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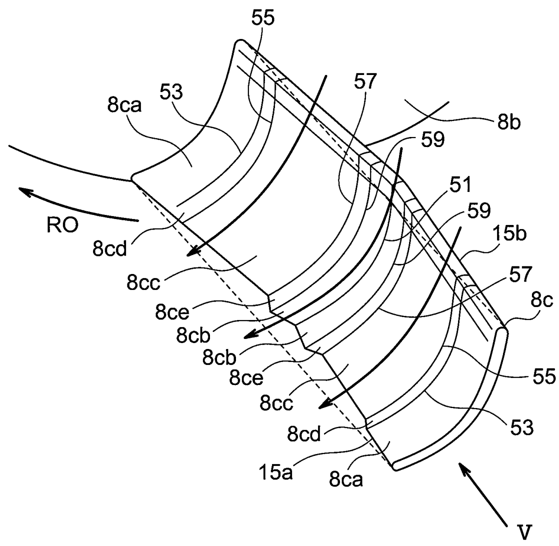
(54) CROSS-FLOW FAN AND AIR CONDITIONER

(57) A cross-flow fan (8) includes an impeller (8a) and a shaft configured to support the impeller (8a) in a rotatable manner. The impeller (8a) of the cross-flow fan (8) includes a plurality of support plates (8b) and a plurality of blades (8c) arranged between a pair of the support plates (8b) at intervals in a circumferential direction. Each of the plurality of blades (8c) has an outer diameter and an inner diameter that are identical in a rotational axis direction between the pair of support plates (8b), and includes at least one region that is advanced or retreated in a rotational direction.

FIG. 4



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Description

Technical Field

[0001] The present invention relates to a cross-flow fan and an air conditioner using the cross-flow fan.

Background Art

[0002] In Patent Literature 1, there is disclosed a transverse fan including blades, each being inclined at a predetermined angle with respect to a fan axis and being mounted with unequally set mounting pitches. Further, in the transverse fan, each blade is thin in an impeller longitudinal direction.

[0003] In Patent Literature 2, there is disclosed an axial fan including blades each formed so that a blade cross section orthogonal to a rotational axis decreases in size as approaching from a base portion to a distal end portion of each of the blade portions arranged side by side on a main surface. Further, in the axial fan, a center of the blade cross section orthogonal to the rotational axis is displaced frontward or backward in a direction of rotation about the rotational axis as approaching from the base portion of the blade portion toward the tip portion of the blade portion. Further, the blade cross section is curved radially outward.

[0004] Further, in Patent Literature 3, there is disclosed a fan including first components in each of which a tip portion of a blade is inclined in a rotational direction from a base of the blade, and second components in each of which the tip portion of the blade is inclined in a counter-rotational direction from the base of the blade. The first components and the second components are alternately stacked.

Citation List

Patent Literature

[0005]

[PTL 1] JP 3107711 B2
[PTL 2] JP 4549416 B2
[PTL 3] JP 09-158890 A

Summary of Invention

Technical Problem

[0006] However, in each of the above-mentioned related-art fans, air blown out from the fan is blown out obliquely in a specific direction between a pair of rings, but non-uniformity in air volume occurs in the entire fan depending on the place or time.

[0007] The present invention has been made in view of the above, and an object of the present invention is to provide a cross-flow fan capable of suitably dispersing a flow over a rotational axis direction in the entire fan.

Solution to Problem

[0008] In order to attain the above-mentioned object, according to one embodiment of the present invention, there is provided a cross-flow fan, including: an impeller; and a shaft configured to support the impeller in a rotatable manner, the impeller including: a plurality of support plates; and a plurality of blades arranged between a corresponding pair of the support plates at intervals in a circumferential direction, each of the plurality of blades having an outer diameter and an inner diameter that are identical in a rotational axis direction between the corresponding pair of the support plates, and including at least one region that is advanced or retreated in a rotational direction.

[0009] Further, the each of the plurality of blades may have at least two different blade outlet angles between the corresponding pair of the support plates.

[0010] Further, at a portion between the corresponding pair of the support plates, the each of the plurality of blades may have an outer diameter and an inner diameter that are identical in the rotational axis direction, have a cross-sectional shape and a blade outlet angle that are identical over the rotational axis direction, and include a plurality of the regions that are advanced or retreated in the rotational direction over the rotational axis direction.

