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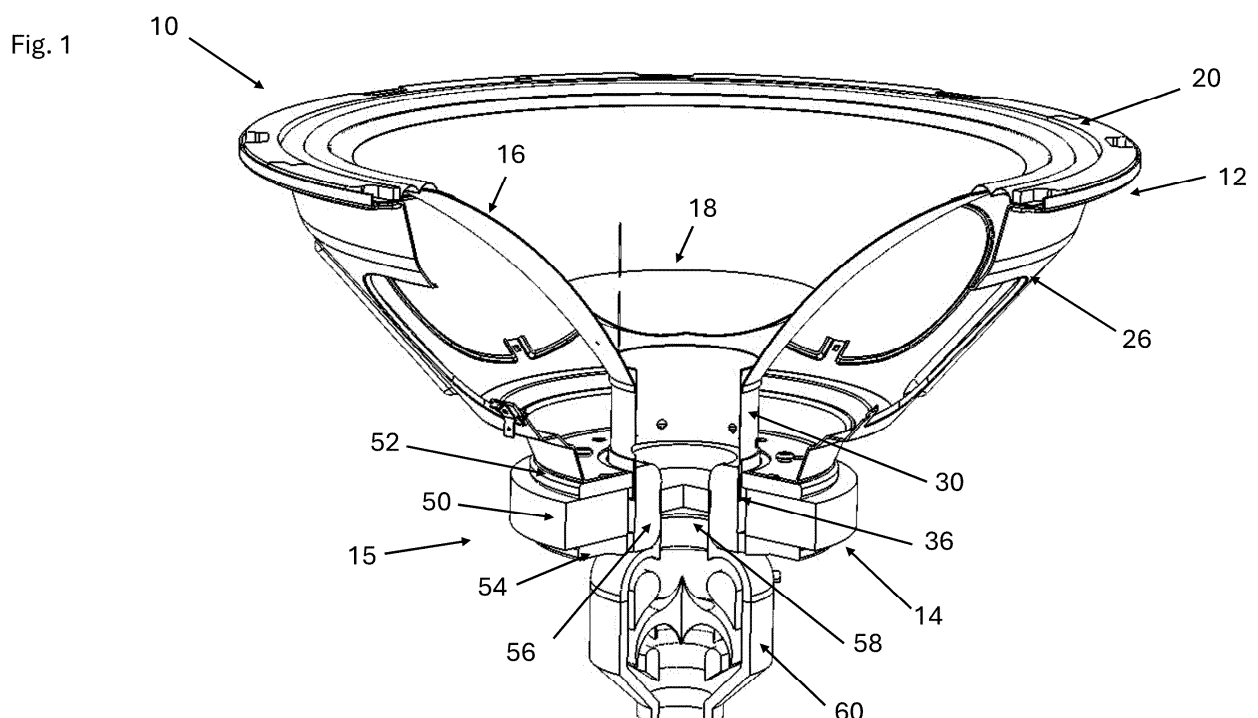
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(54) **LOUDSPEAKER WITH AIRFLOW COOLING SYSTEM**

(57) A loudspeaker includes a diaphragm assembly including a cone attached to a dome and a voice coil former connected to the lower end of the cone; a driver assembly configured to operate the diaphragm assembly for producing acoustical output, including a voice coil mounted on the voice coil former and a permanent magnet assembly that cooperates with the voice coil for

driving the diaphragm assembly; and an airflow director assembly including an inlet part and an outlet part and configured to provide restricted airflow through the airflow director assembly in the direction from the outlet part toward the inlet part so as to promote heat removal from the vicinity of the voice coil.



Description**CROSS REFERENCE TO RELATED APPLICATIONS**

- 5 **[0001]** This application claims priority of U.S. Provisional Application No. 63/791,313 filed on April 18, 2025 under 35 U.S.C. § 119(e), the entire contents of which are hereby incorporated by reference.

Technical Field

- 10 **[0002]** The present invention is related to a loudspeaker and more particularly to a loudspeaker with an improved air cooling system.

Background

- 15 **[0003]** As well known, a loudspeaker system typically contains an acoustic transducer comprising an electromechanical device which converts an electrical signal into acoustical energy in the form of sound waves and a box-type enclosure for directing and amplifying the sound waves produced upon application of the electrical signal. The enclosure also provides mechanical support for the loudspeaker. A loudspeaker is thus the internally mounted electro-mechanical component and the enclosure is the structure for mounting or enclosing the loudspeaker.

- 20 **[0004]** Loudspeakers typically use a driver motor comprising a winding of, usually aluminium or copper, wire about a former forming a voice coil and which coil is suspended within a magnetic field formed by the combination of a top plate, a magnet and a pole piece attached to a back plate. The loudspeaker's cone or diaphragm is attached to the voice coil former. When an electrical current is applied to the winding, the current causes a magnetic field to be generated and thereby the speaker cone moves according to the audio frequency and polarity of the applied signal.
 25 The electrical resistance of the voice coil to current flow generates heat and therefore increases the temperature within the loudspeaker and its enclosure. This resistance to current flow represents a significant part of the driver motor's impedance, and a substantial portion of the electrical input power is converted into heat rather than into acoustic energy.

- 30 **[0005]** Such temperature rise in the voice coil creates various disadvantages. As an example, it has been found that significant temperature rise increases the resistance of the voice coil. This, in turn, results in a substantial portion of the input power of the loudspeaker being converted to heat, thereby further lowering the efficiency and performance of the loudspeaker. In particular, it has been found that increased resistance of the voice coil in the loudspeaker can lead to non-linear loudness compression effects at high sound levels.

- 35 **[0006]** When additional power is supplied to compensate for the increased resistance, additional heat is produced, which again causes an increase in the resistance of the voice coil. At some point, any additional power input will be converted mostly into heat rather than acoustic output. Further, significant temperature rise can melt bonding materials in the voice coil or overheat the voice coil, resulting in permanent structural damage to the loudspeaker.

- 40 **[0007]** The prior art offers solutions to a loudspeaker cooling. By way of example, US 8,831,263 B2, discloses that a loudspeaker includes an enclosure and an acoustic driver having a motor structure. Two ports are positioned in the enclosure so that one port is positioned lower in the enclosure than the other port. There is a DC airflow transferring heat away from the motor structure through the upper port and out of the enclosure, thereby cooling the motor structure. The loudspeaker is cooled by providing a slightly non-symmetrical airflow over the motor structure so that the hot air is migrated away from the voice coil and replaced with cooler air. However, the DC airflow is not directed specially to the voice coil, which is the primary heat-generating part of the transducer, and the cooling effect for the
 45 loudspeaker is not particularly effective. In addition, unwanted noise is generated.

[0008] It is therefore desirable to provide a loudspeaker with a cooling system that can directly cool the voice coil during operation. Reducing voice coil temperature will increase both the efficiency and power capacity of a loudspeaker, as well as its reliability and service life.

- 50 **[0009]** US 6,390,231 B1 discloses a loudspeaker with an improved air-cooling system. The loudspeaker comprises a speaker frame and a diaphragm connected to the speaker frame for reciprocal movement relative thereto. A generally tubular former is connected to the diaphragm, and a voice coil is connected to the former at a location spaced from the diaphragm. A permanent magnet has a central opening and a pole piece has a pole vent opening that is coincident with the central opening. The voice coil is located in a space formed between the permanent magnet and the pole piece. An airflow director is positioned at least partially in the former, with a first gap being formed
 55 between the airflow director and an inner surface of the former and a second gap being formed between the airflow director and the pole piece. The first and second gaps are in fluid communication with each other and the pole vent opening, such that movement of the diaphragm causes airflow through the first and second gaps and the pole vent opening. With this construction, heat generated in the coil during operation of the loudspeaker is transferred to the

former through conduction, and heat present in the former is transferred through the first and second gaps and the pole vent opening through convection to thereby cool the loudspeaker.

[0010] In this loudspeaker, air which moves past the voice coil gives some cooling effect, but the air moves back and forth in a symmetrical fashion following the frequency of cone motion and an input signal. This means that hot air will be passing back and forth over the voice coil winding giving limited cooling effect.

[0011] It is therefore desirable to provide a loudspeaker that can reduce hot air from moving back and forth over the voice coil or even greatly reduce the temperature of air moving across the voice coil.

Summary of the Invention

[0012] The object of the invention is to provide a loudspeaker which is self-cooled without the use of external blowers or other such structures. It is a further object of the present invention to provide a loudspeaker that can reduce hot air from moving back and forth over the voice coil or even greatly reduce the temperature of air moving across the voice coil.

[0013] The above objectives are achieved and the present invention is defined by the appended claims.

[0014] A loudspeaker according to one example of the present disclosure and invention comprises:

a diaphragm assembly including a cone attached to a dome and a voice coil former connected to the lower end of the cone;

a driver assembly arranged and configured to operate the diaphragm assembly for producing an acoustical output, including a voice coil mounted on the voice coil former and a permanent magnet assembly arranged and configured to work with the voice coil for driving the diaphragm assembly; and

an airflow director assembly comprising a housing which includes an inlet part and an outlet part so arranged and configured to allow airflow through the airflow director assembly in the direction from the inlet part to the outlet part and provide restricted airflow through the airflow director assembly in the direction from the outlet part toward the inlet part so as to promote heat removal from the vicinity of the voice coil.

[0015] According to the present invention, a loudspeaker is provided that can be cooled without the use of external blowers, which often generate audible noise and may use power, or other such structures. Further, a loudspeaker of the present invention can reduce hot air from moving back and forth over the voice coil or even greatly reduce the temperature of air moving across the voice coil. Further advantages of the examples of the present disclosure and invention are described in the following also with regard to the attached drawings.

Brief Description of the Drawings

[0016] The preferred embodiments of the present invention will hereinafter of the loudspeaker be described in conjunction with the appended drawings, wherein:

FIG. 1 shows a schematic layout of a loudspeaker according to Embodiment 1.

FIG. 2 shows a schematic layout of an airflow director assembly according to Embodiment 1.

FIG. 3 shows a schematic layout of an assembly process of an airflow director assembly according to Embodiment 1.

FIG. 4A shows an enlarged section view of the airflow director assembly of Fig. 2 showing airflow from an inlet part to an outlet part.

FIG. 4B shows an enlarged section view of the airflow director assembly of Fig. 2 showing airflow from an outlet part.

FIG. 5 shows a schematic layout of a loudspeaker according to a modification of Embodiment 1.

FIG. 6 shows a schematic layout of a loudspeaker according to Embodiment 2.

FIG. 7 shows a schematic layout of an airflow director assembly according to Embodiment 2.

FIG. 8 shows a schematic layout of an airflow director assembly according to Embodiment 2.

FIG. 9 shows a schematic layout of a bottom part of an airflow director assembly according to Embodiment 2.

FIG. 10 shows a schematic layout of a modification of one-way valve part of an airflow director assembly according to Embodiment 2.

FIG. 11 shows a schematic layout of a loudspeaker according to Embodiment 3.

FIG. 12 shows a schematic layout of an airflow director assembly according to Embodiment 3.

FIG. 13 shows a schematic layout of an assembly process of a loudspeaker according to Embodiment 3.

FIG. 14 shows a schematic layout of a loudspeaker according to a modification of Embodiment 3.

FIG. 15 shows a schematic layout of a loudspeaker according to Embodiment 4.

FIG. 16 shows a schematic layout of an airflow director assembly according to Embodiment 4.

FIG. 17 shows a schematic layout of a bottom part of an airflow director assembly according to Embodiment 4, showing an airflow within the airflow director assembly.

Detailed Description

Embodiment 1

[0017] Referring now to the drawings, and in particular to FIG. 1, a loudspeaker 10 according to Embodiment 1 of the present invention is shown in partial cross section. The loudspeaker 10 comprises a diaphragm assembly 12 and a driver assembly 14 that operates the diaphragm assembly 12 for producing acoustical output. The diaphragm assembly 12 includes a cone 16 attached to a dome 18 through adhesive or the like to form a diaphragm 20 and a rigid frame 26. A lower end of the cone 16 is connected to a voice coil former 30 which forms part of the driver assembly 14. With this arrangement, the diaphragm 20 is free to move in an axial direction - which is the vertical direction in FIG. 1.

[0018] The driver assembly 14 includes a voice coil 36 mounted on the voice coil former 30 and a permanent magnet assembly 15 that cooperates with, and generally surrounds, the voice coil 36 for driving the diaphragm 20. The voice coil 36 is typically constructed of copper or aluminium wire and may be attached to the voice coil former 30 through a conventional adhesive.

[0019] The permanent magnet assembly 15 is usually generally annular in shape and is centrally located with respect to a central axis of the diaphragm assembly 12. The permanent magnet assembly 15 includes a permanent magnet 50 disposed between a top plate 52 and a bottom plate 54. The top plate 52 is rigidly connected to the lower end of the rigid frame 26. The top and bottom plates are typically constructed of a material capable of carrying magnetic flux, such as steel. A pole piece 56 of generally cylindrical shape is connected to the bottom plate 54 and extends generally toward the diaphragm 20. The pole piece 56 includes a pole vent 58 that is coincident with an opening in the bottom plate 54. A space or gap is formed between the pole piece 56 and the top plate 52, permanent magnet 50, and bottom plate 54. The voice coil 36 is positioned within the gap.

