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(54) **RADIANT COOLER FOR LOUDSPEAKERS**

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H04R 9/06 (2006.01)
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H04R 25/00 (2006.01)

(52) **U.S. Cl.** **381/397**; 381/150; 381/396

(58) **Field of Classification Search** 381/397
See application file for complete search history.

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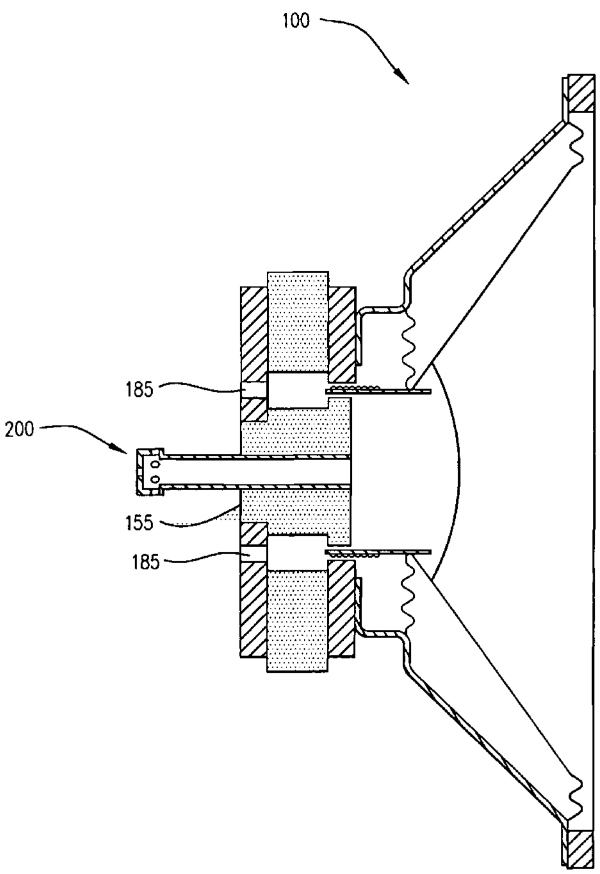
(57) **ABSTRACT**

An apparatus, system, and method is disclosed for providing auxiliary heat dissipating capacity to a loudspeaker assembly. The apparatus comprises a plug that is inserted into a vent at the back of a loudspeaker assembly and extends away therefrom. The plug makes a thermal connection with the pole piece through which the vent is bored, so that the plug conducts at one end the heat from the pole piece that is radiated thereto by the voice coil and radiates this heat to the ambient air at its other end. A plate may be affixed to it other end to provide an additional heat sink for the apparatus. The apparatus may be removable or permanently affixed to the pole piece.