[0011] In this case, the each of the plurality of blades may be formed bilaterally symmetrically across a central cross-sectional portion, and includes, in an order of increasing a distance from the central cross-sectional portion, a pair of inter-blade-ring center portions 8cb, a pair of inter-blade portions 8cc, and a pair of blade ring vicinity portions 8ca, and as for a blade outlet angle $\beta b2$ and a blade inclination deviation angle $\Delta 2$ at the inter-blade-ring center portions, a blade outlet angle $\beta b3$ and a blade inclination deviation angle $\Delta 3$ at the inter-blade portions, and a blade outlet angle $\beta b1$ and a blade inclination deviation angle $\Delta 1$ at the blade ring vicinity portions, the each of the plurality of blades may be formed so that the blade outlet angles satisfy $\beta b2<\beta b1<\beta b3$ and the blade inclination deviation angles satisfy $\Delta 3<\Delta 1<\Delta 2$.

[0012] Further, in order to attain the above-mentioned object, according to one embodiment of the present invention, there is provided an air conditioner, including: a stabilizer configured to partition an inlet-side air duct and an outlet-side air duct inside a main body; a cross-flow fan arranged between the inlet-side air duct and the outlet-side air duct; a ventilation resistor arranged inside the main body; and a guide wall configured to guide air discharged from the cross-flow fan to an air outlet of the main body, the cross-flow fan being the above-mentioned cross-flow fan according to the one embodiment of the present invention.

Advantageous Effects of Invention

[0013] According to the one embodiment of the present invention, it is possible to suitably disperse the flow over the rotational axis direction in the entire fan.

Brief Description of Drawings

[0014]

FIG. 1 is a view for illustrating an installing state of an air conditioner according to a first embodiment of the present invention when viewed from the interior of a room.
FIG. 2 is a vertical sectional view of the air conditioner of FIG. 1.
FIG. 3 is a view for illustrating a front side and a lateral side of an impeller of a cross-flow fan to be mounted on the air conditioner of FIG. 1.
FIG. 4 is a perspective view of a single blade of the impeller of the cross-flow fan when viewed from a surface on an impeller rotational direction side (blade pressure surface).
FIG. 5 is a view for illustrating the entire blade in a pro jective manner from a rotational axis direction.
FIG. 6 is a view for illustrating a blade ring vicinity portion of the blade in a projective manner from the rotational axis direction.
FIG. 7 is a view for illustrating an end side coupling portion of the blade in a projective manner from the rotational axis direction.
FIG. 8 is a view for illustrating an inter-blade portion of the blade in a a projective manner from the rotational axis direction.
FIG. 9 is a view for illustrating a center side coupling portion of the blade in a projective manner from the rotational axis direction.
FIG. 10 is a view for illustrating an inter-blade-ring center portion of the blade in a projective manner from the rotational axis direction.
FIG. 11 is a view for illustrating a blade shape in a cross section taken along the line A-A in FIG. 3.
FIG. 12 is a view for illustrating the blade shape in the cross section taken along the line A-A in FIG. 3.
FIG. 13 is a view for illustrating the blade shape in the cross section taken along the line A-A in FIG. 3.
FIG. 14 is a view for illustrating a second embodiment of the present invention in the same manner as in FIG. 3.
FIG. 15 is a view for illustrating a blade shape in a cross section taken along the line B-B in FIG. 14.
FIG. 16 is a view for illustrating a third embodiment of the present invention in the same manner as in FIG. 3.
FIG. 17 is a view for illustrating the third embodiment of the present invention in the same manner as in FIG. 4.
FIG. 18 is a view for illustrating a blade shape in a cross section taken along the line C-C in FIG. 16.

Description of Embodiments

[0015] Now, an air conditioner according to embodiments of the present invention is described with reference to the accompanying drawings. Note that, in the drawings, the same reference symbols represent the same or corresponding parts.

First Embodiment

[0016] FIG. 1 is an installation schematic view of an air conditioner having a cross-flow fan mounted thereon according to a first embodiment of the present invention when viewed from a room. FIG. 2 is a vertical sectional view of the air conditioner of FIG. 1. FIG. 3 is a view for illustrating a front side and a lateral side of an impeller of the cross-flow fan to be mounted on the air conditioner of FIG. 1.

[0017] As illustrated in FIG. 1, an air conditioner (indoor unit) 100 includes a main body 1 and a front panel 1b installed on the front side of the main body 1, which form an outer shape of the air conditioner 100. In this case, in FIG. 1, the air conditioner 100 is installed on a wall 11a of a room 11 that is a space to be air-conditioned. That is, FIG. 1 is an illustration of the air conditioner 100 of a wall-mounting type as an example, but the present invention is not limited to this mode. For example, a ceiling concealed type may be employed. Further, the air conditioner 100 is not limited to be installed in the room 11, and may be installed in a room of a building or a storehouse, for example.