[0020] The voice coil 36 produces a magnetic field when current is passed therethrough which interacts with the magnetic field produced by the permanent magnet assembly 15. The interaction of the magnetic fields causes the voice coil 36 to oscillate linearly in accordance with the applied changing current. Oscillation of the voice coil 36 in turn moves the diaphragm 20 linearly to generate sound. Movement of the diaphragm causes a change in volume of the airspace between the diaphragm assembly 12 and driver assembly 14. When the diaphragm 20 moves away from the pole piece 56, air is drawn toward the diaphragm 20 through the vent opening of the bottom plate 54 and the pole vent opening of the pole piece 56. Likewise, when the diaphragm 20 moves toward the pole piece 56, air is pushed through the pole vent 58 and the opening. Movement of air through the pole vent 58 in this manner provides some cooling effect for the pole piece 56, but the cooling effect is relatively small, because the hot air tends to return from the pole piece 56 when the diaphragm 20 once again moves away from the pole piece 56.

[0021] With reference now to FIG. 1, the loudspeaker 10 includes an airflow director assembly 60 that is preferably arranged on the bottom of the driver assembly 14. The airflow director assembly 60 is preferably constructed of a relatively rigid material that exhibits stable material properties at the maximum operating temperature of the loudspeaker 10.

[0022] The airflow director assembly 60 is preferably bonded to the bottom surface of the bottom plate 54 with a suitable high temperature adhesive, e.g., a thermally conductive adhesive. Alternatively, a mechanical fitment such as

screw thread or bayonet fitting can be used.

Airflow director assembly 60:

[0023] Fig. 2 is a schematic diagram for illustrating the airflow director assembly 60 of the present invention.

[0024] The airflow director assembly 60 includes an inlet body 68, an outlet body 64, a first valve module 65, a second valve module 66, and a third valve module 67. The first valve module 65, the second valve module 66 and the third valve module 67 are retained within a housing provided by the inlet body 68 and the outlet body 64, each comprising through holes as an inlet and outlet port, respectively, to facilitate airflow into and out of the airflow director assembly 60.

[0025] The outlet body 64 comprises a tapered part 64b, a generally cylindrical part 64a extending in the longitudinal direction of the airflow director assembly 60 from the tapered part 64b toward the inlet body 68. The outlet body 64 may comprise a rib part 64c extending away from the tapered part 64b. The inlet body 68 comprises a bowl-shaped part 68a having an opening 682 (shown in Fig. 3). The inlet body 68 may comprise a raised rib portion 68b next to and extending around the inlet port. One end part of the bowl-shaped part 68a near the third valve module 67 may comprise one or more female interlocking members 681 (shown in Fig. 3). The female interlocking members 681 are preferably slits. The end part of the bowl-shaped part 68a near the outlet body 64 matches the end part of the cylindrical part 64a to form the housing. Preferably, the end part of the cylindrical part 64a and the end part of the bowl-shaped part 68a can be bonded with a suitable adhesive to form the housing, or may be mechanically connected together.

[0026] The raised rib portion 68b is preferably dimensioned so as to extend into and fit snugly within the pole vent 58. In this manner, the airflow director assembly 60 can be quickly and easily aligned and installed on the bottom plate 54 during assembly of the loudspeaker 10.

[0027] Fig. 3 is a schematic diagram for illustrating the assembly of the airflow director assembly 60 of the present invention.

[0028] The first valve module 65 includes a ring portion 652 preferably with at least two projections 651 extending in the longitudinal direction of the airflow director assembly 60 from a surface of the ring portion 652 nearer the inlet body 68. Another outer surface of the ring portion 652 nearer the outlet body 64 comprises a tapered shape generally matching the profile along the inner wall of the tapered part 64b of the outlet body 64. The circumference of the tapered part of the ring portion 652 is smaller than that of the inner wall of the tapered part 64b of the outlet body 64, such that an airflow passage is formed between the inner wall of the tapered part 64b of the housing and the outer surface of the tapered part of the ring portions 652.

[0029] The second valve module 66 is located between the first valve module 65 and the inlet body 68. The second valve module 66 comprises a first central projection 661a extending in the longitudinal direction of the airflow director assembly 60 from the inner bottom surface nearer the first valve module 65 toward the first valve module 65; the second valve module 66 also comprises a second central projection 661b extending in the longitudinal direction of the airflow director assembly 60 from the outer bottom surface nearer the inlet body 68 of the second cup-shaped valve module 66 and toward the inlet body 68. The circumference of the inner wall of the second valve module 66 is greater than that of the outer wall of the first valve module 65, and the upper edge of the second valve module 66 is disposed so as to generally surround the lower portion of the first valve module 65, thereby providing a first return airflow passage between the first valve module 65 and the second cup-shaped valve module 66. The airflow entering the outlet body 64 is split by the upper edge of the first valve module 65 nearer the inlet body 68, such that the air travelling through the first return airflow passage is directed into the air flowing between the housing and the first valve module 65 but in the counter-direction and back toward the outlet body 64.

[0030] According to the invention, the airflow director assembly 60 provides generally more restricted airflow in the direction from the outlet body 64 toward the inlet body 68 by means of the first return airflow passage as compared with the airflow in the direction from the inlet body 68 toward the outlet body 64. The airflow from the inlet body 68 to the outlet body 64 is generally direct or laminar, the airflow from the outlet body 64 to the inlet body 68 is generally restricted and may even be turbulent.

[0031] According to Fig. 2 and Fig. 3, the cross-section view of the second valve module 66 has a circularly symmetrical shape. The second valve module 66 may further comprise at least two openings 662 for inserting the projections 651 of the first valve module 65.

[0032] The third valve module 67 comprises a cylindrical part 67a and preferably at least two apertures or recesses 672 for receiving the projections 651 of the first valve module 65. As seen in Fig. 2, in cross-section view, the cylindrical part 67a has a droplet-like-shape, with the cross-section of the sidewall thickening from a first pointed end located nearer the outlet body 64 towards a second, rounded end located nearer the inlet body 68.

[0033] The circumference of the outer wall of the cylindrical part 67a is smaller than that of the inner wall of the bowl-shaped part 68a and the cylindrical part 64a such that an airflow passage is formed between the outer surface of the

third valve module 67 and the housing formed by the inlet body 68 and the outlet body 64.

[0034] The third valve module 67 preferably comprises one or more male interlocking members 671 protruding radially outward from the outer wall of the cylindrical part 67a for engagement with the female interlocking members 681 of the inlet body 68. The male interlocking members 671 protrude from less than half, or about half, the height of the outer wall of the cylindrical part 67a. In this case, the end on the inlet body 68 side is considered a bottom part of the cylindrical part 67a and with another end on the second valve module 66 side is considered an upper part of the cylindrical part 67a. Preferably, the male interlocking members 671 protrude from about one third the height of the outer wall of the cylindrical part 67a.

[0035] The projections 651 passing through the openings 662 are positioned in the recesses 672 so that the airflow passages are formed between the first valve module 65 and the second valve module 66 and between the second valve module 66 and the third valve module 67, thereby providing the first return airflow passage between the first valve module 65 and the second cup-shaped valve module 66 and a second return airflow passage between the second valve module 66 and the third valve module 67.

[0036] The male interlocking members 671 of the third valve module 67 engage the female interlocking members 681 of the inlet body 68. Therefore, the valve modules are retained in the housing formed by the inlet body 68 and the outlet body 64 and fixed to prevent circumferential movement in the housing. The advantage of this configuration is that no lubrication is required to assemble the airflow director assembly 60. Thus, the assembly process can be simplified.

[0037] In use of the airflow director assembly 60, the heat air is pumped into the inlet body 68 through the inlet port of the airflow director assembly 60 from the pole vent 58, when the diaphragm 20 moves toward the pole piece 56. Fig. 4A shows the airflow from the inlet body 68 toward the outlet body 64. The air flows from the inlet body 68 in the direction of arrow X to the outlet body 64. Fig. 4B shows that airflow entering the outlet body 64 would be split due to the first valve module 65 and the portion interacting with the second valve module 66 would be guided and the first valve module 65 in the counter-direction and back to the outlet body 64. The air flowing in the direction of arrow Y from the outlet body 64 is turned around in the counter-direction by means of the first return airflow passage and interferes with the air flowing in the direction of arrow Z from the outlet body 64.

[0038] Further, even if air were to flow through the air passage between the housing and the second valve module 66, the air flowing in the direction of arrow Y1 may be turned around in the counter-direction by means of the second return airflow passage and interact with the air flowing in the direction of arrow Z1. Therefore, the airflow director assembly 60 constitutes a restricted airflow or an almost impassable barrier to its airflow from the outlet body 64. As a result, the configuration of the airflow director assembly 60 allows the heated air from the loudspeaker 10 to flow preferentially in one direction from the inlet body 68 to the outlet body 64 and away from the voice coil 36, by allowing free outward flow but restricting inward flow. This restricts, or at least hinders and minimizes, the hot air from passing back and forth over the voice coil 36. The heat from the voice coil 36 can be convectively removed from the loudspeaker by air flowing in the direction of arrow X in Fig. 4A during movement of the diaphragm 20 toward the pole piece 56. Thus, the voice coil 36 can be cooled during operation of the loudspeaker.

[0039] The configuration of the Embodiment 1 can achieve a loudspeaker that provides efficient cooling for the sound-generating components, such as the voice coil 36, without the use of active air circulation components, which often generate audible noise and may even use power. Thus, there is no risk of generating audible noise.

[0040] In this manner, the loudspeaker is capable of operation at higher temperature or electrical power and will have less noise and distortion.

Modification of Embodiment 1

[0041] Fig. 5 is a schematic diagram for illustrating a loudspeaker 100 with the airflow director assembly 60, according to a modification of Embodiment 1.

[0042] As illustrated in Fig. 5, in the modification of the Embodiment 1 of the present invention, preferably, the loudspeaker 100 includes the airflow director assembly 60 disposed inside or within the voice coil former 30.

[0043] The airflow director assembly 60 is preferably constructed of a relatively rigid material that exhibits stable material properties at the maximum operating temperature of the loudspeaker 100. The airflow director assembly 60 is preferably bonded to the upper surface of the pole piece 56 with a suitable high temperature adhesive, e.g., a thermally conductive adhesive. The outlet body 64 preferably comprises a raised rib portion 64c of the outlet body 64 dimensioned so as to extend into and fit snugly with the pole piece 56.

[0044] The configuration of the airflow director assembly 60 allows the heated air to flow preferentially in one direction from the inlet body 68, through the inlet port, to the outlet body 64 and out of the outlet port, by allowing free outward flow but restricting inward flow. The airflow director assembly 60 disclosed in the voice coil former 30 is configured to provide restricted airflow through the airflow director assembly 60 in the direction from the outlet body 64 toward the inlet body 68, so as to promote heat removal from the vicinity of the voice coil 36. In this manner, it is

therefore possible to restrict, or minimize, hot air from passing back and forth over the voice coil 36. As a result, heat from the voice coil 36 can be convectively removed from the loudspeaker by air flowing during movement of the diaphragm 20 toward the pole piece 56. Thus, the voice coil 36 can be cooled during operation of the loudspeaker. In addition, as the airflow director assembly 60 is located within the voice coil former 30, it is possible to prevent that the loudspeaker increases in size with the extra airflow director assembly 60. As a result, the configuration of the modification of the Embodiment 1 can achieve a compact loudspeaker that provides efficient cooling for the sound-generating components, like voice coil, without the use of active air circulation components. Thus, there is no risk of generating audible noise.

Embodiment 2

[0045] Fig. 6 is a schematic diagram for illustrating a loudspeaker 200 with an airflow director assembly 600 according to Embodiment 2. Embodiment 2 differs from Embodiment 1 in that the airflow director assembly 600 has a preferably circular, thin and flat structure, preferably a disc structure as shown in Fig. 7. In Embodiment 2, parts that are common to Embodiment 1 are denoted by the same reference symbols, and descriptions thereof are omitted. Further, features that are different from Embodiment 1 are mainly described.

[0046] Fig. 7 and Fig. 8 show schematic diagrams for illustrating the assembly of the airflow director assembly 600 of the present invention. The airflow director assembly 600 comprises a top part 610 having an inlet part 611 preferably including a raised rib in the centre and generally surrounding the inlet port, and a bottom part 620 having at least one outlet part 621 in the outer circumferential side thereof each comprising an outlet port. The top part 610 may be replaced with the rear of the bottom plate 54 or T yoke. The advantage of this configuration is that it can simplify the design to a single plastic moulding adhered to the bottom plate 54 or the T yoke and thus reduce the cost. In addition, assembly processes can be reduced.

[0047] The airflow director assembly 600 may further comprise one or more female interlocking members 612 and one or more male interlocking members 622 for engaging the female interlocking members 612 of the top part 610. The top part 610 and bottom part 620 are fitted together to provide an air passage within the airflow director assembly 600. The advantage of this configuration is that no lubrication is required to assemble the airflow director assembly 600. Thus, the assembly process can be simplified. In addition, use of the interlocking members inhibits rotation of the top part 610 relative to the bottom part 620, ensuring that the top part 610 and the bottom part 620 remain properly engaged.

[0048] The airflow director assembly 600 is preferably bonded to the bottom surface of the bottom plate 54 with a suitable high temperature adhesive, e.g., a thermally conductive adhesive. The raised rib surrounding the inlet port of the inlet part 611 is preferably dimensioned so as to extend into and fit snugly with the pole vent 58. In this manner, the airflow director assembly 600 can be quickly and easily aligned and installed on the bottom plate 54 during assembly of the loudspeaker 200.

