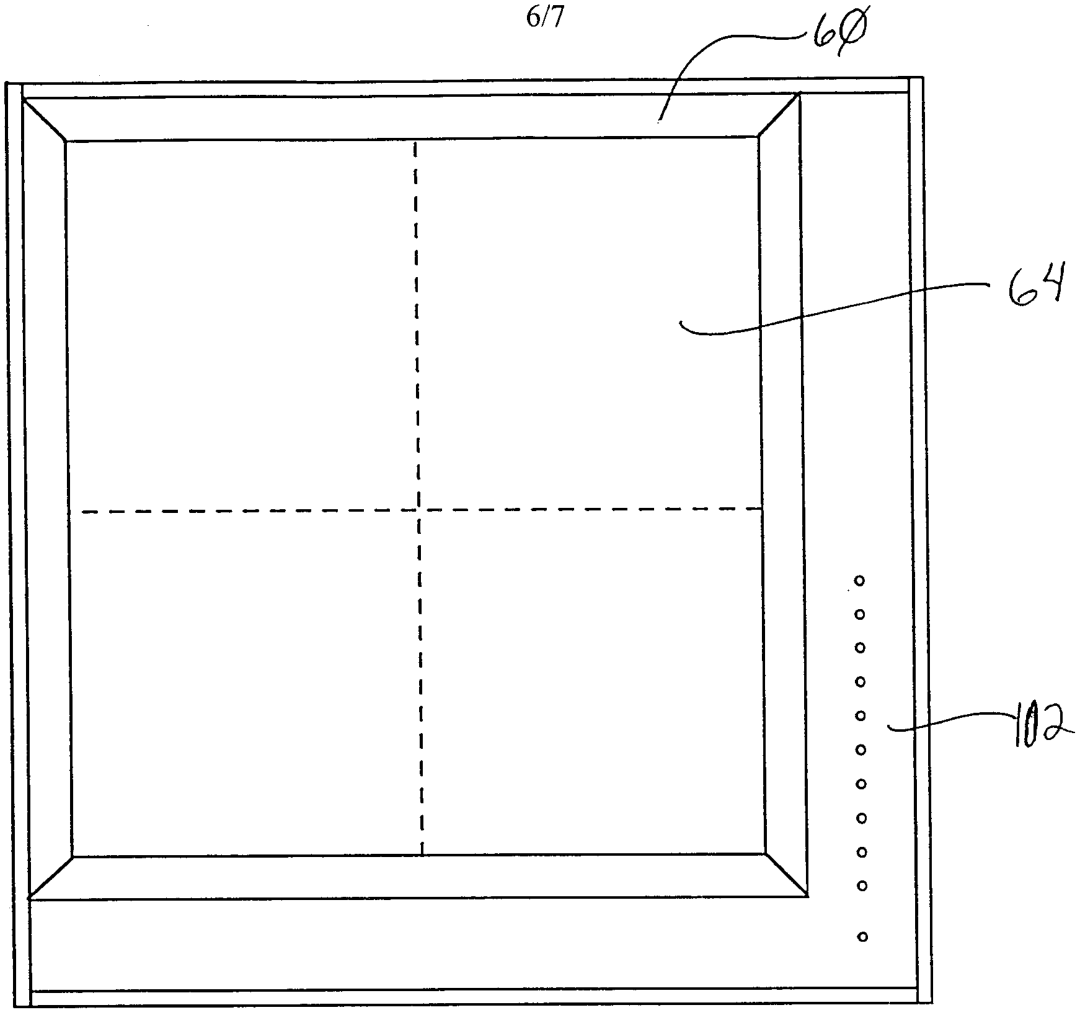


FIG. 12

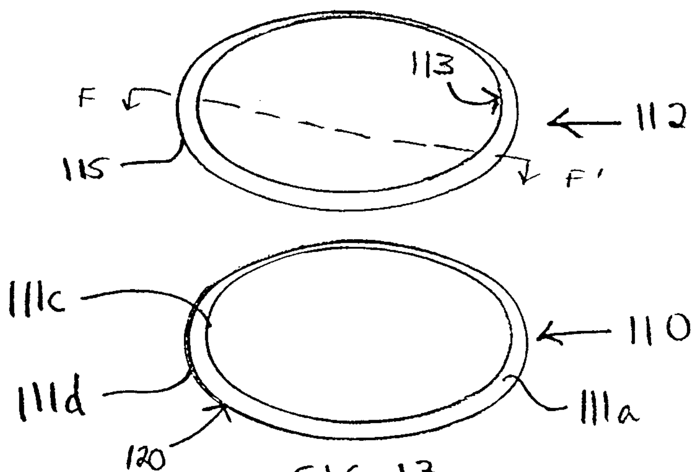
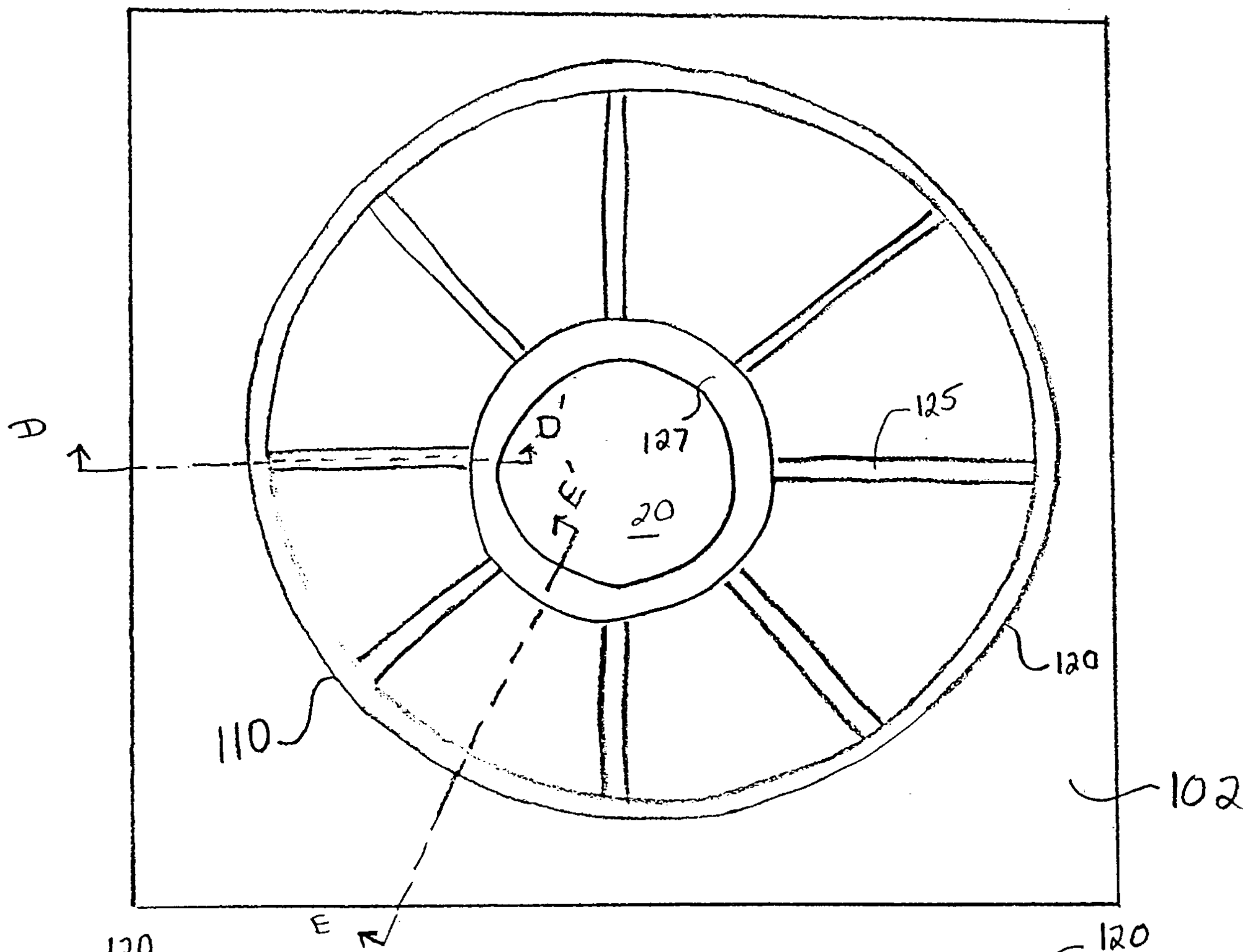
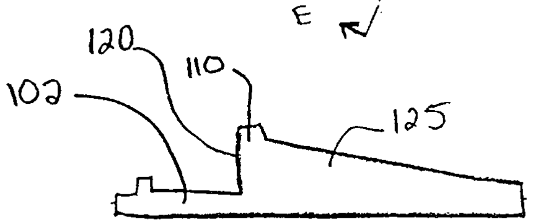


FIG. 13

FIG. 14a





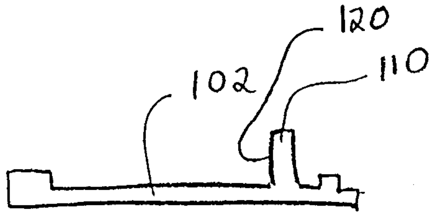


FIG. 14b

FIG. 14c