19 Claims, 3 Drawing Sheets



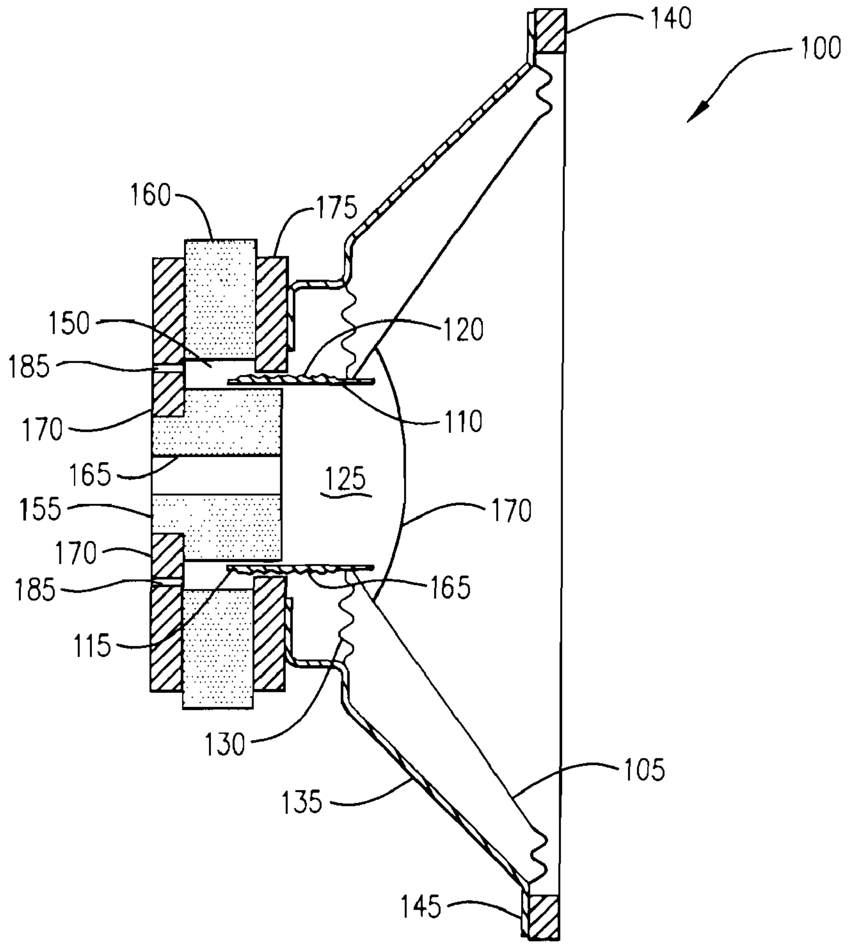


FIG. 1 (PRIOR ART)

