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(72) Inventors:
• **VILLA, Luca**
20097 San Donato Milanese MI (IT)
• **SPATAFORA, Grazia**
20097 San Donato Milanese (MI) (IT)

(74) Representative: **Rondano, Davide**
Società Italiana Brevetti S.p.A.
Via Carducci 8
20123 Milano (IT)

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(71) Applicant: **Faital S.p.A.**
20097 San Donato Milanese (MI) (IT)

(54) **LOUDSPEAKER WITH A NON-CIRCULAR CONE AND A BALANCED SURROUND**

(57) The loudspeaker (10) comprises a diaphragm (12), a basket (14) carrying the diaphragm (12), an electric coil (16) and a magnetic circuit (18), wherein the diaphragm (12) has a top end (12a) having in plan view a racetrack shape, with a pair of straight sides parallel to each other and a pair of semi-circular sides connecting said straight sides, and wherein the loudspeaker (10) further comprises a flexible suspension member (20) connecting the top end (12a) of the diaphragm (12) to an upper portion of the basket (14). The flexible suspension member (20) is made as a membrane having a non-uniform cross-section, with two convex membrane portions (26), two concave membrane portions (28), and four transition portions (30a, 30b), wherein each transition portion (30a, 30b) connects a convex membrane portion (26) with the adjacent concave membrane portion (28) and has a cross-sectional shape that gradually changes from the cross-sectional shape of said convex membrane portion (26) to the cross-sectional shape of said adjacent concave membrane portion (28).

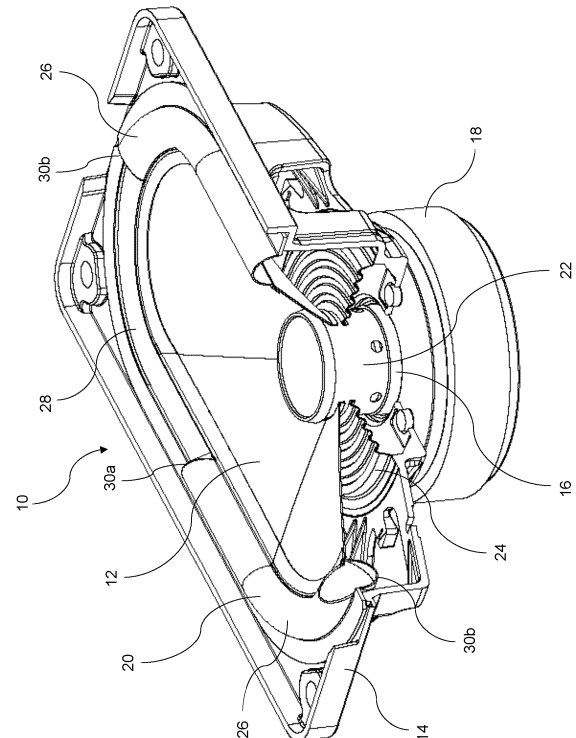


FIG. 1

Description

Technical field of the invention

[0001] The present invention generally relates to an electrodynamic loudspeaker (hereinafter simply referred to as loudspeaker), and more specifically to a loudspeaker comprising a non-circular diaphragm (or cone), i.e., a diaphragm having a non-circular shape in plan view.

State of the art

[0002] As it is known, a loudspeaker basically comprises a diaphragm (or cone), a rigid basket, an electric coil (normally referred to as voice coil) and a magnetic circuit. The diaphragm is connected at its top end (wider end) to an upper portion of the basket via a first flexible suspension member, typically called surround, and at its bottom end (narrower end) to a support member, typically called former, supporting the voice coil. Furthermore, the support member is connected to a lower portion of the basket via a second flexible suspension member, typically called spider. The voice coil is constrained, by virtue of the connection of the diaphragm and of the support member with the basket via the above-mentioned first and second flexible suspension members, respectively, to move axially through a cylindrical air gap of the magnetic circuit. When an electrical current is applied to the voice coil, the interaction between the electric current in the voice coil and the magnetic field in the air gap generates a mechanical force that moves the voice coil axially through the air gap and, thus, the support member and the diaphragm attached thereto. Application of alternating electric current in the voice coil under control of an amplifier causes therefore the diaphragm to move back and forth, thereby reproducing sound.

[0003] Typically, the surround is made as a membrane having a uniform cross-section, that is to say, a cross-section whose profile does not change all over the surround. More specifically, a conventional surround has a cross-section with a convex (or concave) half-round profile. Such a conventional surround does not ensure a constant effective radiating area of the loudspeaker during operation, as the distance between the top point of the surround cross-section (corresponding to the diameter used to calculate the effective radiating area) and the central axis of the loudspeaker varies as the diaphragm moves vertically back and forth. This continuous change in the effective radiating area of the loudspeaker during operation increases the amplitude modulation distortion (and therefore the intermodulation distortion) of the loudspeaker that may cause undesired acoustic effects and deteriorate sound quality. Moreover, conventional uniform half-round surrounds may have poor movement control at high excursions (low frequency and/or high power) due to unbalanced deformation of the surround during operation.