[0049] The bottom part 620 has a central air passage aligned, or generally aligned, with the inlet part 611, into which air from the loudspeaker flows from the inlet part 611 into the airflow director assembly 600. As illustrated in Fig. 9, the bottom part 620 further comprises one or more turbulent flow air passages 623 connected between the central air passage and the outlet port in the outlet part 621, through which the air from the loudspeaker flows out from the outlet part 621. The turbulent flow air passage 623 is provided with one or more turbulent flow valve parts, each including a straight passage 623a, a dogleg shaped passage 623b, a bucket passage 623c and an independent partition 623d separating the dogleg shaped passage 623b and bucket passage 623c from the straight passage 623a. This turbulent flow valve constitutes a restricted, maybe even an almost impassable barrier, to airflow in the direction from outlet part 621 to the central air passage. The straight passage 623a has a straight passage extending from the central air passage to the outlet part 621. The dogleg shaped passage 623b consists of two passages forming an obtuse angle to the straight passage 623a. The bucket passage 623c is a U-shaped passage connecting the straight passage 623a with one passage of the dogleg shaped passage 623b not connected to the outlet part 621. The independent partition 623d may have a parallelogram shape. The dogleg shaped passage 623b, the bucket passage 623c and the independent partition 623d constitute a return airflow passage arranged to guide the airflow entering from the outlet part 621 to the straight passage 623a in the direction to return said airflow back to the outlet part 621. The turbulent flow valve part is provided so that the air flowing through the dogleg shaped passage 623b from the outlet part 621 is turned around and interferes with the air flowing directly through the straight passage 623a from the outlet part 621. According to the invention, the airflow director assembly 600 provides restricted airflow in the direction from the outlet part 621 toward the inlet part 611 by means of the return airflow passage as compared with the airflow in the direction from the inlet part 611 toward the outlet part 621.

[0050] Fig. 9 shows how hot air from the voice coil 36 flows from the inlet part 611 in the direction of X1 to the outlet part 621. The air flowing through the dogleg shaped passage 623b from the outlet part 621, that is the opposite direction, is turned around and interferes with the air flowing through the straight passage 623a from the outlet part

621. Therefore, the airflow director assembly 600 constitutes a restricted airflow for air passing from the outlet part 621 to the inlet part 611, even an almost impassable barrier to its flow from the outlet body. As a result, the configuration of the airflow director assembly 600 allows the heated air to flow preferentially in one direction from the inlet part 611 to the outlet part 621. This restricts or minimizes the hot air from passing back and forth over the voice coil 36.

[0051] The heat from the voice coil 36 can be convectively removed from the loudspeaker by air flowing in the direction of arrow X1 in Fig. 9 during movement of the diaphragm 20 toward the pole piece 56. Thus, the voice coil 36 can be cooled during operation of the loudspeaker. The one-way valve part may have a Tesla valve structure.

[0052] Each of the one-way air passages preferably has more than two one-way valve parts as shown in Fig. 10.

[0053] The loudspeaker 200 may further comprise the airflow director assembly 60 disposed in the voice coil former together with the airflow director assembly 600.

Embodiment 3

[0054] Fig. 11 is a schematic diagram for illustrating a loudspeaker 210 with an airflow director assembly 700, according to Embodiment 3. As illustrated in Fig. 11, in the Embodiment 3 of the present invention, a loudspeaker 210 includes an airflow director assembly 700 that has a ring-shape and is preferably disposed between the permanent magnet assembly 15 and the diaphragm assembly 12, instead of the airflow director assembly 600 arranged at the bottom surface of the bottom plate 54. Since the assembly 700 is positioned near the permanent magnet assembly 15, the heat around the voice coil 36 thus can be convectively removed from the loudspeaker through the airflow director assembly 700. The loudspeaker 210 further includes a permeable plug placed within the pole vent 58 so as to ensure that there is a tendency to have airflow to be encouraged through the airflow director assembly 700 to the pole vent 58. The permeable plug may fully block the pole vent 58.

[0055] As illustrated in Fig. 12, the airflow director assembly 700 includes a bottom part 720 having one or more turbulent flow air passages 723 and a top part 710 attached to the bottom part 720 to form the air passage from the inlet port at an inlet part 721 to the outlet port at an outlet part 711 of the airflow director assembly 700. The top part 710 may be replaced by connecting the bottom part 720 directly to the outer rear surface of the frame 26 of the loudspeaker. The advantage of this configuration is that it can simplify the design to a single plastic moulding adhered to the frame 26 and thus reduce the cost. In addition, assembly processes are reduced.

[0056] The turbulent flow air passage 723 is provided with one or more turbulent flow valve parts, each including an inlet part 721, an outlet part 711, a straight passage 723a, a dogleg shaped passage 723b, a bucket passage 723c and an independent partition 723d separating and forming the dogleg shaped passage 723b and bucket passage 723c from the straight passage 723a. The straight passage 723a is a straight passage extending from the inlet part 721 to the outlet part 711. The dogleg shaped passage 723b consists of two passages forming an obtuse angle with the straight passage 723a. The bucket passage 723c is a U-shaped passage connecting the straight passage 723a with one passage of the dogleg shaped passage 723b not connected to the inlet part 721. The independent partition 723d preferably has a parallelogram shape.

[0057] According to the invention, the configuration of the airflow director assembly 700 provides restricted airflow in the direction from the outlet part 711 toward the inlet part 721, when compared with the airflow in the direction from the inlet part 721 toward the outlet part 711.

[0058] Fig. 12 shows how cool air outside the loudspeaker 210 flows in the direction of X2 from the inlet port of the inlet part 721 to the outlet port of the outlet part 711 and into the loudspeaker 210. As a result, the configuration of the airflow director assembly 700 restricts the amount of air that can be expelled from the space between the permanent magnet assembly 15 and the diaphragm assembly 12 but allows cool air from outside the loudspeaker to be drawn in more easily. The cool air outside the loudspeaker 210 can be convectively drawn into the loudspeaker 210 by air flowing in the direction of arrow X2 in Fig. 12 during movement of the diaphragm 20. Thus, the voice coil 36 can be cooled during operation of the loudspeaker.

[0059] Fig. 13 is a schematic diagram for illustrating the assembly of the loudspeaker 210 of the present invention. The airflow director assembly 700 having a ring shape is positioned between the permanent magnet assembly 15 and the diaphragm assembly 12. The airflow director assembly 700 may be bonded to the permanent magnet assembly 15 and the diaphragm assembly 12 with a suitable high temperature adhesive, e.g., a thermally conductive adhesive. The advantage of this configuration is that the airflow director assembly 700 can be added very easily during the loudspeaker assembly process.

Modification of Embodiment 3

[0060] The loudspeaker 220 may comprise the airflow director assembly 60, which is disposed inside the voice coil former 30 and/or the airflow director assembly 600, together with the airflow director assembly 700, as illustrated in Fig. 14. The airflow director assembly 700 may restrict the amount of air that can be expelled from the space between

the permanent magnet assembly 15 and the diaphragm assembly 12 but allow cool air from outside the loudspeaker 220 to be drawn in more easily. As the airflow director assembly 60 is configured so that air can more easily leave the enclosed space of the airflow director assembly 60 and the airflow director assembly 700 disposed between the permanent magnet assembly 15 and the diaphragm assembly 12 more easily allows cool air to be drawn into the loudspeaker 220, a more controlled DC airflow of fresh air from an area between the permanent magnet assembly 15 and the diaphragm assembly 12 down around the voice coil 36 and through the pole vent 58 is potentially achieved. As the result, further cooling effect for the loudspeaker can be obtained.

Embodiment 4

[0061] Fig. 15 is a schematic diagram for illustrating a loudspeaker 300 with an airflow director assembly 800 according to Embodiment 4. Embodiment 4 differs from Embodiment 1 in that the loudspeaker has an airflow director assembly 800 instead of the airflow director assembly 60. In Embodiment 4, parts that are common to Embodiment 1 are denoted by the same reference symbols, and descriptions thereof are omitted. Further, features that are different from Embodiment 1 are mainly described.

[0062] The airflow director assembly 800 has a circular, thin and flat structure, like a disc structure with at least two extended outlet parts 821. The extended outlet parts 821 preferably extend from the outer circumference of the airflow director assembly 800, parallel with each other and in opposite directions so that the air flowing from the outlet port of outlet parts 821 can be guided in opposite directions. The airflow director assembly 800 includes a bottom part 820 having at least two partitions 822 and a top part 810 having an inlet part 811 preferably including a raised rib in the centre surrounding the inlet port as shown in Figs. 16-17.

[0063] As illustrated in Figs. 16-17, the top part 810 may include at least two sleeves 813 having a female interlocking members 812, and the bottom part 820 may include at least two sleeves 823 having a male interlocking member 823a for engaging the female interlocking members 812 of the top part 810. The male interlocking member 823a of the bottom part 820 engages the female interlocking member 812 of the top part 810. The advantage of this configuration is that no lubrication is required to assemble the airflow director assembly 800. Thus, the assembly process can be simplified. Since the sleeves 823 are arranged between the outside of the airflow director assembly 800 and the extended outlet parts 821, so as to connect the outlet part 821 and the outer area of the airflow director assembly 800. This allows the extended outlet parts 821 to have some rigidity, and prevents damage to the extended outlet parts 821.

[0064] Each of the partitions 822 is placed inwardly and form-matching the inner circumference of the bottom part 820 to form a Y-shaped air passage constructed by the partition 822 and the extended outlet part 821 near the outlet part 821. The length of the partition may be long enough to form the Y-shaped air passage near the outlet part 821.

[0065] In use of the airflow director assembly 800, heated air is pumped through the inlet port into the inlet part 811 of the airflow director assembly 800 from the pole vent 58, when the diaphragm 20 moves toward the pole piece 56. Fig. 17 shows how the air within the airflow director assembly 800 flows to the outlet part 821 when heated air is pumped into the inlet part 811 of the airflow director assembly 800.

[0066] The airflow director assembly 800 is configured so that the outlet parts 821 are positioned to direct the air from outside tangentially to the circular structure, which tend to create circular vortices that prevent the air flow from easily reaching the inlet part 811, since the momentum vector is perpendicular to the axis of the inlet part 811. As a result, the configuration of the airflow director assembly 800 ensures that the heated air preferentially flows into the inlet part 811 and exits through the outlet parts 821.

[0067] This restricts the hot air from passing back and forth over the voice coil 36. The heat from the voice coil 36 can be convectively removed from the loudspeaker by air flowing in the direction of arrow X3 in Fig. 17 during movement of the diaphragm 20 toward the pole piece 56. Thus, the voice coil 36 can be cooled during operation of the loudspeaker.

[0068] The loudspeaker 300 may further comprise the airflow director assembly 60 disposed in the voice coil former and/or the airflow director assembly 700 positioned between the permanent magnet assembly 15 and the diaphragm assembly 12, together with the airflow director assembly 800. As the result, further cooling effect for the loudspeaker can be obtained.

[0069] The airflow director of the invention is preferably constructed of a relatively rigid material that exhibits stable material properties at the maximum operating temperature of the loudspeaker.

Reference sign list

[0070]

10,100,200,210,300 loudspeaker

12	diaphragm assembly
14	driver assembly
5 15	permanent magnet assembly
60,600,700,800	airflow director assembly
20	diaphragm
10 16	cone
18	dome
15 30	voice coil former
36	voice coil
50	permanent magnet
20 52	top plate
54	bottom plate
25 56	pole piece
58	pole vent

Claims

- 30 1. A loudspeaker (10,100,200,210,220,300) comprising:
- a diaphragm assembly (12) including a cone (16) attached to a dome (18) and a voice coil former (30) connected to the lower end of the cone (16);
- 35 a driver assembly (14) arranged and configured to operate the diaphragm assembly (12) for producing an acoustical output, including a voice coil (36) mounted on the voice coil former (30) and a permanent magnet assembly arranged and configured to work with the voice coil (36) for driving the diaphragm assembly (12); and
- 40 an airflow director assembly (60,600,700,800) comprising a housing which includes an inlet port in an inlet part (68,611,711,811) and an outlet port in an outlet part (64,621,721,821) so arranged and configured to allow airflow through the airflow director assembly (60,600,700,800) in a direction from the inlet part (68,611,711,811) to the outlet part (64,621,721,821) and provide restricted airflow, in comparison, through the airflow director assembly (60,600,700,800) in a direction from the outlet part (64,621,721,821) toward the inlet part (68,611,711,811) so as to promote heat removal from the vicinity of the voice coil (36).
- 45 2. The loudspeaker (10) according to claim 1, wherein the airflow director assembly (60) further comprises:
- a first valve module (65) located near the outlet part comprising a ring portion (652);
- 50 a second cup-shaped valve module (66) located between the first valve module (65) and the inlet part (68) comprising a first central projection extending in a longitudinal direction of the airflow direction assembly from the interior bottom near the first valve module (65) toward the first valve module (65) and a second central projection extending in the longitudinal direction of the airflow direction assembly from the exterior bottom near the inlet part (68) of the second cup-shaped valve module (66) toward the inlet part (68); and
- 55 a third valve module (67) having a cylindrical part (67a) located between the second cup-shaped valve module (66) and the inlet part (68),
- wherein in cross-section view, the cylindrical part (64a) has a droplet-shape, with the cross-sectional wall thickening from a first pointed end located nearer the outlet part towards a second rounded end located nearer the inlet part (68), and

wherein the first valve module (65), the second valve module (66) and the third valve module (67) are retained within the housing formed by the inlet part (68) and the outlet part so as to form air passages between the valve modules and between each of the valve modules and the housing.