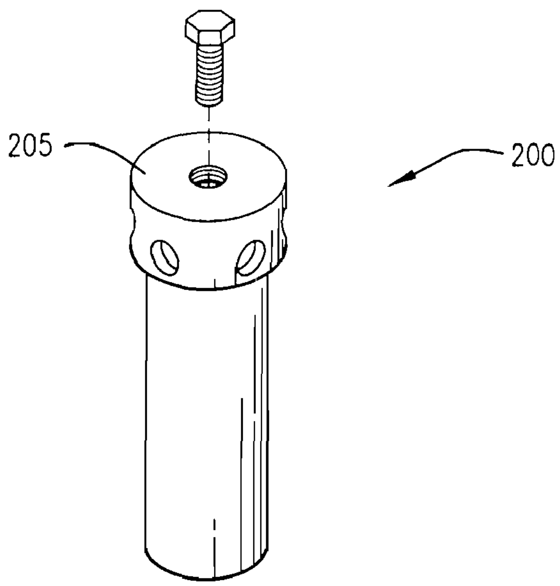


FIG. 2

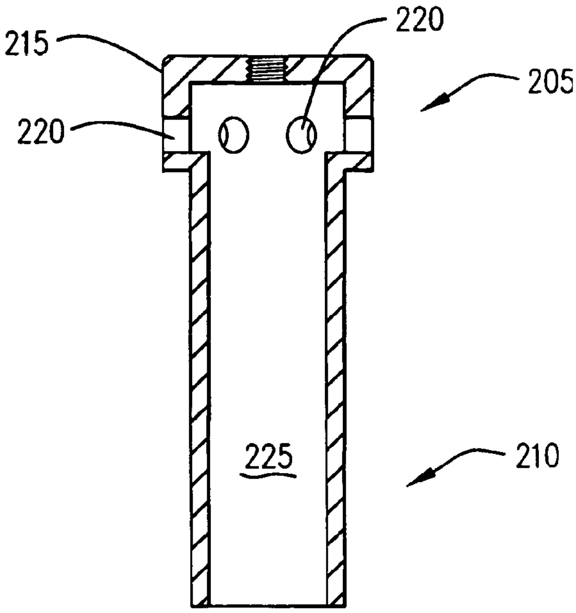


FIG. 3

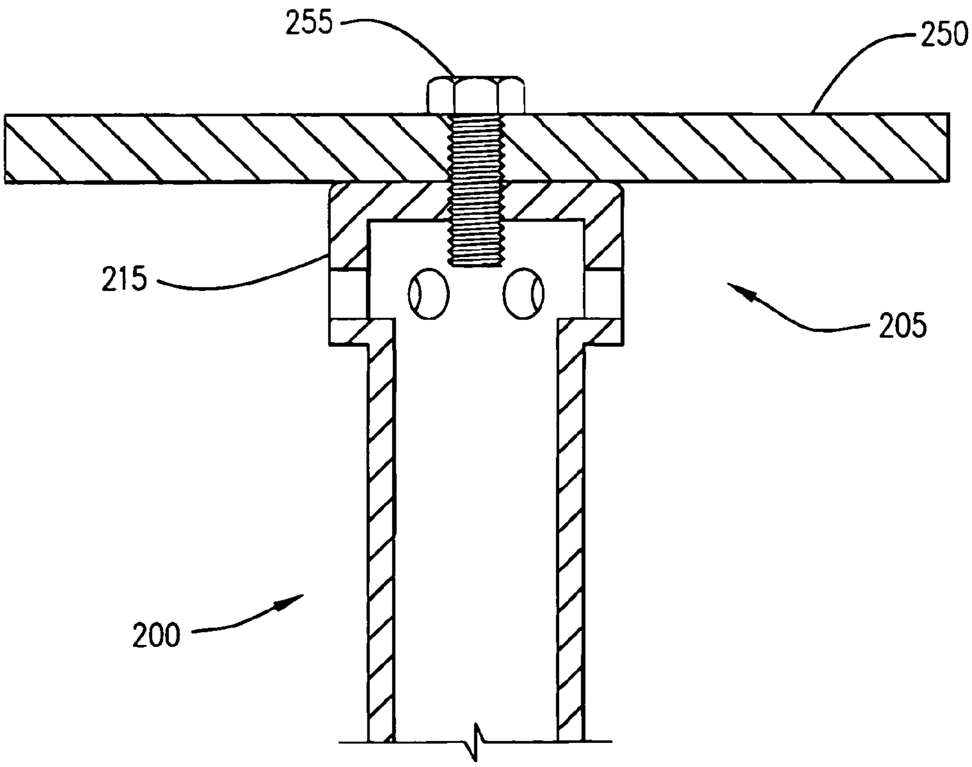


FIG. 4

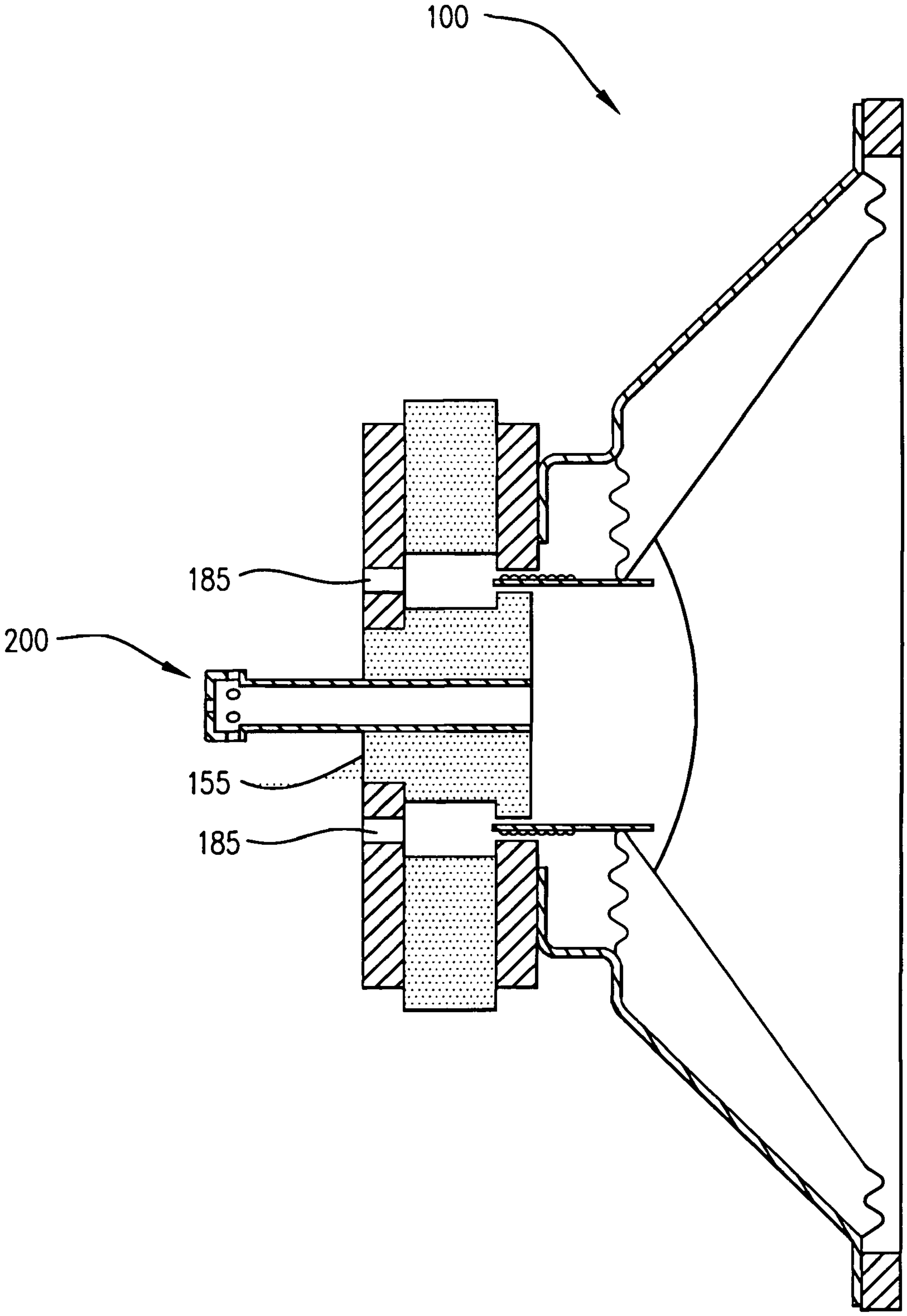


FIG. 3

RADIANT COOLER FOR LOUDSPEAKERS

CROSS-REFERENCES TO RELATED APPLICATIONS

Background of the Invention

The present invention generally relates to methods and devices for removing excess heat from loudspeakers.

A loudspeaker is regarded as a transducer that transforms electrical energy into acoustic energy. This is generally accomplished by causing a voice coil suspended between a magnet surrounding the voice coil and an axially-positioned pole piece to move back and forth within a gap between the magnet and the pole piece. The voice coil is usually constructed as a cylindrical form (also known as a former or bobbin) about which an electrical wire is wound and held in place with an adhesive. A modulated electrical signal is routed through the wire comprising the voice coil, which causes an excursion of the voice coil within the gap. This movement varies according to the modulation of the electrical signal. The resulting kinetic energy of the voice coil is transformed into acoustic energy by affixing a diaphragm in the form of a cone to the voice coil. Kinetic energy of the voice coil is thus transferred to the diaphragm, which results in acoustic wave being produced.

However, this transformation from electrical energy to kinetic energy to acoustic energy isn't 100% efficient, so that much of the kinetic energy is dissipated as heat in the wire comprising the voice coil. The most efficient speakers are generally only about 25% efficient, and many are under 1%. The vast majority of loudspeakers are less than 10% efficient, so that heat dissipation becomes a serious concern to those who design loudspeakers. This heat will result in permanent damage to the loudspeaker elements if it is not dissipated, and in fact the most common failure mode of a loudspeaker is caused by thermal stress. The voice coil of high-power loudspeakers may reach temperatures of several hundred degrees, which weakens the adhesive holding in place the wire comprising the voice coil. The coil will eventually unravel and rub against the pole piece causing a buzzing or grinding sound. Ultimately the wire will break and the loudspeaker will fail.