[0004] In order to avoid these problems, non-uniform

surrounds have been proposed which have a cross-section with a variable profile, i.e., a profile that varies along the surround. An example of such non-uniform surrounds is disclosed in EP0556786. According to this known solution, the surround comprises an even number of convex peripheral portions with a half-round cross-section and an even number of concave peripheral portions with a half-round cross-section, wherein each convex peripheral portion is arranged between two adjacent concave peripheral portions and vice versa. The surround further comprises an even number of connecting portions having a cross-sectional shape that gradually changes from one peripheral portion (convex or concave) to the neighbouring one (concave or convex, respectively). Such a known solution aims at reducing the harmonic distortion of the loudspeaker without deterioration of suspension linearity. This would be achieved by maintaining constant the air volume displaced by the surround as the diaphragm moves vertically back and forth.

[0005] This kind of surrounds are designed for circular loudspeakers. Circular loudspeakers, however, are difficult to integrate into modern car cockpits, for example into modern car doors, because of the stricter and stricter space constraints posed nowadays by car manufacturers. Therefore, there is currently a tendency to prefer more compact loudspeakers than the circular ones as car loudspeakers, in particular as car door loudspeakers. An example of more compact loudspeakers are the so-called racetrack loudspeakers, i.e. loudspeakers with a geometric shape formed by a rectangle and a pair of semi-circles at the opposite sides of the rectangle.

[0006] However, if on the one hand the racetrack geometry has the advantage of being more compact than the circular one, on the other it has a number of disadvantages. In particular, the racetrack geometry results in a reduced effective radiating area, with the same maximum size of the loudspeaker. Furthermore, the racetrack geometry leads to a lower mechanical stability of the loudspeaker moving parts, since the racetrack aspect ratio implies a variable diaphragm slope that causes resonant modes during movement of the loudspeaker.

[0007] JPH06315194, on which the preamble of independent claim 1 is based, discloses a loudspeaker with a non-circular diaphragm, and therefore with a non-circular surround, wherein the surround is made as a membrane having a non-uniform cross-section, with convex portions, concave portions and transition portions, wherein each transition portion connects a convex membrane portion with the adjacent concave portion and has a cross-sectional shape that gradually changes from the cross-sectional shape of the convex portion to the cross-sectional shape of the adjacent concave portion. More specifically, JPH06315194 discloses a loudspeaker in which the surround has a racetrack shape, i.e., a shape comprising a pair of straight long sides parallel to each other, and a pair of semi-circular short sides connecting the long sides, and in which each transition portion is

arranged in the middle of a respective long side or short side of the surround. According to this known solution, each transition portion is formed by two semi-circular sections, namely a convex semi-circular section and a concave semi-circular section, respectively. The convex semi-circular section has a diameter that gradually decreases from the convex portion to the concave portion, whereas the concave semi-circular section has a diameter that gradually increases from the convex portion to the concave portion. Because of this particular shape of the cross-section of each transition portion, the length of the profile of the cross-section in each point along the transition portion is smaller than the length of the profile of the cross-section at the beginning and at the end of the transition portion. This reduces the extent of the axial movement of the surround during operation of the loudspeaker, which leads to a local increase in the axial stiffness of the surround. Therefore, higher and non-uniform stresses are generated along the surround, which may adversely affect the acoustic performance at low frequencies and the integrity of the loudspeaker.

Summary of the invention

[0008] It is therefore an object of the present invention to provide a loudspeaker that is not affected by the above-discussed disadvantages of the prior art.

[0009] This and other objects are fully achieved by virtue of a loudspeaker having the features set forth in independent claim 1.

[0010] Further advantageous features of the invention are defined in the dependent claims, whose subject-matter is intended to form an integral part of the following description.

[0011] In short, the invention is based on the idea of providing a racetrack loudspeaker wherein the surround is made as a membrane having a non-uniform cross-section, and shaping the transition portions of the surround in such a manner each transition portion comprises a middle convex or concave sub-portion and a pair of lateral concave or convex portions, respectively, whereby the length of the profile of the cross-section of each transition portion in each point along the transition portion is equal to, or greater than, the length of the profile of the cross-section at the beginning and at the end of the transition portion.

[0012] The choice of a racetrack shape for the loudspeaker makes the latter more compact than conventional circular loudspeakers, while at the same time the choice of a non-uniform cross-sectional shape for the surround allows to obtain a more balanced surround, with reduced resonant modes and hence with reduced deformation. This results in higher reliability of the loudspeaker, as well as in greater linearity of the frequency response of the loudspeaker.

[0013] Furthermore, the particular shape of the cross-section of the transition portions allows to avoid reduction in the extent of the axial movement of the surround during

operation and thus to avoid the resulting problems discussed above with reference to the prior art.

[0014] Further features and advantages of the invention will be evident to those skilled in the art from the following detailed description, given purely by way of non-limiting example.