[0018] As illustrated in FIG. 2, in a main body upper portion 1a forming the upper portion of the main body 1, a suction grille 2 configured to suck air inside the room into the air conditioner 100 is formed. On the lower side of the main body 1, an air outlet 3 configured to supply the conditioned air into the room is formed, and further a guide wall 10 configured to guide the air discharged from a cross-flow fan 8 described later to the air outlet 3 is formed.

[0019] As illustrated in FIG. 2, the main body 1 includes a filter (ventilation resistor) 5 configured to remove dust and the like in the air sucked through the suction grille 2, a heat exchanger (ventilation resistor) 7 configured to generate conditioned air by transferring hot or cold energy of refrigerant to air, a stabilizer 9 configured to partition an inlet-side air duct E1 and an outlet-side air duct E2, the cross-flow fan 8, which is arranged between the inlet-side air duct E1 and the outlet-side air duct E2, and is configured to suck air through the suction grille 2 and blow out air through the air outlet 3, and a vertical airflow-direction vane 4a and a lateral airflow-direction vane 4b configured to adjust the direction of the air blown out from the cross-flow fan 8.

[0020] The suction grille 2 is an opening through which the air inside the room is forcibly introduced into the air conditioner 100 by the cross-flow fan 8. The suction grille 2 is formed as an opening in the upper surface of the main body 1. The air outlet 3 is an opening through which air, which has been sucked through the suction grille 2 and passed through the heat exchanger 7, passes when the air is supplied into the room. The air outlet 3 is formed as an opening in the front panel 1b. The guide wall 10 forms the outlet-side air duct E2 in cooperation with the lower surface side of the stabilizer 9. The guide wall 10 forms a helical surface from the cross-flow fan 8 toward the air outlet 3.

[0021] The filter 5 is formed into, for example, a mesh shape, and is configured to remove dust and the like in the air sucked through the suction grille 2. The filter 5 is mounted on the downstream side of the suction grille 2 and on the upstream side of the heat exchanger 7 in the air duct from the suction grille 2 to the air outlet 3 (center portion inside the main body 1).

[0022] The heat exchanger 7 (indoor heat exchanger) functions as an evaporator to cool the air during cooling operation, and functions as a condenser (radiator) to heat the air during heating operation. The heat exchanger 7 is mounted on the downstream side of the filter 5 and on the upstream side of the cross-flow fan 8 in the air duct from the suction grille 2 to the air outlet 3 (center portion inside the main body 1). Note that, in FIG. 2, the heat exchanger 7 is shaped so as to surround the front side and the upper side of the cross-flow fan 8. However, this shape is merely an example, and the present invention is not limited thereto.

[0023] The heat exchanger 7 is connected to an outdoor unit of a known mode including a compressor, an outdoor heat exchanger, an expansion device, and the like, to thereby construct a refrigeration cycle. Further, as the heat exchanger 7, for example, a cross-fin type fin-and-tube heat exchanger including a heat transfer tube and a large number of fins is used.

[0024] The stabilizer 9 is configured to partition the inlet-side air duct E1 and the outlet-side air duct E2, and as illustrated in FIG. 2, the stabilizer 9 is mounted on the lower side of the heat exchanger 7. The inlet-side air duct E1 is positioned on the upper surface side of the stabilizer 9, and the outlet-side air duct E2 is positioned on the lower surface side of the stabilizer 9. The stabilizer 9 includes a drain pan 6 configured to temporarily accumulate dew condensation water adhering on the heat exchanger 7.

[0025] The cross-flow fan 8 is configured to suck air inside the room through the suction grille 2 and blow out conditioned air through the air outlet 3. The cross-flow fan 8 is mounted on the downstream side of the heat exchanger 7 and on the upstream side of the air outlet 3 in the air duct from the suction grille 2 to the air outlet 3 (center portion inside the main body 1).

[0026] The cross-flow fan 8 includes, as illustrated in FIG. 3, an impeller 8a made of a thermoplastic resin such as an AS resin (styrene-acrylonitrile copolymer) with glass fibers, a motor 12 configured to rotate the impeller 8a, and a motor shaft 12a configured to transmit the rotation of the motor 12 to the impeller 8a. The impeller 8a itself rotates to suck the air inside the room through the suction grille 2 and send the conditioned air to the air outlet 3.