Heat is transferred from the voice coil by three mechanisms, i.e. transfer from the voice coil wire to the former by conduction, transfer to the air forced through the vents by convection, and transfer to the magnet and pole piece by radiation. The conduction path by direct connection to the voice coil is not particularly good, so it is not a very effective cooling method. The contact area in the voice coil between the wire and the former is small, and this thermal interface is poor. In addition, the materials from which the former and diaphragm are fabricated are not usually good thermal conductors. Some methods have been employed to improve heat transfer by conduction through direct conduction with the voice coil, but they have proven to have limited effectiveness. Forced air convection is the method most often employed for loudspeaker cooling. It has proven to be somewhat effective in spite of the fact that voice coil surface area is small. The most common method of forced air convection is to use the motion of the diaphragm to move air within the gap to move across the voice coil and exit the gap through cooling vents in the pole piece and the backplate. Some methods have employed cooling fans to blow air through the gap which helps increase convective airflow, but these methods also increase system complexity and may cause a pressure differential between the front and back of the diaphragm, resulting in cone offset and ultimately increased audio distortion. Heat transfer by radiation has heretofore been largely overlooked in the loudspeaker art; however, radiation as a heat transfer mechanism is simple and effective.

A number of prior art patents have addressed this heating problem in loudspeakers. The use of conduction to cool the voice coil is illustrated by Gault (U.S. Pat. No. 3,358,088), which discloses a voice coil in which the inner surface of the former has a thermally conductive material adhered thereto in order to conduct heat away from the coil.

However, majority of such patents focus on the concept of heat transfer by convection. Engholm (U.S. Pat. No. 2,261,110) discloses a loudspeaker design in which a dome shaped enclosure is shown to prevent debris from entering the air gap within the coil and thus causing problems. As part of this design, Engholm discloses an inner pole piece that is inserted into the coil, having openings about its circumference to allow air to surge back and forth between the chamber, which is located behind the cap and that behind a flexible support for the voice coil. Proni (U.S. Pat. No. 6,243,479) discloses a loudspeaker having a pole piece extending up into the cylindrical space surrounded by the voice coil. The pole piece has an upper end with vent bores spaced around its circumference and an open port at its lower end. A second patent to Proni (U.S. Pat. No. 6,327,371) discloses a loudspeaker similar to that disclosed in the '479 patent, with the voice coil having vent bores spaced circumferentially around the former of the voice coil. These disclosure all illustrate the use of conductive heat transfer.