Brief description of the drawings

[0015] In the following detailed description reference will be made to the appended drawings, where:

- Figure 1 is a perspective, partially cutaway, view of a loudspeaker according to an embodiment of the present invention;
- Figure 2 is a perspective view of the diaphragm and surround of the loudspeaker of Figure 1;
- Figure 3 shows the cross-sectional profiles of convex and concave portions of the surround of the loudspeaker of Figure 1;
- Figure 4 is a plan view of the surround of the loudspeaker of Figure 1;
- Figure 5 shows, on an enlarged scale, the cross-sections of the surround of Figure 4 through section lines A-A, B-B, C-C and D-D in that Figure; and
- Figure 6 shows, on an enlarged scale, the cross-sections of the surround of Figure 4 through section lines E-E, F-F, G-G and H-H in that Figure.

Detailed description

[0016] With reference first to Figure 1, a loudspeaker according to an embodiment of the present invention is generally indicated with 10 and basically comprises a diaphragm (or cone) 12, a rigid basket (or frame) 14 carrying the diaphragm 12, an electric coil (or voice coil) 16 and a magnetic circuit 18.

[0017] The diaphragm 12 has a top end (wider end) 12a and a bottom end (narrower end) 12b. The top end 12a of the diaphragm 12 is connected to an upper portion of the basket 14 via a first flexible suspension member 20, hereinafter referred to as surround (as it is usually called by the persons skilled in the art), while the bottom end 12b of the diaphragm 12 is connected to a support member 22 (typically called former) supporting the electric coil 16. Furthermore, the support member 22 is connected to a lower portion of the basket 14 via a second flexible suspension member 24, typically called spider. The top end 12a of the diaphragm 12, and therefore also the surround 20, has in plan view a racetrack shape, i.e., a shape formed by a rectangle and a pair of semi-circles at the opposite sides of the rectangle. The surround 20 thus has, in plan view, two straight sides (long sides), parallel

to each other, connected at their opposite ends by two semi-circular sides (short sides). The support member 22, and therefore also the bottom end 12b of the diaphragm 12, has on the other hand a circular shape in plan view.

[0018] With reference to Figures 2 and 4, the surround 20 is made as a membrane having a non-uniform cross-section, that is to say, a cross-section whose profile is not constant or uniform all over said component. More specifically, the surround 20 comprises two convex membrane portions 26, two concave membrane portions 28, and four transition portions 30a and 30b, wherein each transition portion 30a, 30b connects a convex membrane portion 26 with the adjacent concave membrane portion 28. More specifically, considering to move along the surround 20 in the clockwise direction, the transition portions connecting each convex membrane portion 26 with the following adjacent concave membrane portion 28 are indicated as 30a, while the transition portions connecting each concave membrane portion 28 with the following adjacent convex membrane portion 26 are indicated as 30b.

[0019] Furthermore, the surround 20 comprises an inner peripheral edge 32 for connection of the surround with the diaphragm 12 and an outer peripheral edge 34 for connection of the surround with the basket 14. The inner peripheral edge 32 is inclined to the outer peripheral edge 34, as it follows the slope of the diaphragm 12. The outer peripheral edge 34 is a planar edge.

[0020] Each of the convex membrane portions 26 and concave membrane portions 28 preferably has a uniform cross-section, i.e., a cross-section that has the same shape through the entire length of said portions. As shown in Figure 3, the convex membrane portions 26 extend above a plane P of the outer peripheral edge 34 (that is to say, outwardly of the loudspeaker 10 with respect to said plane P), while the concave membrane portions 28 extend below said plane P (that is to say, inwardly of the loudspeaker 10 with respect to said plane P). Moreover, the shape of the cross-section of the convex membrane portions 26 and the shape of the cross-section of the concave membrane portions 28 are symmetrical to each other with respect to the plane P. Preferably, such a shape is semi-elliptical, with the semi-major axis (whose length is indicated with A) of the semi-ellipse extending perpendicular to the plane P and the minor axis (whose length is indicated with B) of the semi-ellipse extending along the plane P.

[0021] With reference in particular to Figure 4, in the present embodiment, where the surround 20 has two convex membrane portions 26 and two concave membrane portions 28, each of said membrane portions extend along half a straight side and half a semi-circular side of the racetrack shape of the surround 20. Therefore, in the present embodiment two of the transition portions 30a and 30b, namely the transition portions 30a, are arranged in the middle of the straight sides of the racetrack shape of the surround 20, while the other two

transition portions, namely, the transition portions 30b, are arranged in the middle of the semi-circular sides.

[0022] Each transition portion 30a, 30b has a cross-sectional shape that gradually changes from the cross-sectional shape of a convex membrane portion 26 (or concave membrane portion 28) to the cross-sectional shape of the adjacent concave membrane portion 28 (or convex membrane portion 26, respectively), as illustrated in Figures 5 and 6. Moreover, as shown in Figure 4, each transition portion 30a, 30b has a length L which is equal to, or less than, the radial size of the convex membrane portions 26 and of the concave membrane portions 28 (which radial size, in the present embodiment, is the length B of the minor axis of the semi-elliptical shape of said membrane portions).