3. The loudspeaker according to claim 2, wherein the first valve module (65) comprises at least two projections (651) extending in the longitudinal direction of the airflow direction assembly (60) from the surface of the ring portion (652) near the second cup-shaped valve module (66) toward the inlet part (68),

wherein the second cup-shaped valve module (66) comprises at least two openings (662) through which the projections (651) extend, and wherein the third valve module (67) comprises at least two recesses (672) to receive the projections (651) so that airflow passages are formed between the first valve module (65) and the second cup-shaped valve module (66) and between the second cup-shaped valve module (66) and the third valve module (67).

4. The loudspeaker according to claim 2 or claim 3, wherein the outlet part (64) comprises a tapered part (64b) and a cylindrical part (64a) extending in the longitudinal direction of the airflow direction assembly from the tapered part (64b) toward the inlet part (68),

wherein the outer surface of the ring portion (652) near the outlet part comprises a tapered shape generally matching the profile along the inner wall of the tapered portion of the outlet part and a circumference of the tapered shape surface of the ring portion (652) is smaller than that of the inner wall of the tapered part (64b) of the outlet body such that an airflow passage is formed between the outlet part and the outer surface of the first valve module (65), and

wherein circumferences of the outer wall of the second cup-shaped valve module (66) and the third valve module (67) are smaller than that of the inner wall of the cylindrical part (64a) such that an airflow passage is formed between the outlet part (64) and the second and third valve modules (66,67).

5. The loudspeaker according to any one of claims 2 to 4, in particular claim 4,

wherein a circumference of the inner wall of the second cup-shaped valve module (66) is greater than that of the outer wall of the first valve module (65), and the upper edge of the second cup-shaped valve module (66) is disposed so as to surround a lower portion of the first valve module (65), thereby providing a return airflow passage between the first valve module (65) and the second cup-shaped valve module (66) so that the airflow entering the outlet part would be split and a portion interacting with the cup-shaped valve module would be guided back to join a portion of the airflow between the housing and the first valve module (65) in the counter-direction and back toward the outlet part, and wherein the airflow director assembly (60) is thereby configured to provide restricted airflow in a direction from the outlet part toward the inlet part through the return airflow passage as compared with airflow in the direction from the inlet part toward the outlet part.

6. The loudspeaker according to claim 1, wherein the airflow director assembly (600) has a disc shape, and further comprises a top part (610) having an inlet port at the inlet part (611) in the upper surface thereof, preferably in the center, and a bottom part (620) having an outlet port at the outlet part (621) in an outer circumferential side thereof, and

wherein the bottom part (620) comprises a central air passage aligned with the inlet part (611) and one or more one-way air passages (623), each including a one-way valve part configured to provide restricted airflow from the outlet part (621) toward the inlet part (611).

7. The loudspeaker according to claim 6, wherein the one-way valve part comprises a straight passage (623a), a dogleg shaped passage (623b), a bucket passage (623c) and an independent partition (623d) separating the dogleg shaped passage (623b) and bucket passage (623c) from the straight passage (623a),

wherein the dogleg shaped passage (623b), the bucket passage (623c) and the independent partition (623d) constitute a return airflow passage arranged to guide the airflow entering from the outlet part (621) to the straight passage (623a) in the direction to return the airflow back to the outlet part (64), and

wherein the airflow director assembly (600) is configured to provide restricted airflow from the outlet part (621) toward the inlet part (611), when compared with airflow from the inlet part to the outlet part, through the return airflow passage.

8. The loudspeaker according to claim 1, wherein the airflow director assembly (800) has a disc shape, and further comprises a top part (810) having an inlet port at the inlet part (811) in the upper surface thereof, preferably in the center, and a bottom part (820), wherein the top part (810) and the bottom part (820) comprise at least two extended outlet parts comprising outlet ports on the side,

wherein the bottom part (820) comprises at least two partitions (822), each of said partitions (822) being placed inwardly and form-matching the inner circumference of the bottom part (820) to form a Y-shaped air passage near the outlet part (821), and

wherein the outlet ports are arranged to direct the air from outside tangentially to the circular structure.

9. The loudspeaker according to any one of claims 1 to 8, wherein the permanent magnet assembly (15) comprises:

a permanent magnet (50) disposed between a top plate (52) and a bottom plate (54); and

a pole piece (56) connected to the bottom plate (54) and having a pole vent (58) that is coincident with an opening in the top plate (52),

wherein the inlet part (68,611,811) has a raised rib to extend into and fit with the pole vent (58) of the permanent magnet assembly (15).

10. The loudspeaker according to any one of claims 1 to 8, wherein the permanent magnet assembly (15) comprises:

a permanent magnet (50) disposed between a top plate (52) and a bottom plate (54); and

a pole piece (56) connected to the bottom plate (54) and having a pole vent (58) that is coincident with an opening in the top plate (52),

wherein the outlet part (64,621,821) has a raised rib to extend into and fit with the pole vent (58) of the permanent magnet assembly (15).

11. The loudspeaker according to any one of claims 1-9, wherein the airflow director assembly (60,600,800) is arranged at the bottom surface of the bottom plate of the permanent magnet assembly (15).

12. The loudspeaker according to claim 1, wherein the airflow director assembly (700) has a ring-shape, and further comprises one or more one-way air passages (723), each including a one-way valve part, the one-way valve part comprising an inlet port at the inlet part (721) located on the outer surface of the airflow director assembly (700), the outlet part comprising an outlet port located on the inner surface of the airflow director assembly (700), a straight passage (723a), a dogleg shaped passage (723b), a bucket passage (723c) and an independent partition (623d) separating the dogleg shaped passage (723b) and bucket passage (723c) from the straight passage (723a), and wherein the airflow director assembly (700) is configured to provide restricted airflow from the outlet part (711) toward the inlet part (721), when compared with airflow from the inlet part (721) to the outlet part, by means of the return airflow passage.

13. The loudspeaker according to claim 12, wherein the airflow director assembly (700) is positioned between the permanent magnet assembly (15) and the diaphragm assembly (12).

14. The loudspeaker according to claim 13, further comprising an airflow director assembly (60) arranged at a bottom surface of the bottom plate (54) of the permanent magnet assembly (15),

wherein the airflow director assembly (60) comprises:

a first valve module (65) located near the outlet part (64), which comprises an outlet port, comprising a ring portion (652);

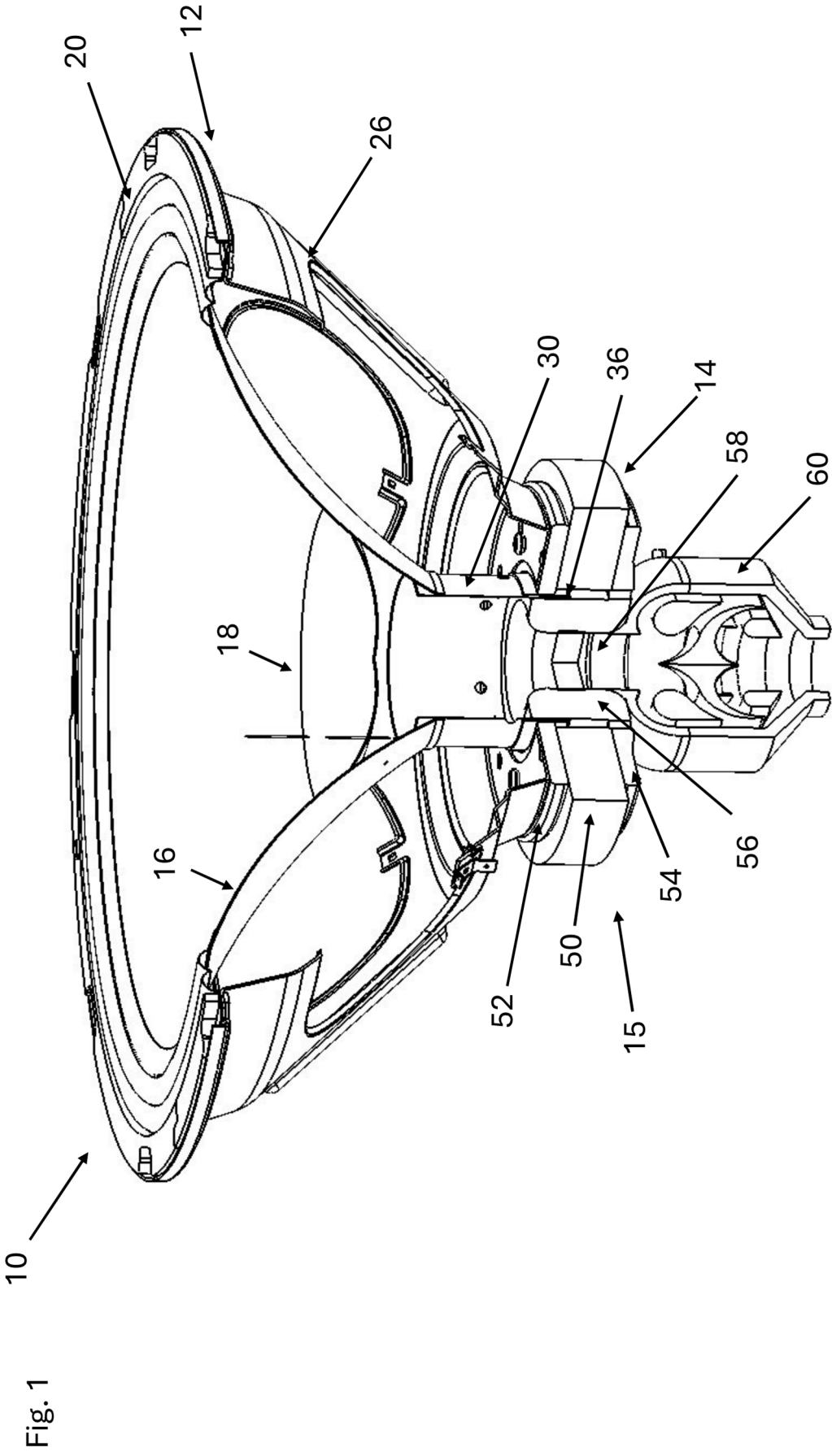
a second cup-shaped valve module (66) located between the first valve module (65) and the inlet part (68), which comprises an inlet port, comprising inner and outer central projections (661) at the inner bottom and outer bottom of the second cup-shaped valve module (66); and

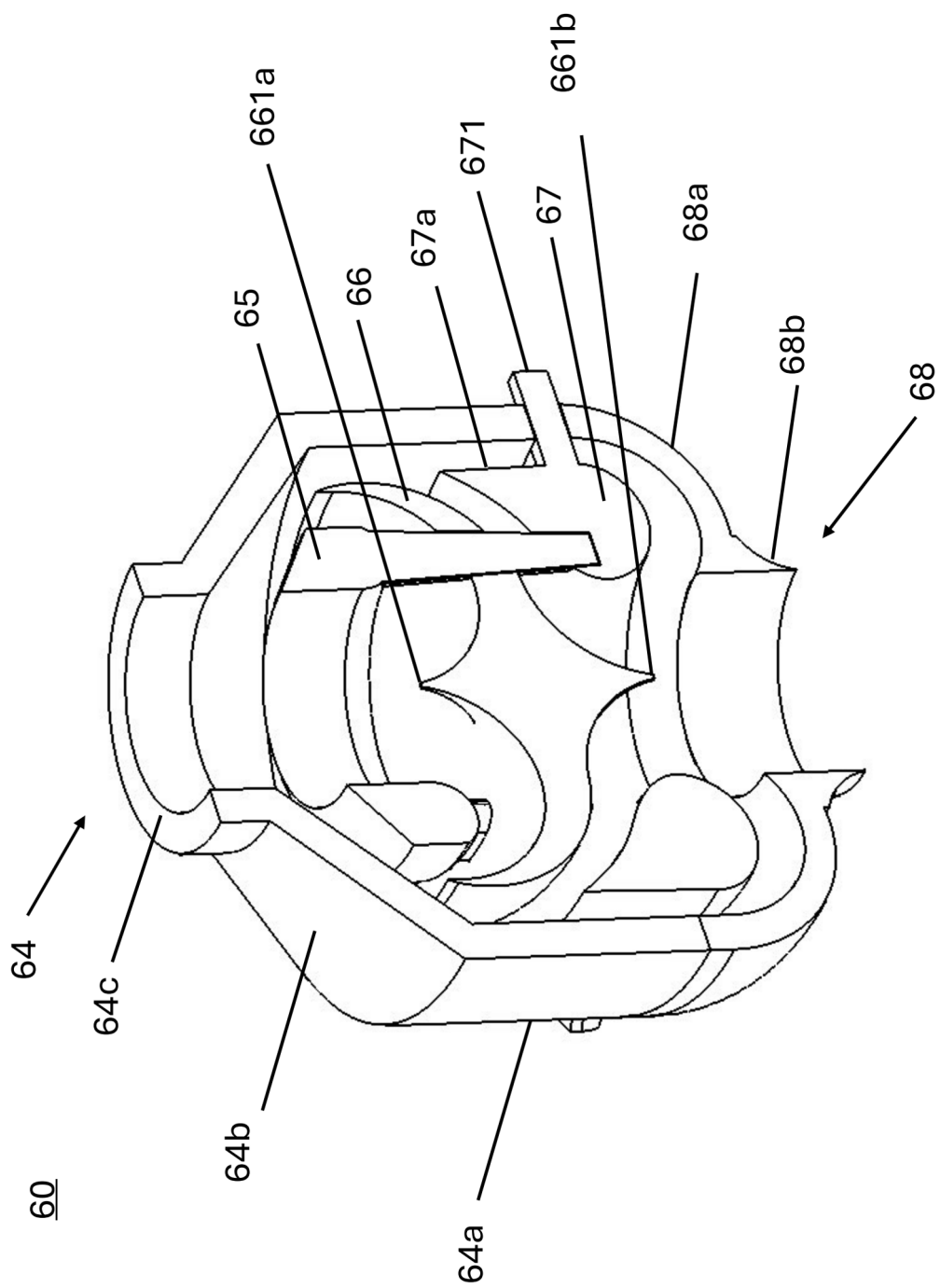
a third valve module (67) located between the second cup-shaped valve module (66) and the inlet part (68) having a cylindrical part (67a) and more than one male interlocking member (671) protruding radially outwards from the outer wall of the cylindrical part (67a),

wherein in cross-section view, the cylindrical part (67a) has a droplet-shape, with the cross-sectional wall