Sukurai et al. (U.S. Pat. No. 4,210,778) discloses a heat pipe extending rearwardly from the voice coil of a loudspeaker and folded to release the heat outside the enclosure of the loudspeaker. The heat pipe is sealed at both ends and contains a fluid that absorbs heat by evaporation, transfers the heat to the opposing end of the heat pipe, and releases the heat by condensation, all in a closed, adiabatic cycle. The disclosure does not take advantage of the natural convection action present in the interior of the loudspeaker, which is promoted by the pumping action of the diaphragm of the loudspeaker and is one of the few disclosure that illustrate heat transfer by radiation.

The ability of native heat dissipation devices may be exceeded by excess power spikes being intermittently sent to the loudspeaker assembly or by continuous operation at the maximum allowable power. It would be desirable to augment this heat dissipation as necessary by some convenient means. The use of radiation as a heat transfer mechanism, in cooperation with pre-existing modes of heat transfer, would be useful because it is simple and effective. Any temperature difference between the voice coil and the metal elements surrounding it (i.e. the pole piece, the backplate, the top plate, etc.) provides a heat transfer path via radiation. In a typical loudspeaker, the pole piece reaches temperatures that approach that of the voice coil because of radiated heat from the voice coil. If the pole piece is cooler than the voice coil, then this differential in temperature will cause the pole piece to absorb heat radiated from the voice coil. However, if this temperature differential between the pole piece and the voice coil is low, then transfer of heat is not nearly as efficient. It would therefore be desirable to remove heat from the pole piece, so that the pole piece can continue to work as an effective radiant cooler. There is a need for a device that can be retrofit to an existing loudspeaker assembly, which will augment the capacity of the loudspeaker assembly to dissipate excess heat. Furthermore, such a device should work cooperatively with any heat transfer path that may already be in place.

SUMMARY OF THE INVENTION

The invention provides cooling plug that can be inserted into the loudspeaker cooling vent. The invention functions as a heat sink for removing excess heat radiated by the voice coil to the pole piece, by means of conducting the heat from the pole piece and radiating it to the ambient air along the surface of the cooling plug. Additionally, a large metal disk that serves as an auxiliary heat sink may be attached to the cooling plug to provide additional surface area for radiating the excess heat away from the loudspeaker assembly. The cooling plug of the invention cooperates with convective heat transfer methods by allowing the pumping action of the diaphragm to transfer hot air from the vent to be forced through the cooling plug to exit to the ambient air, while simultaneously allowing heat conducted from the pole piece to be radiated to the ambient air along its length and through any heat sink device that may be attached at its end.

In one aspect of the invention, an apparatus is provided for cooling a loudspeaker assembly, where the loudspeaker assembly has a front side from which sound emanates; a back side; and a voice coil surrounded by a magnet and moving freely about a pole piece with a central vent. The apparatus comprises a plug having a first end and a second end, the second end of the plug snugly inserted within the vent with the first end extending away from the back side and the second end being in contact with the pole piece from within the vent, so that heat radiated from the voice coil to the pole piece is conducted away from the pole piece and radiated to the atmosphere by the plug. Additionally, the apparatus may comprise a plate connected to the first end to augment the capacity of the plug to radiate heat.

In another aspect of the invention, a loudspeaker assembly is provided, where the assembly comprises a loudspeaker and a plug. The loudspeaker has a cone, a voice coil attached to the cone, and a pole piece about which the voice coil moves freely, and the pole piece having a central vent and the voice coil radiating heat to the pole piece. The plug has a first end and a second end, the second end of the plug snugly inserted into the vent with the first end extending away from the pole piece, the second end being in contact with the vent to conduct heat away from the pole piece and radiate the heat to the atmosphere.

In still another aspect of the invention, a method of cooling a loudspeaker assembly is provided, where the method comprises the steps of fabricating an apparatus comprising a cylindrical plug with a first end and a second end, the plug having a plate attached to the first end; inserting the second end into a vent of a loudspeaker assembly, the vent extending through a pole piece of the loudspeaker assembly so that the second end frictionally maintains contact with the pole piece to conduct heat radiated from a voice coil to the pole piece away from the pole piece; and conducting heat generated by the pole piece away from the pole piece to the plate, which radiates the heat to the ambient air.