[0023] With reference to Figure 5, the change in the cross-section of each transition portion 30a connecting a convex membrane portion 26 (as shown in section A-A) to the following adjacent concave membrane portion 28 (as shown in section D-D) is obtained by intersecting the final semi-elliptical shape of the concave membrane portion 28 with a convex semi-ellipse that gradually moves from above to below the plane P along a direction substantially perpendicular to said plane. Therefore, each transition portion 30a comprises a middle convex sub-portion 30a', that becomes gradually smaller from the initial section A-A to the final section D-D, and a pair of lateral concave sub-portions 30a", that become gradually larger from the initial section A-A to the final section D-D and extend below the plane P.

[0024] Likewise, with reference to Figure 6, the change in the cross-section of each transition portion 30b connecting a concave membrane portion 28 (as shown in section H-H) to the following adjacent convex membrane portion 26 (as shown in section E-E) is obtained by intersecting the final semi-elliptical shape of the convex membrane portion with a concave semi-ellipse that gradually moves from below to above the plane P along a direction substantially perpendicular to said plane. Therefore, each transition portion 30b comprises a middle concave sub-portion 30b', that becomes gradually smaller from the initial section H-H to the final section E-E, and a pair of lateral convex sub-portions 30b", that become gradually larger from the initial section H-H to the final section E-E and extend above the plane P.

[0025] By virtue of such a shape of the transition portions 30a and 30b, the length of the profile of the cross-section of each transition portion 30a, 30b (i.e., the sum of the lengths of the middle convex sub-portion 30a' and of the lateral concave sub-portions 30a", as far as the transition portions 30a are concerned, and the sum of the lengths of the middle concave sub-portion 30b' and of the lateral convex sub-portions 30b", as far as the transition portions 30b are concerned) in each point along the transition portion 30a, 30b is not smaller than (i.e., equal to or greater than) the length of the profile of the cross-section at the beginning and at the end of the transition portion 30a, 30b. This allows to avoid reduction in the

extent of the axial movement of the surround 20 during operation, and therefore to avoid the problems of the prior art discussed in the introductory part of the present description. A loudspeaker according to the present invention offers a number of advantages over the prior art.

[0026] The use of a racetrack shape makes the loudspeaker more compact than conventional circular loudspeakers, thereby facilitating the use of the loudspeaker within modern car cockpits, for example as car door loudspeaker.

[0027] The non-uniform cross-sectional shape of the surround of the loudspeaker allows to obtain a more balanced surround, with reduced resonant modes and hence with reduced deformation. This results in higher reliability of the loudspeaker, as well as in greater linearity of the frequency response of the loudspeaker.

[0028] Furthermore, the proposed configuration of the surround allows to improve the stability in rest position, the movement control at high excursions (i.e., low frequency and/or high power) and the loudspeaker sensitivity.

[0029] Additionally, by dividing the surround into an even number of convex and concave portions with very limited transition portions therebetween, variations of the effective radiating area of the loudspeaker depending on the axial position of the surround are extremely reduced. This allows to decrease the amplitude modulation distortion of the loudspeaker, thereby positively affecting the sound quality.

[0030] Moreover, the particular shape of the cross-section of the transition portions allows to avoid reduction in the extent of the axial movement of the surround during operation and thus to avoid the problems (reduced acoustic performance at low frequencies and higher risks of breakages of the loudspeaker) of the prior art discussed above.

[0031] The present invention has been described herein with reference to a preferred embodiment thereof. It is however clear that other embodiments may be envisaged, which share with the one disclosed herein the same inventive core, as defined by the appended claims.

Claims

1. Loudspeaker (10) comprising a non-circular diaphragm (12), a basket (14) carrying the diaphragm (12), an electric coil (16), a magnetic circuit (18), and a flexible suspension member (20) connecting a top end (12a) of the diaphragm (12) to an upper portion of the basket (14),

wherein the flexible suspension member (20) has, in plan view, a pair of long sides, which are made as straight sides and extend parallel to each other, and a pair of short sides connecting said long sides to each other,
wherein the flexible suspension member (20) is

made as a membrane having a non-uniform cross-section, with two convex membrane portions (26), two concave membrane portions (28), and four transition portions (30a, 30b), each transition portions (30a, 30b) connecting a convex membrane portion (26) with the adjacent concave membrane portion (28) and having a cross-sectional shape that gradually changes from the cross-sectional shape of said convex membrane portion (26) to the cross-sectional shape of said adjacent concave membrane portion (28),
wherein each of the convex and concave membrane portions (26, 28) extends along half a long side and half a short side of the flexible suspension member (20),

characterized

in that the short sides of the flexible suspension member (20) are semi-circular sides, and
in that each transition portion (30a, 30b) comprises a middle convex or concave sub-portion (30a', 30b') and a pair of lateral concave or convex portions (30a'', 30b''), respectively, whereby the length of the profile of the cross-section of each transition portion (30a, 30b) in each point along the transition portion (30a, 30b) is equal to, or greater than, the length of the profile of the cross-section at the beginning and at the end of the transition portion (30a, 30b).