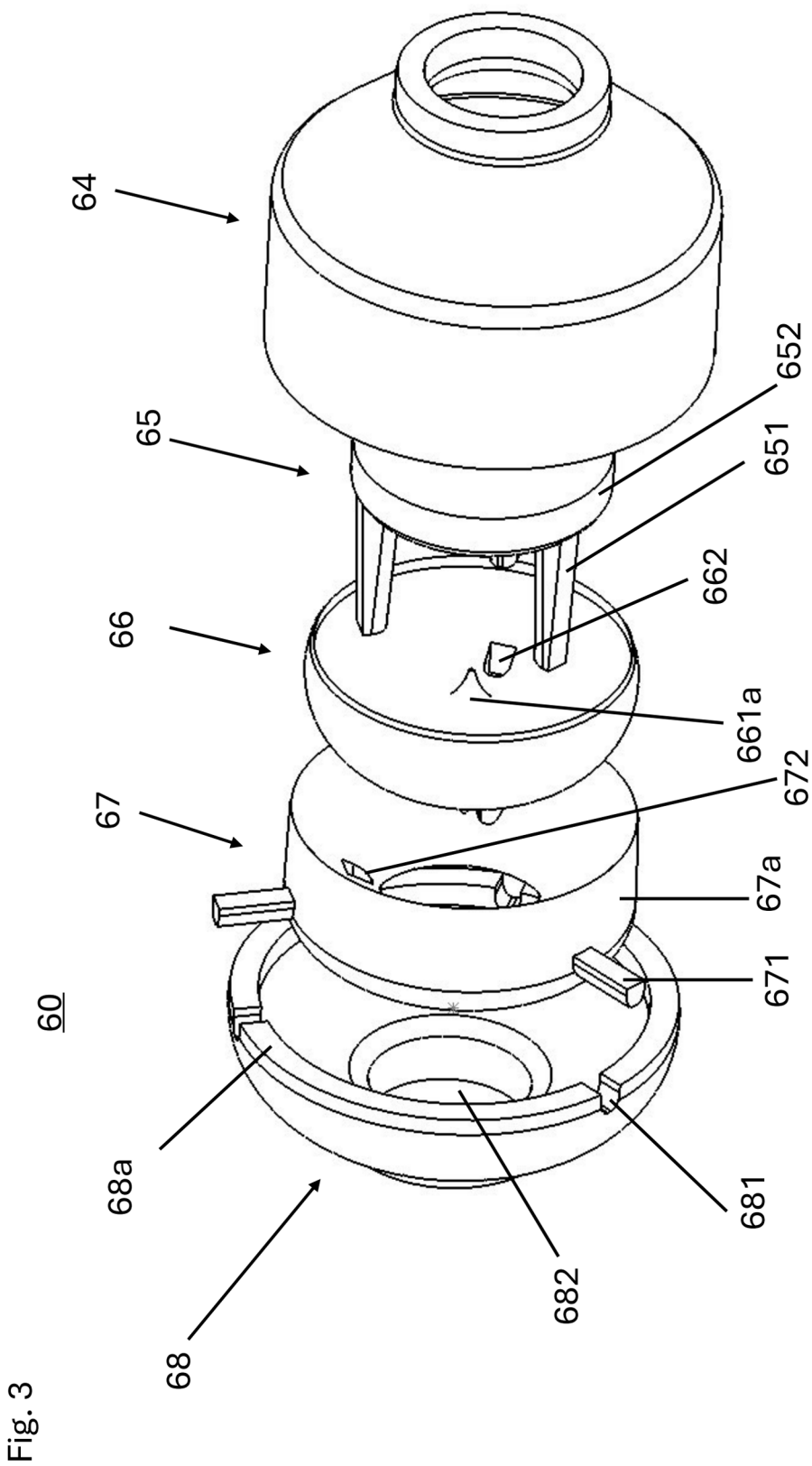
thickening from a first pointed end located nearer the outlet part towards a second, rounded end located nearer the inlet part, and
wherein the first valve module (65), the second valve module (66) and the third valve module (67) are retained within the housing formed by the inlet part (68) and the outlet part (64) to form air passages between the valve modules and between each of the valve modules and the housing.

15. The loudspeaker according to any one of claims 1 to 14, further comprising the airflow director assembly (60) of any one of claims 2 to 5, which is disposed inside the voice coil former (30).





File 2



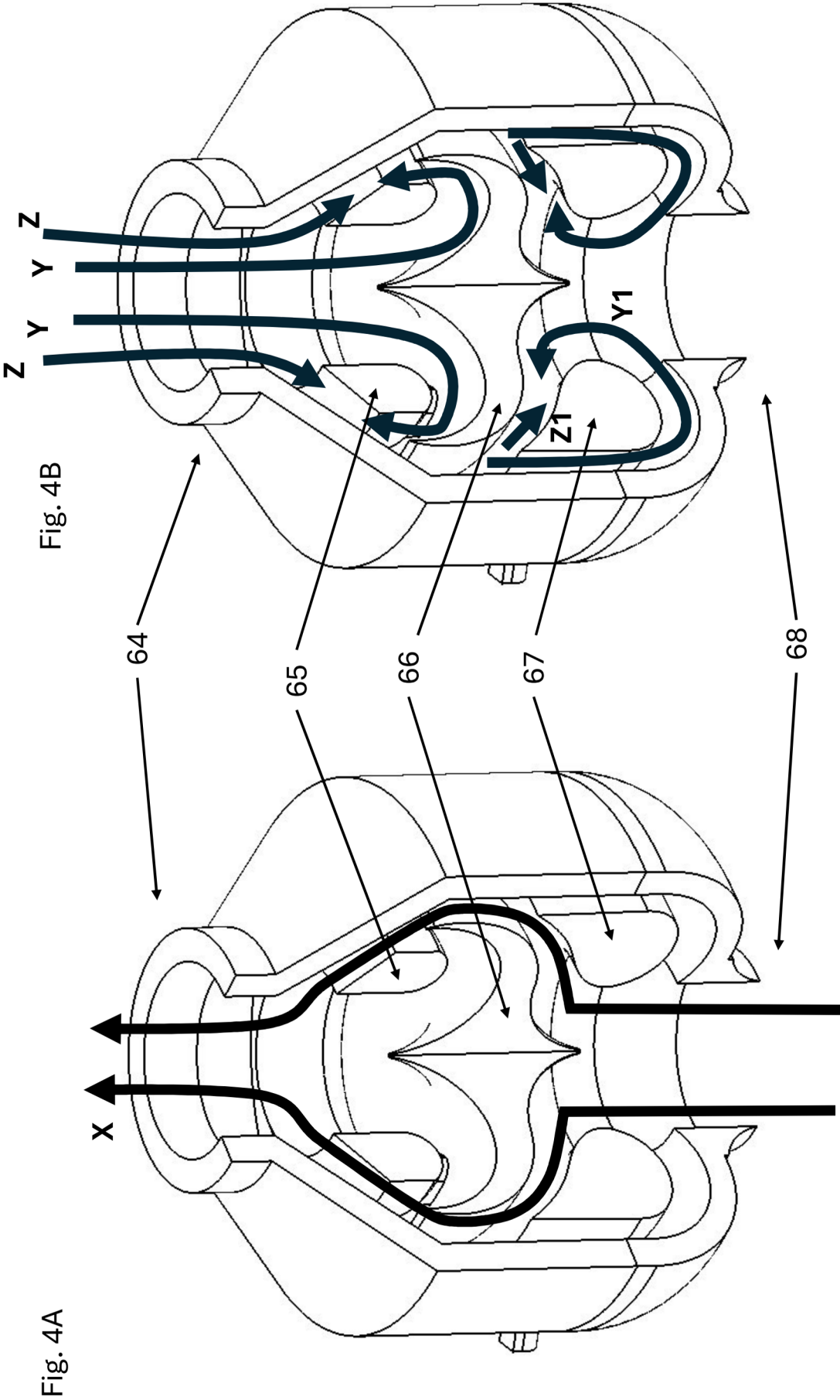
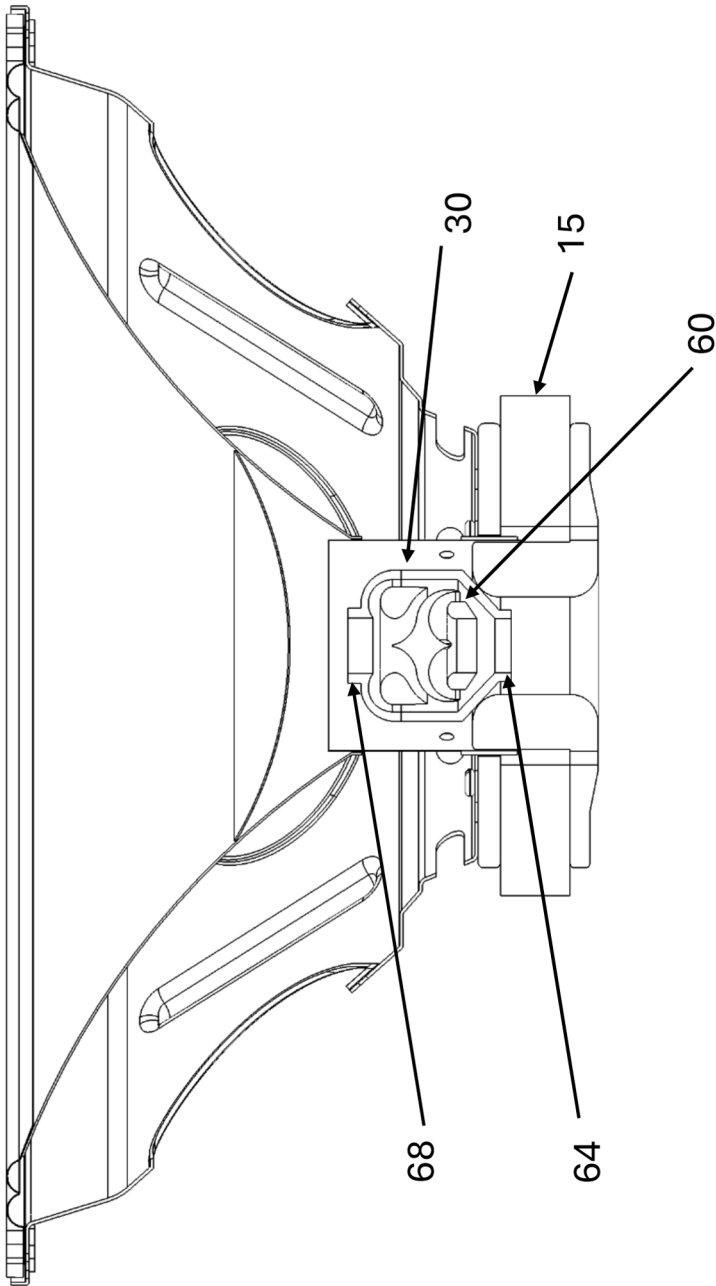