These and other features, aspects, and advantages of the present invention will become better understood with reference to the following drawings, description, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** shows a generic loudspeaker assembly according to the prior art;

FIG. **2** shows a perspective view of a cooling plug, according to an embodiment of the invention;

FIG. **3** shows a cross-section of a cooling plug, according to an embodiment of the invention;

FIG. **4** shows a cross section of a cooling plug with a plate attached thereon, according to an embodiment of the invention; and

FIG. **5** shows a loudspeaker assembly having a cooling plug that is removably attached to a vent in the pole piece, according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The following detailed description is of the best currently contemplated modes of carrying out the invention. The description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention, since the scope of the invention is best defined by the appended claims.

Broadly, the current invention includes systems, devices, and methods for cooling the voice coil of a loudspeaker by radiation. The invention provides a cooling plug that may be sized to manual insertion into the loudspeaker cooling vent, which extends through a central pole piece about which the voice coil moves, and held therein by means of friction. The cooling plug makes physical contact with the pole piece so that heat radiated by the voice coil to the pole piece is conducted away from the pole piece to a large metal disk attached to the opposing end of the cooling plug, which serves as a heat sink. The apparatus thus radiates to the ambient air the heat generated by the coil and serves as a heat exchanger.

The invention may be retrofit to an existing loudspeaker or may be included as an integral part of the loudspeaker assembly. Since heat is conducted away from the immediate vicinity of the voice coil, the voice coil may operate at a lower temperature and be less prone to destructive heat build up that may melt insulation about the electrical wires of the coil, causing it to fail. The invention does not depend solely upon convection of the air within the speaker assembly to cool the voice coil but instead incorporates the additional thermal paths of conduction and radiation. The invention provides this kind of cooling, and it also cooperatively works with vents in the pole piece and the backplate to allow forced air convection to operate as well.

Referring now to FIG. **1**, a generic loudspeaker assembly **100** is illustrated for reference purposes. The loudspeaker assembly **100** has a cone-shaped diaphragm **105** connected to a voice coil **110** which actuates the diaphragm **105** to produce audible sound waves. The voice coil **110** may be constructed as a cylindrical form **115** made from any heat-resistant material, about which is wound a wire coil **120** that is affixed to the form **115**. The wire coil **120** may have an insulation coating typically fabricated of such materials as shellac, epoxies, or varnish.

The voice coil **110** may define a chamber **125** therein. The form **115** may be attached to an element known in the art as a spider **130**. The spider **130** may be fabricated typically from a resin impregnated, clothlike material and may have concentric, circular corrugations formed therein. The spider **130** may resiliently hold the voice coil **110** in position with respect to a frame **135**, which is typically fabricated from a rigid, metallic material. Alternatively, the spider **130** may be integral with the form **115**. The frame **135** may be attached to the speaker enclosure (not shown) by a gasket **140** placed between a rim **145** of the frame and the speaker enclosure. The diaphragm **105** may be fabricated from well-known materials and is attached to the form **115** at one end, while attached to the rim

145 at the other end, possibly with the use of gasket **140**. The rim **145** may be attached to the frame **135**.

The voice coil **110** may operate in a conventional manner in an annular gap **150**, which is positioned between a center pole piece **155** and an annular magnet **160**. The pole piece **155** may optionally have a vent **165** through its central axis so that air in the chamber **125** communicates with the ambient air. The pole piece **155** and magnet **160** may cause the mechanical actuation of the voice coil **110** and the form **115** in and out of the chamber **125** in response to electrical signals received by the voice coil **110**. Since the voice coil **110** is attached to the diaphragm **105** at its outer end, the diaphragm **105** mechanically vibrates in response to produce acoustic waves. A backplate **170** and top plate **175** may secure the pole piece **155** and magnet **160** in place with respect to the frame **135** and direct the magnetic field from the magnet **160**. Peripheral air vents **185** may sometimes be provided through the backplate **170** for a return air path for the vent **165**. A protective dust cap **180** may be placed over the chamber **125**.