2. Loudspeaker according to claim 1, wherein each convex portion (26) and each concave portion (28) has a uniform cross-section.
3. Loudspeaker according to claim 2, wherein each convex portion (26) and each concave portion (28) has a semi-elliptical cross-section.
4. Loudspeaker according to any one of the preceding claims, wherein said flexible suspension member (20) further comprises an outer peripheral edge (34) for connection with the basket (14), wherein said outer peripheral edge (34) is a planar edge, and wherein each convex portion (26) extends above a plane (P) defined by said outer peripheral edge (34) while each concave portion (28) extends below said plane (P).
5. Loudspeaker according to claim 4, wherein the shape of the cross-section of the convex portions (26) and the shape of the cross-section of the concave portions (28) are symmetrical to each other with respect to said plane (P).
6. Loudspeaker according to claim 4 or claim 5, wherein each of said middle convex sub-portion (30a') becomes gradually smaller from the initial section (A-A) to the final section (D-D) of the respective

transition portion (30a), while each of said pair of lateral concave sub-portions (30a") become gradually larger from the initial section (A-A) to the final section (D-D) of the respective transition portion (30a) and extend below said plane (P), and wherein 5
each of said middle concave sub-portion (30b') becomes gradually smaller from the initial section (H-H) to the final section (E-E) of the respective transition portion (30b), while each of said pair of lateral convex sub-portions (30b") become gradually larger from 10
the initial section (H-H) to the final section (E-E) of the respective transition portion (30b) and extend above said plane (P).

7. Loudspeaker according to claim 3 and to either claim 4 or claim 5, wherein each transition portion (30a) 15
connecting a convex membrane portion (26) with the adjacent concave membrane portion (28) that follows said convex membrane portion (26) in the clockwise direction of the flexible suspension member (20) has a cross-section obtained by intersecting 20
the final semi-elliptical shape of the cross-section of said concave membrane portion (28) with a convex semi-ellipse that gradually moves from above to below said plane (P) along a direction substantially 25
perpendicular to said plane (P), and wherein each transition portion (30b) connecting a concave membrane portion (28) with the adjacent convex membrane portion (26) that follows said concave membrane portion (28) in the clockwise direction of the 30
flexible suspension member (20) has a cross-section obtained by intersecting the final semi-elliptical shape of said convex membrane portion (26) with a concave semi-ellipse that gradually moves from below to above said plane (P) along a direction 35
substantially perpendicular to said plane (P).
8. Loudspeaker according to any one of the preceding claims, wherein each transition portion (30a, 30b) 40
has a length (L) which is equal to, or less than, a radial size of the convex membrane portions (26) and of the concave membrane portions (28).

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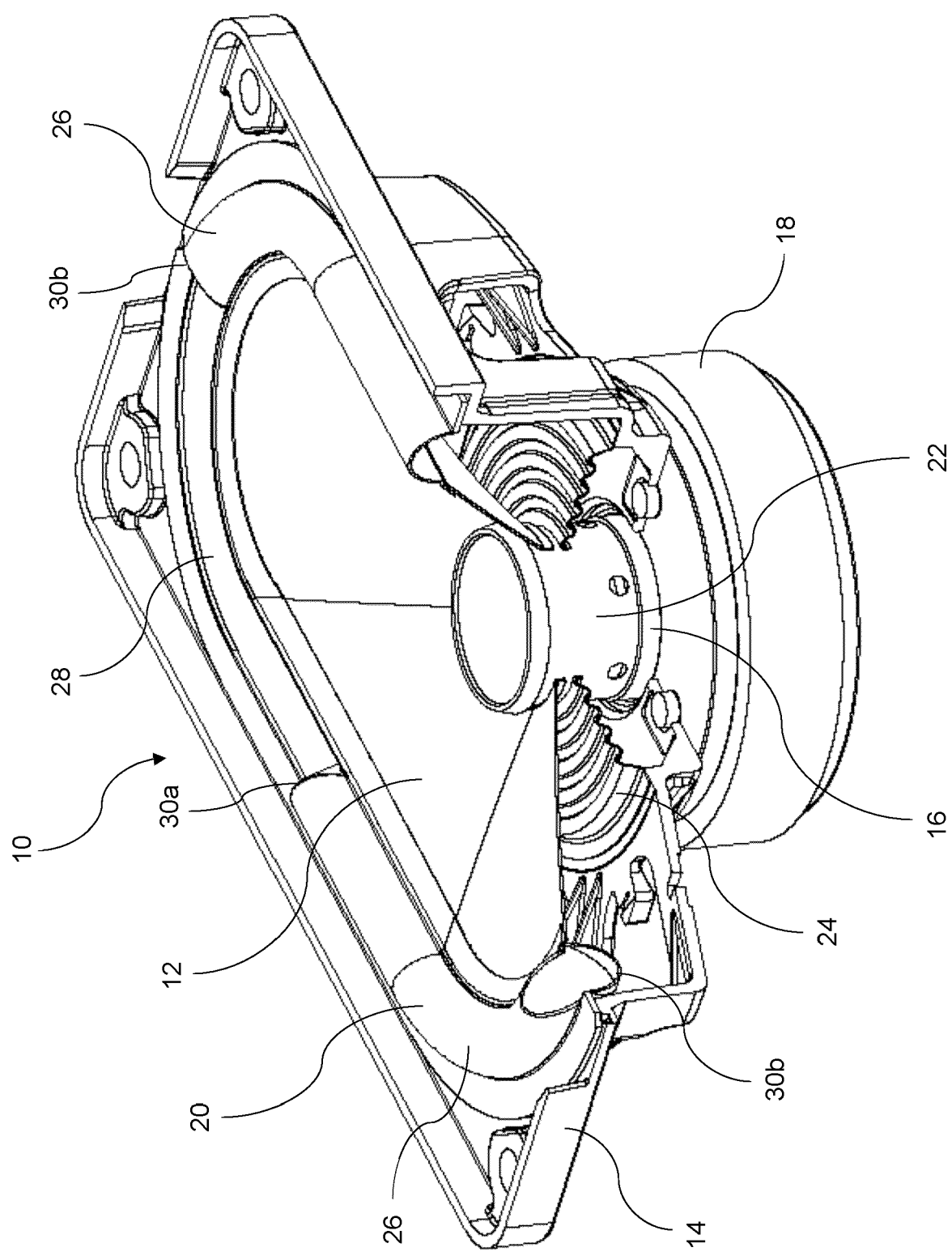