Fig. 5

100



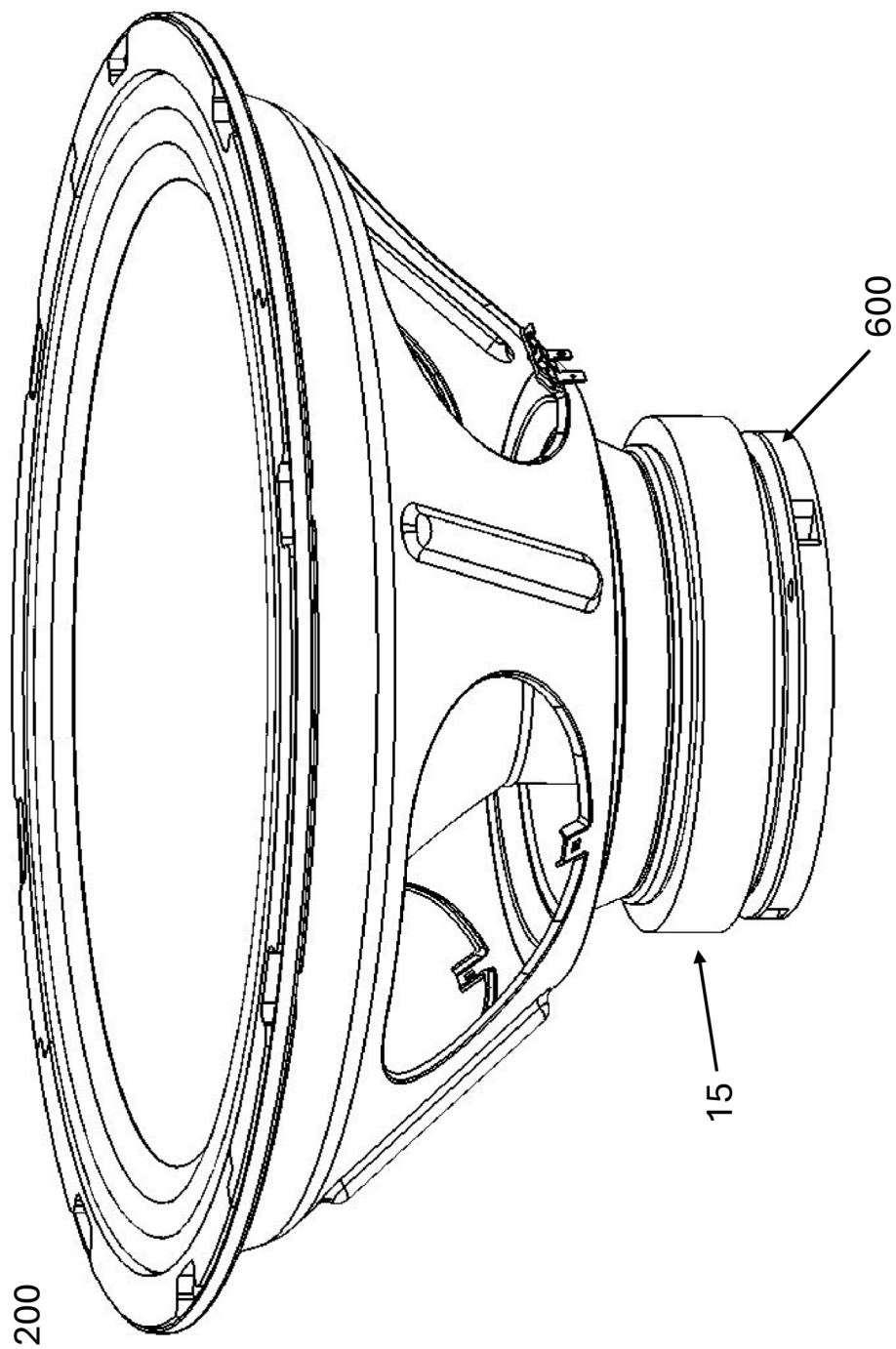
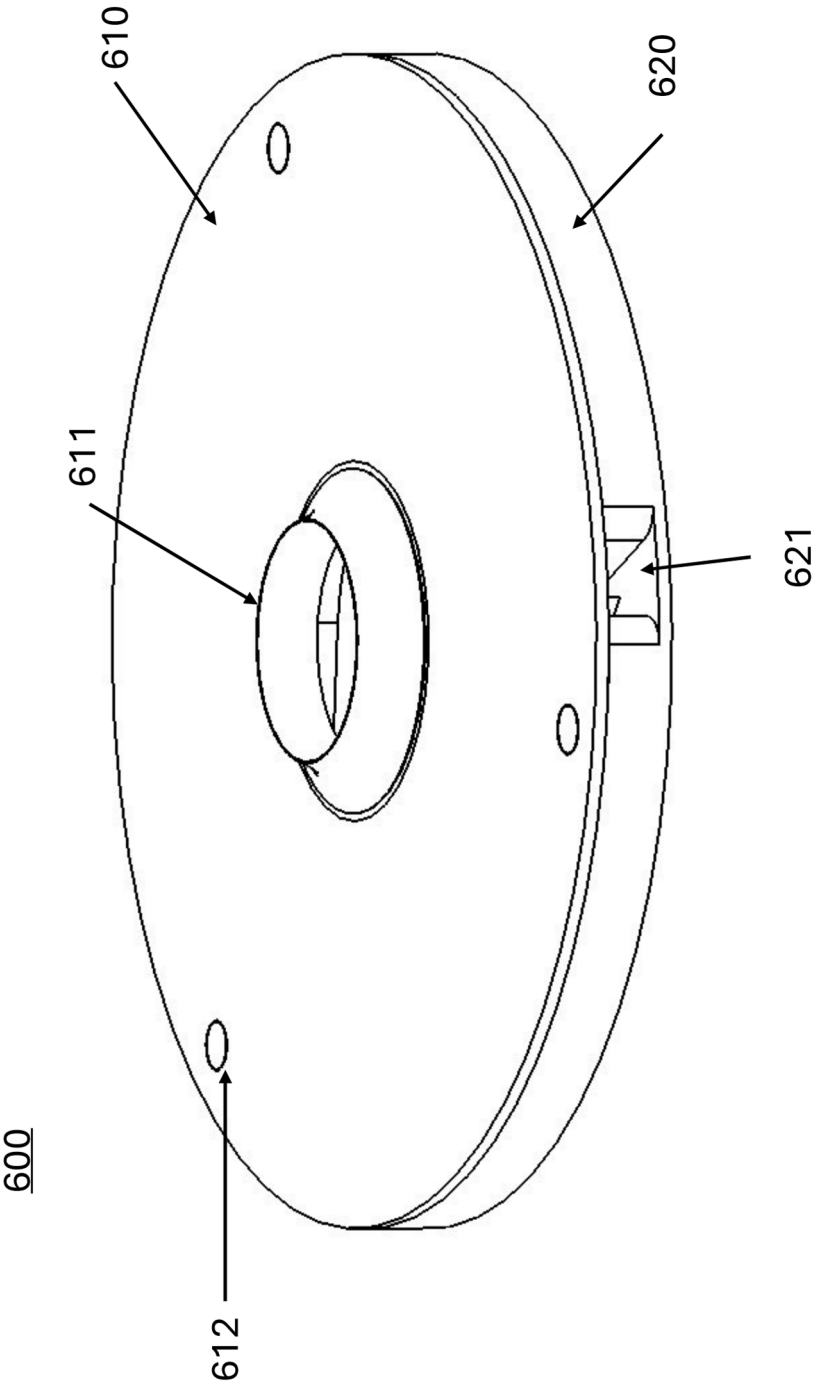
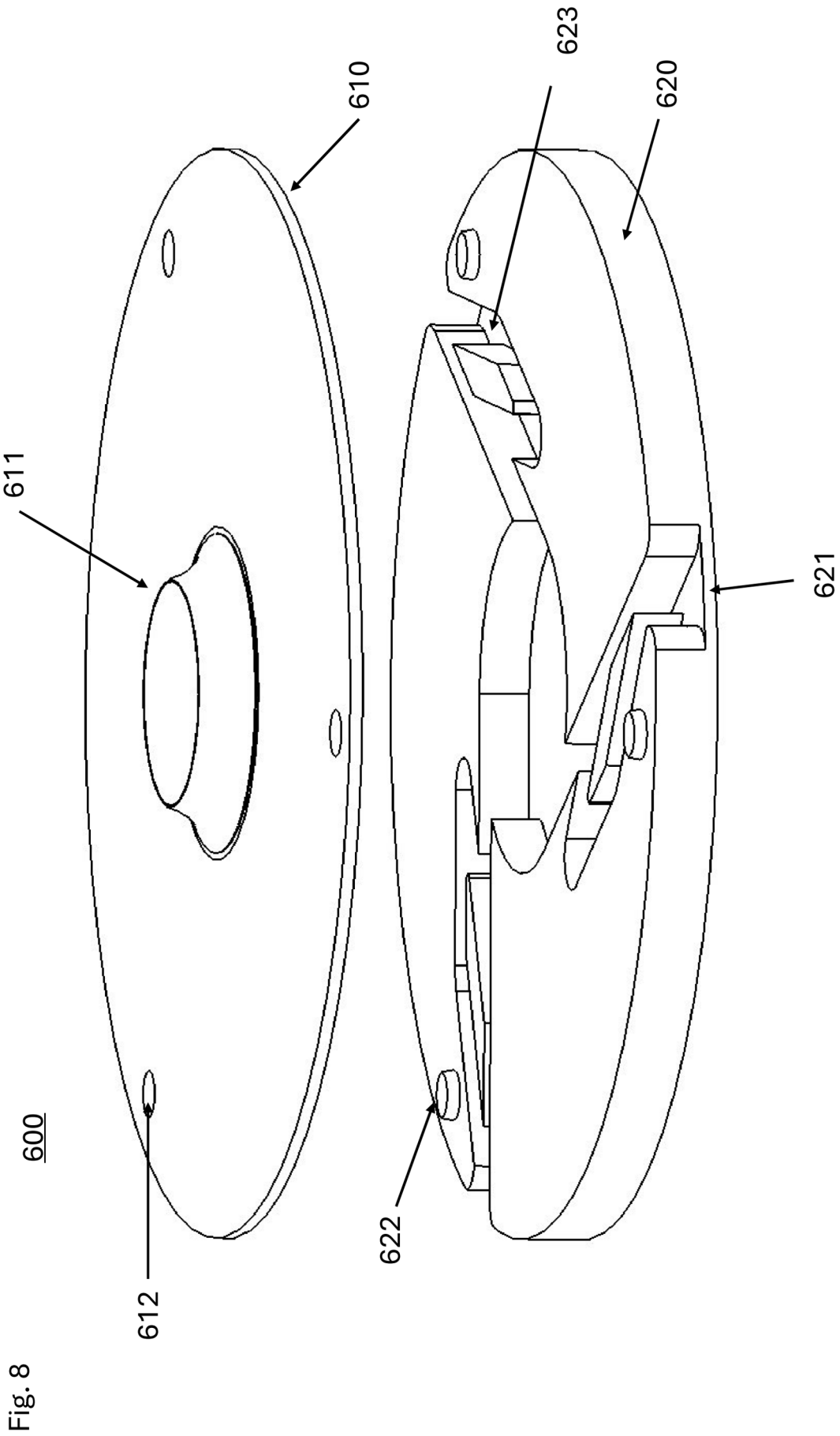