When the electrical signal or current is supplied to the voice coil **110**, the diaphragm **105** vibrates in accordance with the audio frequency and polarity of the electrical signal. The winding used to form the wire coil **120** has an electrical resistance to the flow of current and generates heat. This heat increases the temperature within the loudspeaker assembly **100** and its enclosure. As heat is generated in the voice coil **110**, it is dissipated by three processes. First, the heat may be conducted away from the voice coil **110** by means of both the thermally conductive form **115**. Second, heat may be convected away by forced air passing through the vent **165** and the peripheral cooling vents **185**. Finally, heat may be radiated by the voice coil **110** to the magnet **160**, pole piece **155**, top plate **175** and backplate **170**, all of which surround the voice coil **110**. For high power loudspeaker systems, the temperature of the voice coil **110** and its enclosure correspondingly increases. Heat sinks may be provided in addition to the top plate **175** to dissipate the excess heat, but sometimes the heat may exceed the dissipative capacity of these components, resulting in damage to the loudspeaker assembly.

Referring now to FIGS. **2** and **3**, a cooling plug **200** is shown according to an embodiment of the invention. As can be seen from the figure, the cooling plug **200** may comprise a cylinder or tube of arbitrary length. The length of the cooling plug **200** may be a design choice according to the manufacturer of the loudspeaker assembly or the enclosure within which it is to be installed, but as the length of the cooling plug **200** increases, its surface area also increases so that more heat may be dissipated. Heat transfer between the pole piece and the cooling plug **200** may be maximized by inserting an end of the cooling plug **200** into the vent **165** so that the entire inner surface area of the vent **165** may be in contact with the cooling plug **200**. A first end **205** of the cooling plug **200** may optionally have a knob **215** with holes **220** radially positioned about the circumferential wall of the knob **215** so that the interior **225** of the cooling plug **200** is in communication with the ambient air. The holes **220** may have the function of allowing heated air being pumped in and out of the chamber **125** of the loudspeaker assembly **100** to be vented to the ambient air, so as to provide an additional means for cooling the loudspeaker assembly **100**.

The cooling plug **200** may be fabricated from any heat conductive material, such as aluminum, stainless steel, copper, and the like. It may be preferably machined from single billet of metal, such as aluminum, although separate portions may be fabricated and permanently attached to one another using standard means well known in the art, without departing from the scope of the invention.

Referring now to FIG. **4**, a plate **250** is shown removably attached to the first end **205** of the cooling plug **200**. Like the cooling plug **200**, the plate **250** may be fabricated from any heat conductive material, such as aluminum, stainless steel, copper, and the like. However, the materials comprising the cooling plug **200** and the plate **250** should be chosen so that a dielectric is not created or so that corrosion is not promoted by dissimilar materials. Where a thermal junction exists, heat conductive grease may be employed along the top **205** of the cooling plug **200** to reduce thermal resistance and improve heat transfer. Also, the top **205** may be machined so that it is smooth and mates closely with the plate **250**. The shape of the plate **250** may be arbitrary, although for aesthetic reasons it may be in the shape of a circular disk. The plate **250** may also contain grooves or fins to increase radiating surface area. Other shapes and sizes of the plate **250** may be chosen without departing from the scope of the invention. In the embodiment shown, the plate **250** may be attached to the knob **215** of the cooling plug **200** by a bolt **255** inserted through the plate **250** and fastened into a threaded hole in the knob **215**. A thermal connection may be maintained between the plate **250** and the cooling plug **200** by fabricating the bolt **255** from a heat conducting material compatible with the material comprising the plate **250** and the cooling plug **200**. Alternatively, the plate **250** may be permanently affixed to the knob **215** by means of welding, braising, heat-conducting epoxy, and the like. Any such means may be used without departing from the scope of the invention, as long as a thermal connection is maintained between the plate **250** and the cooling plug **200**.

Referring now to FIG. **5**, the cooling plug **250** may be removably inserted into the vent **165** of the loudspeaker assembly and held therein by friction. The diameter of the cooling plug **200** may be sized appropriately for snug fit of the second end **210** of the cooling plug **200** within the vent **165**. Alternatively, the cooling plug **250** may be removably affixed to the pole piece **155** by providing internal threads within the vent **165** to receive an externally threaded second end **210** of the cooling plug **200**. Any means of removably inserting and affixing the cooling plug **200** to the vent **165** may be used without departing from the scope of the invention, as long as a thermal connection having maximum contact surface area is maintained between the cooling plug **200** and the walls of the pole piece **155**.