FIG. 1

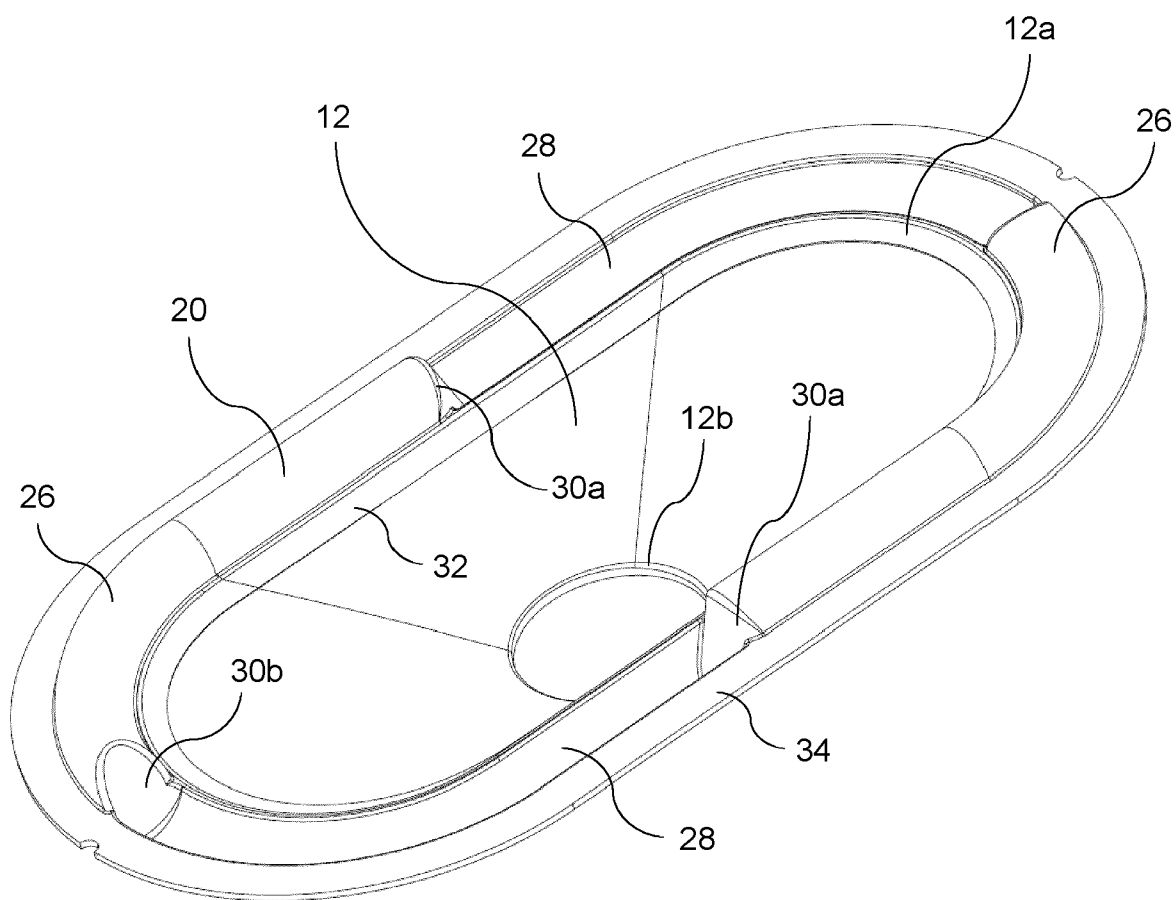


FIG. 2

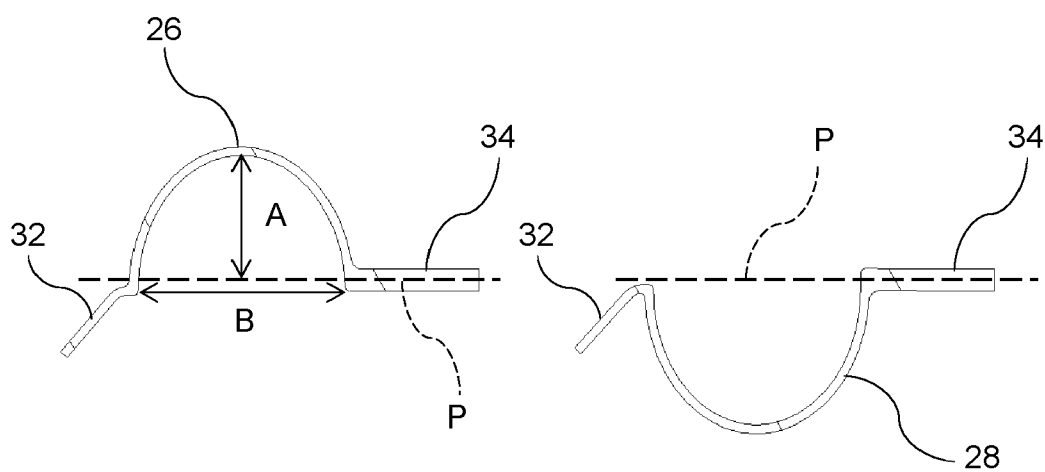


FIG. 3

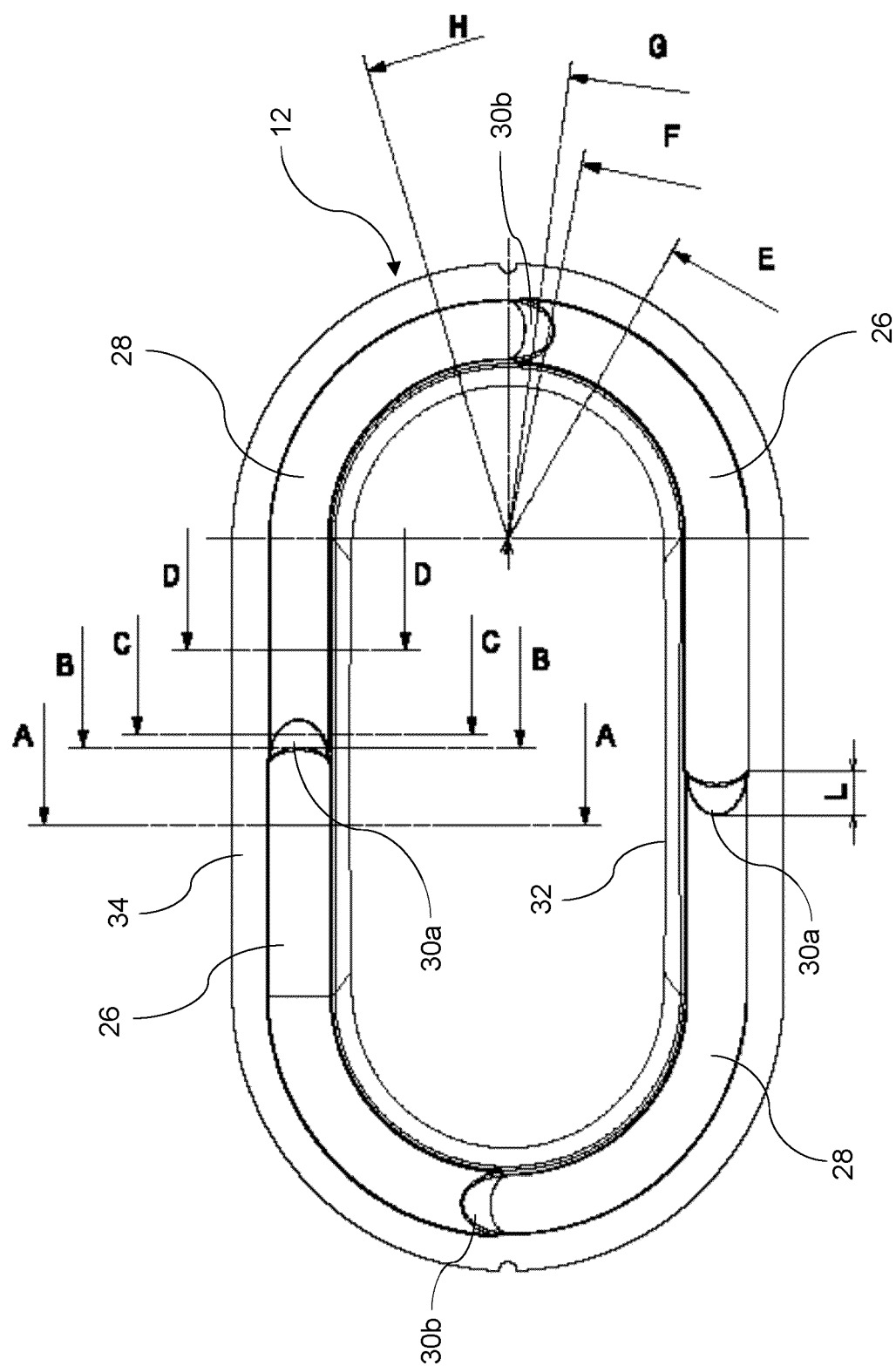


FIG. 4

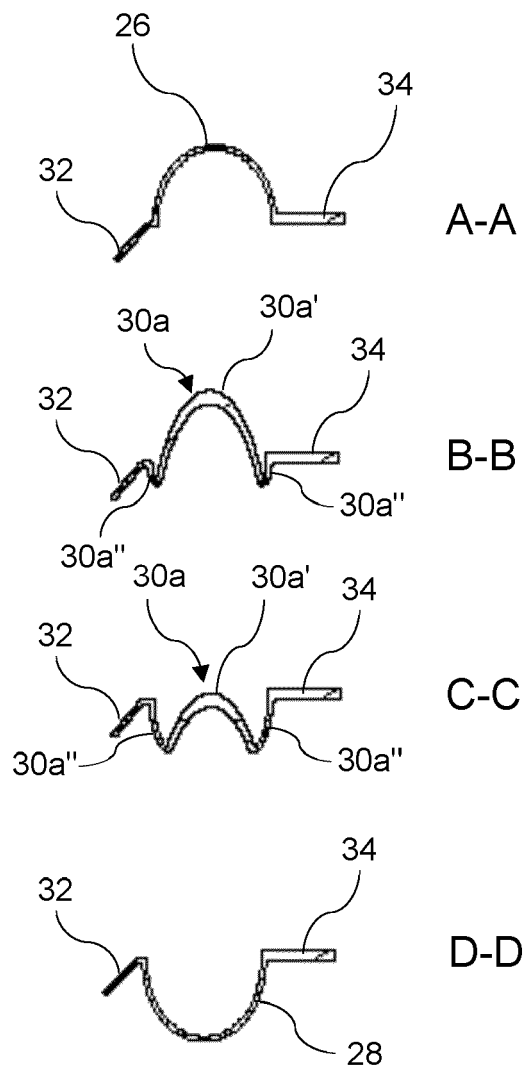


FIG. 5