Fig. 6

Fig. 7





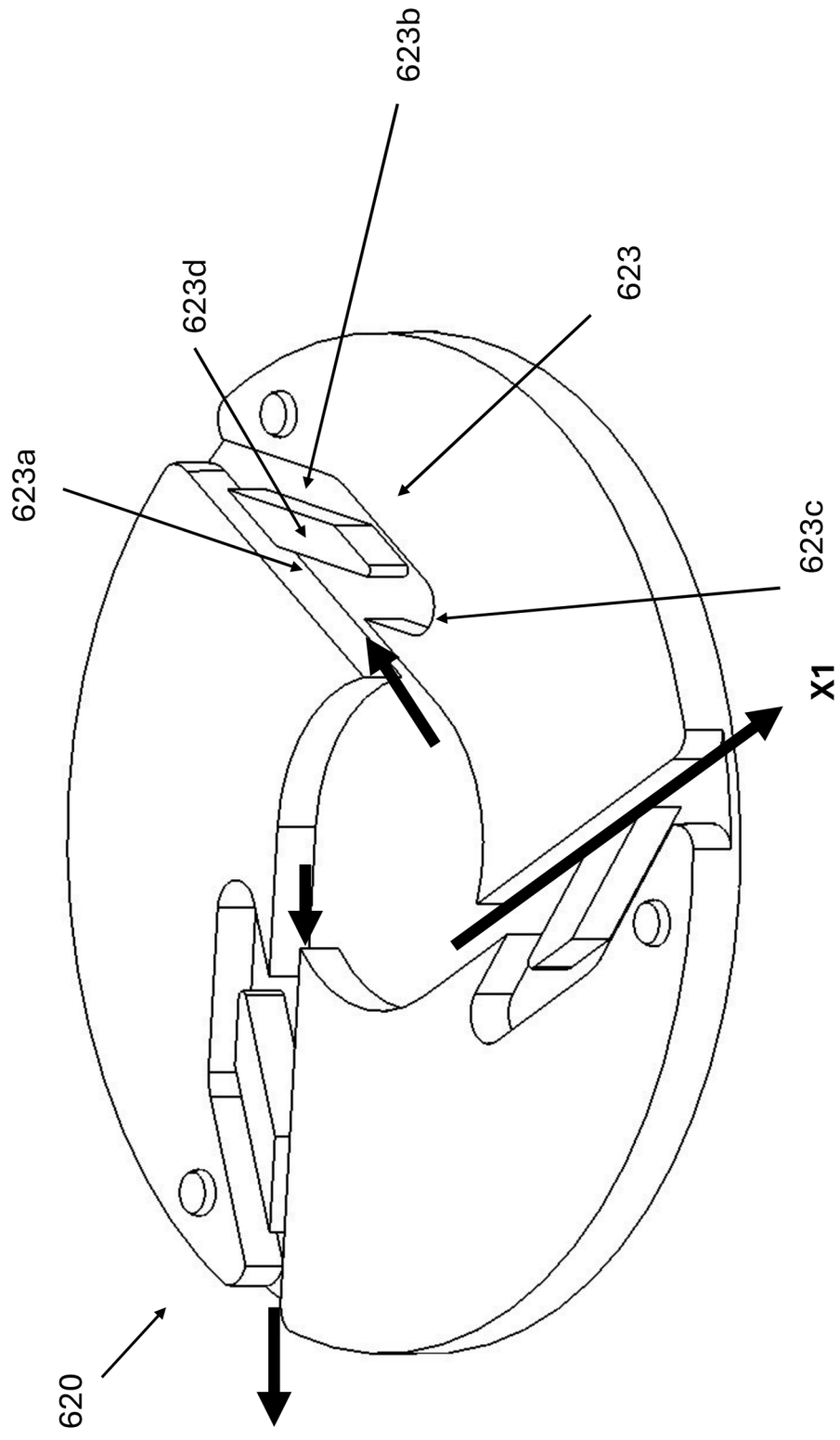


Fig. 9

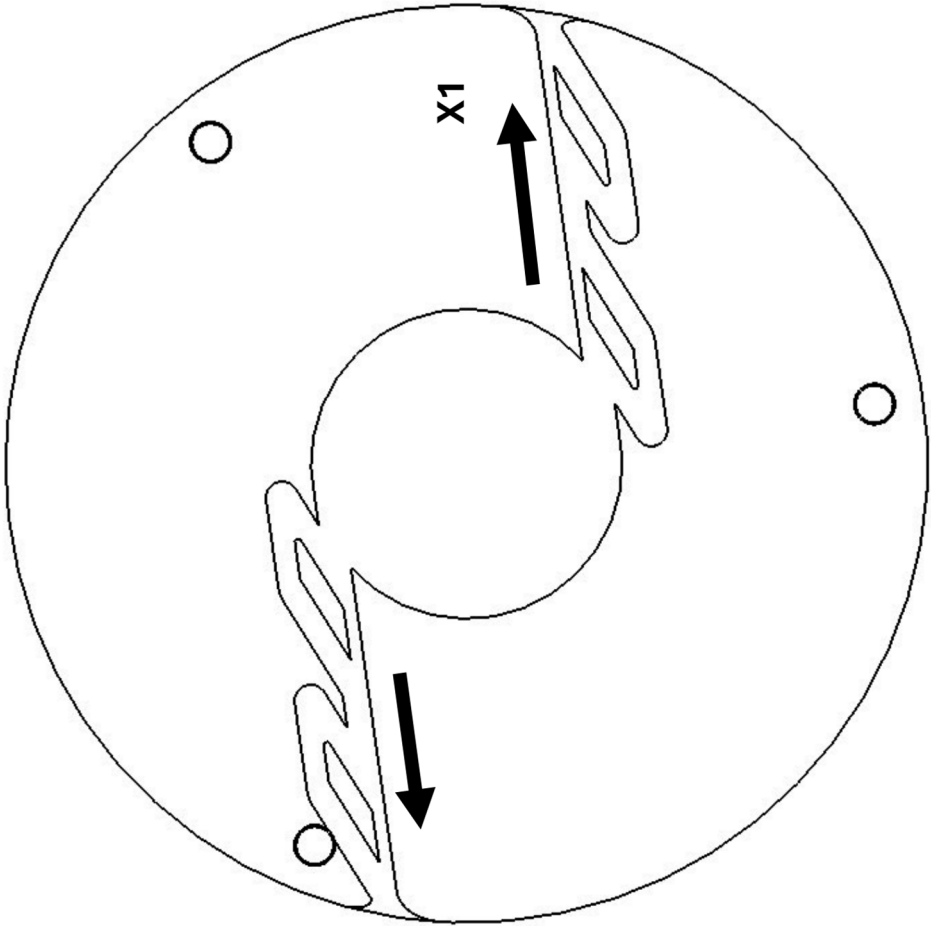
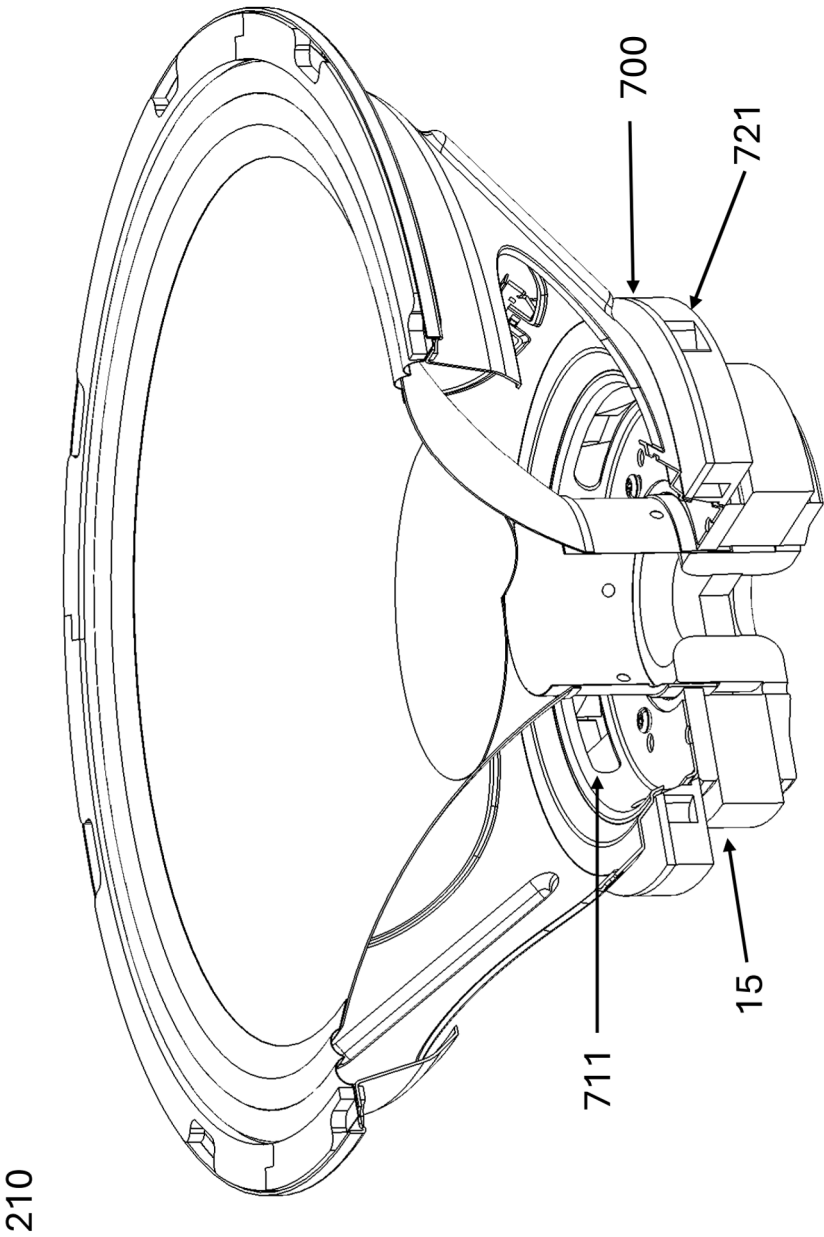