The cooling plug **200** disclosed by this specification may be used as part of a method for augmenting the cooling capacity of a loudspeaker assembly. First, an appropriately sized cooling plug **200** may be fabricated with a diameter compatible with the vent of a selected loudspeaker assembly. Next, the cooling plug **200** may be inserted within the vent **155** of the selected loudspeaker assembly **100** so that maximum thermal contact is made between the pole piece **155** and the cooling plug **200**, with the opposing end of the cooling plug **200** extending a distance away from the back plate **170** of the loudspeaker assembly **100**. Next, heat generated by the may be conducted away from the voice coil **110** through the cooling plug **200** for radiation to the ambient air. The plate **250** may be affixed to the end of the cooling plug **200** to provide additional dissipative capacity to the apparatus.

As can be seen, the invention provides an apparatus, a system, and a method for providing additional heat dissipating capacity to a loudspeaker assembly, which can be installed and removed without special tools or dismantling of the loudspeaker assembly. It should be understood, of course, that the foregoing relates to exemplary embodiments of the invention and that modifications may be made without departing from the spirit and scope of the invention as set forth in the following claims.

We claim:

1. An apparatus for cooling a loudspeaker assembly, the loudspeaker assembly having a front side from which sound emanates and a backplate, the loudspeaker assembly having a voice coil surrounded by a magnet and moving freely about a pole piece having a central vent with an inner surface, wherein the apparatus comprises

a plug having a first end and a second end, the second end of the plug removably and snugly inserted into the vent, the first end extending a distance away from the backplate so that a plug portion extending the distance is exposed to ambient air, the second end being in contact with the inner surface of the central vent, wherein heat radiated from the voice coil to the pole piece is conducted away from the pole piece and radiated to ambient air by the plug portion that extends away from the backplate;

wherein the plug is inserted through the backplate into the vent without disassembly of the loudspeaker assembly.

2. The apparatus described in claim **1**, wherein the plug is hollow and a hole in the first end of the plug provides communication between the ambient air and an interior portion of the plug, wherein heated air within a gap between the magnet and the pole piece is conducted through the plug by convection to exit through the hole to the ambient air.

3. The apparatus described in claim **2**, wherein the first end has holes about its circumference.

4. The apparatus described in claim **2**, wherein the plug is cylindrical.

5. The apparatus described in claim **1**, wherein the apparatus further comprises:

a plate connected to the first end, so that heat conducted by the plug is radiated by the plate to the ambient air.

6. The apparatus described in claim **5**, wherein the plate is removably connected to the first end.

7. The apparatus described in claim **5**, wherein the plate is fixedly connected to the first end.

8. A loudspeaker assembly comprising

a loudspeaker having a cone, a voice coil attached to the cone, and a pole piece about which the voice coil moves freely, the pole piece with a central vent providing communication from the voice coil to the ambient air through a backplate, the voice coil radiating heat to the pole piece;

a plug having a first end and a second end, the second end of the plug snugly inserted into the vent through the backplate, the first end extending a distance away from the pole piece so that a plug portion extending the distance is exposed to ambient air, the second end being in contact with an inner surface of the central vent to conduct heat away from the pole piece and radiate the heat to ambient air by the plug portion;

wherein the plug is inserted through the backplate into the vent without disassembly of the loudspeaker assembly.

9. The apparatus described in claim **8**, wherein the plug is hollow.

10. The apparatus described in claim **9**, wherein the first end has holes about its circumference.

11. The apparatus described in claim **8**, wherein the plug is cylindrical.

12. The apparatus described in claim **8**, wherein the plug is removably inserted into the vent from a back side of the loudspeaker assembly.

13. The apparatus described in claim **8**, wherein the apparatus further comprises:

a plate connected to the first end, so that heat conducted by the plug is radiated by the plate to the ambient air.

14. The apparatus described in claim **13**, wherein the plate is removably connected to the first end.

15. The apparatus described in claim **13**, wherein the plate is fixedly connected to the first end.

16. A method of cooling a loudspeaker assembly comprising the steps of:

fabricating an apparatus comprising a cylindrical plug with a first end and a second end, the plug having a plate attached to the first end;

inserting the second end into a vent of a loudspeaker assembly, the vent extending through a pole piece of the loudspeaker assembly and an external backplate so that the second end frictionally maintains contact with the pole piece to conduct heat radiated from a voice coil to the pole piece away from the pole piece;

allowing a plug portion to extend a distance from the backplate so that it is exposed to ambient air;

conducting heat generated by the pole piece away from the pole piece to the plate; and

radiating heat to the ambient air from the plug portion and the plate.

17. A method of cooling a loudspeaker assembly described in claim **16**, wherein the step of inserting the second end into the vent comprises removably inserting the second end into the vent.

18. The apparatus described in claim **5**, wherein the plate has fins.

19. The apparatus described in claim **1**, wherein the plug is solid.

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