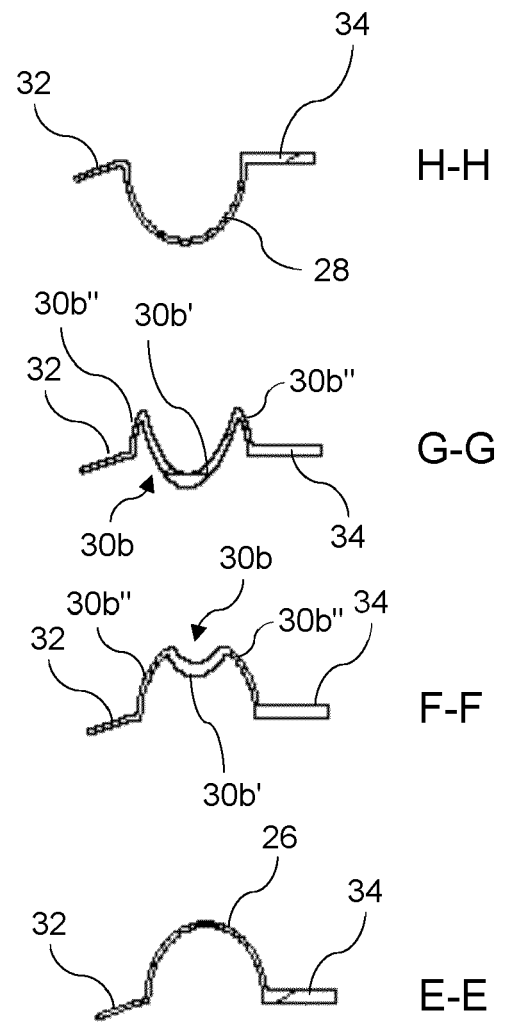


FIG. 6



EUROPEAN SEARCH REPORT

Application Number

EP 24 18 7202

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			TECHNICAL FIELDS SEARCHED (IPC)
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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		4 December 2024	Bensa, Julien
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EP 24 18 7202

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