Fig. 10

Fig. 11



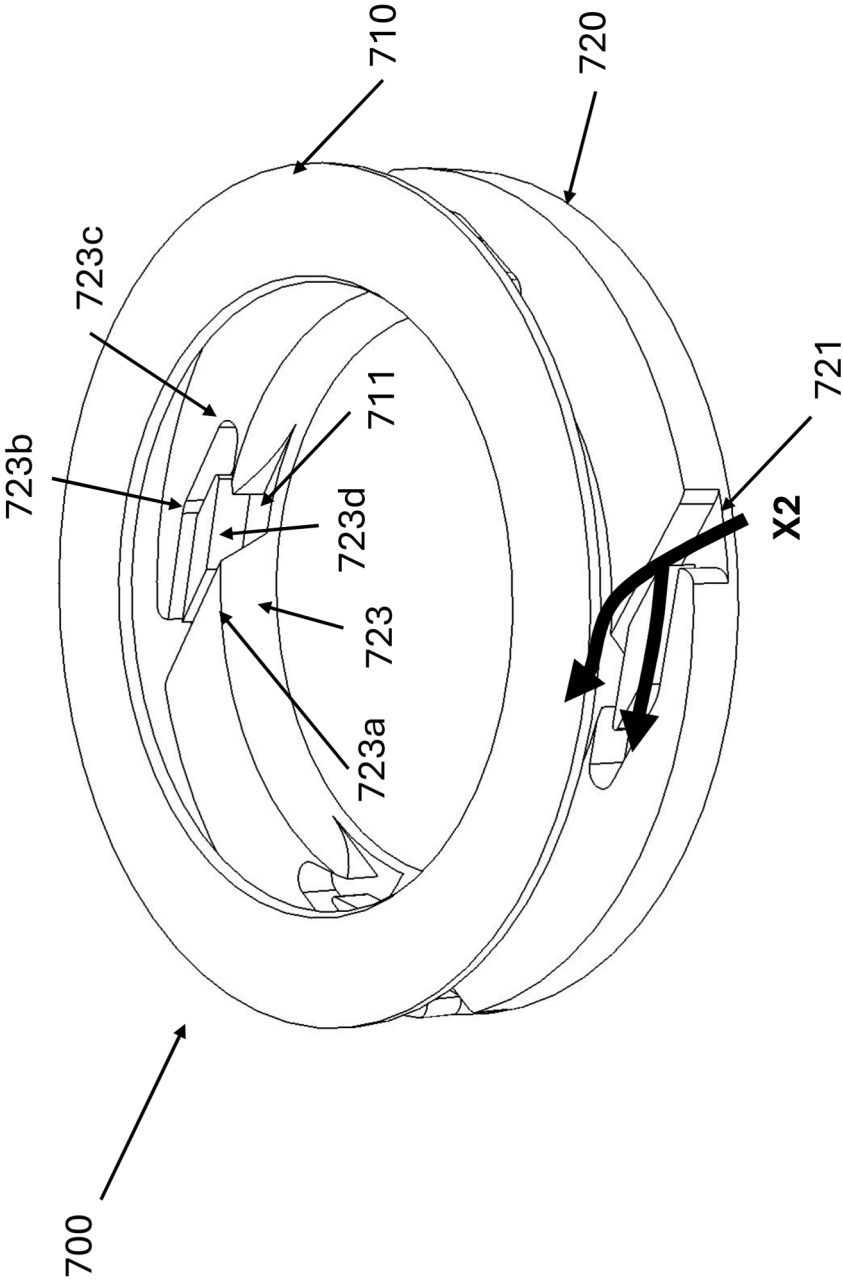


Fig. 12

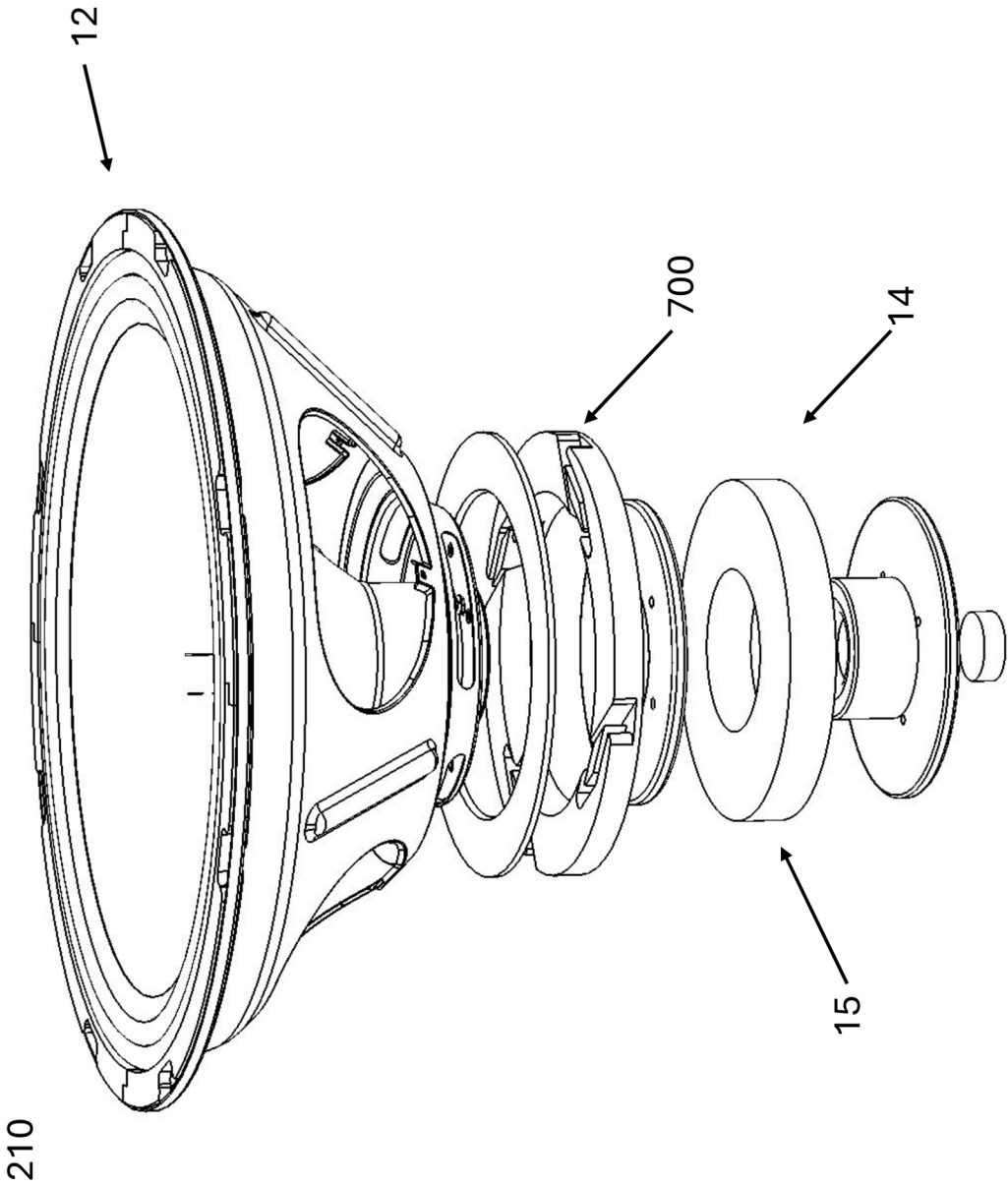


Fig. 13

Fig. 14

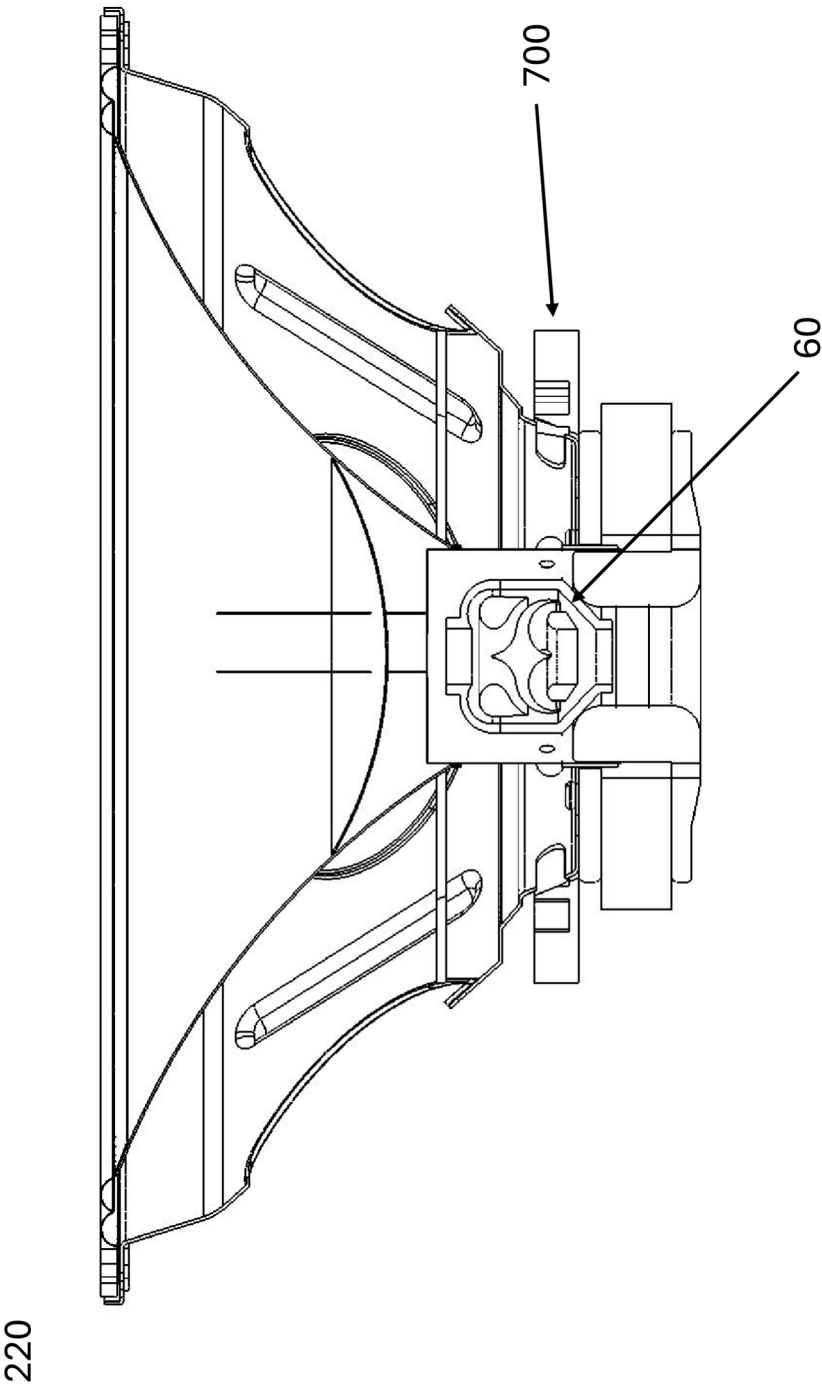
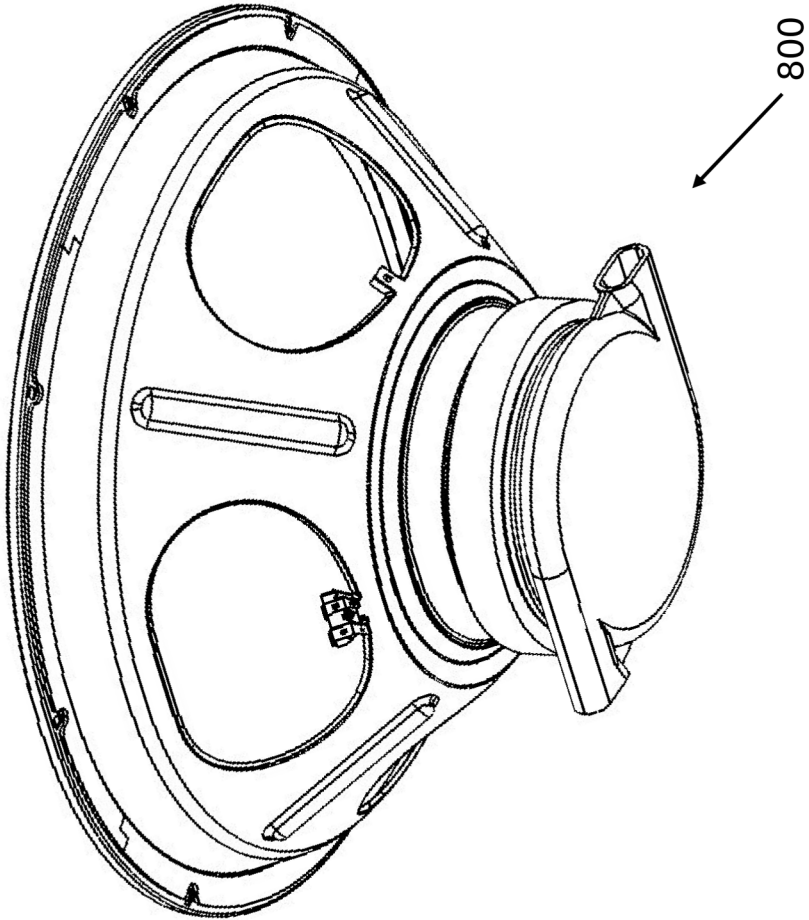


Fig. 15

300



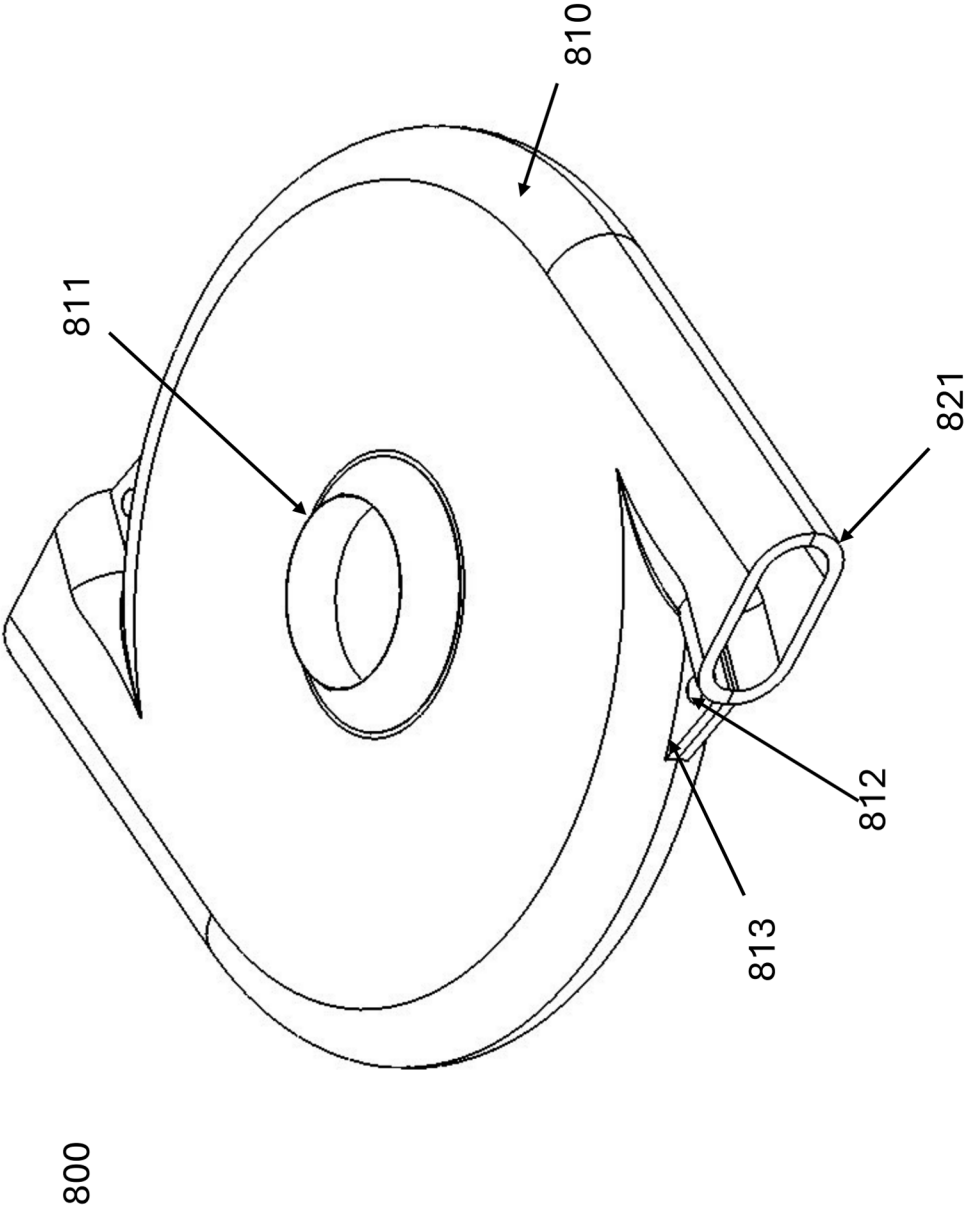


Fig.16

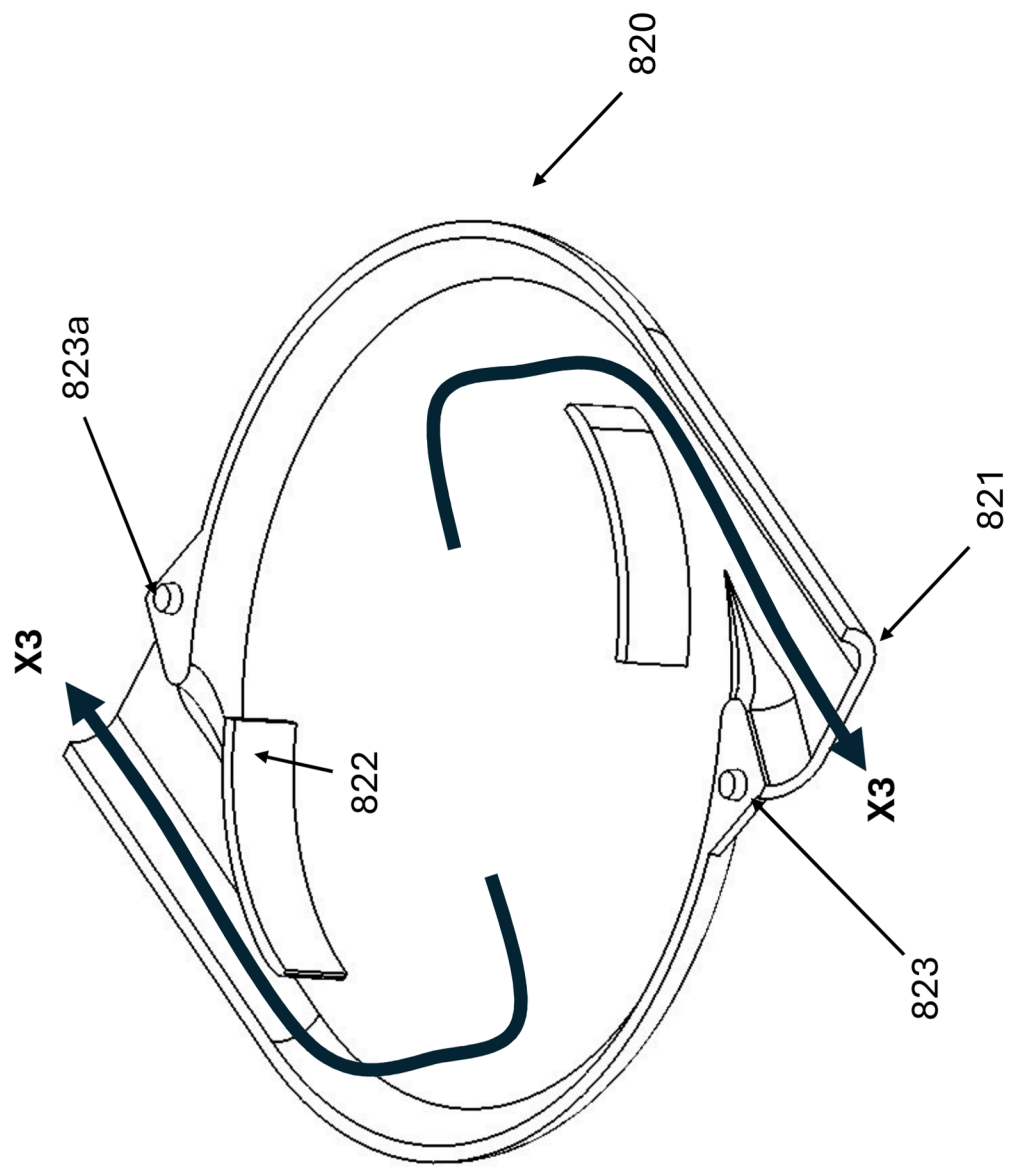


Fig. 17



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Application Number

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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		16 July 2026	Fobel, Oliver
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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