[0027] The impeller 8a is formed by coupling a plurality of impeller elements 8d to each other, and each of the impeller elements 8d includes a plurality of blades 8c and at least one ring (support plate) 8b fixed to the end portion side of the plurality of blades 8c. That is, in the impeller element 8d, each of the plurality of blades 8c extends from a side surface of an outer peripheral portion of the disc-shaped ring 8b so as to be substantially perpendicular to the side surface. In addition, the plurality of blades 8c are arrayed at predetermined intervals in the circumferential direction of the ring 8b. The impeller 8a is integrated by welding and coupling the plurality of impeller elements 8d to each other as described above.

[0028] The impeller 8a includes a fan boss 8e protruding on the inner (center) side of the impeller 8a. The fan boss 8e is fixed to the motor shaft 12a with a screw or the like. Further, in the impeller 8a, one side of the impeller 8a is supported by the motor shaft 12a via the fan boss 8e, and the other side of the impeller 8a is supported by a fan shaft 8f. With this, the impeller 8a rotates in a rotational direction RO about an impeller rotation center O of the impeller 8a under a state in which both end sides thereof are supported, which enables sucking of the air inside the room through the suction grille 2 and sending of the conditioned air through the air outlet 3. Note that, the impeller 8a is described in detail later.

[0029] The vertical airflow-direction vane 4a is configured to vertically adjust the direction of the air blown out from the cross-flow fan 8, and the lateral airflow-direction vane 4b is configured to laterally adjust the direction of the air blown out from the cross-flow fan 8. The vertical airflow-direction vane 4a is mounted on the downstream side with respect to the lateral airflow-direction vane4b. Note that, the vertical direction herein corresponds to the vertical direction of FIG. 2, and the lateral direction herein corresponds to a front-back direction of the drawing sheet of FIG. 2.

[0030] Next, the shape of the blade 8c is described in detail with reference to FIG. 4 to FIG. 10. FIG. 4 is a perspective view of a single blade of the impeller of the cross-flow fan when viewed from a surface on an impeller rotational direction side (blade pressure surface). FIG. 5 is a view for illustrating the entire blade in a a projective manner from a rotational axis direction. R01, R02, and λ as used herein represent an inner diameter of the blade, an outer diameter of the blade, and a forward inclination angle in the blade rotational axis direction, respectively.

[0031] The blade 8c is formed bilaterally symmetrically across a central cross-sectional portion 51. The central cross-sectional portion 51 is a portion having a cross section positioned at the center of the blade 8c in its rotational axis direction among cross sections orthogonal to the rotational axis direction. In an order of increasing the distance from the central cross-sectional portion 51, the blade 8c includes a pair of inter-blade-ring center portions 8cb, a pair of center side coupling portions 8ce, a pair of inter-blade portions 8cc, a pair of end side coupling portions 8cd, and a pair of blade ring vicinity portions 8ca. Further, for the sake of convenience, cross-sectional portions 53, 55, 57, and 59 are illustrated in FIG. 4. The cross-sectional portion 53 forms a boundary between the blade ring vicinity portion 8ca and the end side coupling portion 8cd. The cross-sectional portion 55 forms a boundary between the end side coupling portion 8cd and the inter-blade portion 8cc. The cross-sectional portion 57 forms a boundary between the inter-blade portion 8cc and the center side coupling portion 8ce. The cross-sectional portion 59 forms a boundary between the center side coupling portion 8ce and the inter-blade-ring center portion 8cb.

[0032] The respective portions of the blade 8c are further described in detail with reference to FIG. 6 to FIG. 10. FIG. 6 is a view for illustrating the blade ring vicinity portion 8ca of the blade in a a projective manner from the rotational axis direction. As illustrated in FIG. 4 and FIG. 6, the blade ring vicinity portion 8ca is retreated more in the rotational direction as approaching to the center portion in the rotational axis direction (central cross-sectional portion 51). Further, the blade ring vicinity portion 8ca has a constant blade inclination deviation angle (angle formed between a straight line that is tangent to a blade outer peripheral end portion and a blade inner peripheral end portion and a straight line passing through an arc center of the blade inner peripheral end portion and the impeller rotational axis center point O) $\Delta 1$, and a constant blade outlet angle (angle formed between a line that is tangent to a thickness center line Sb (FIG. 13) of the arc-shaped blade at the arc center of the blade outer peripheral end portion and a line that is perpendicular to a straight line connecting a thickness center of the blade outer peripheral end portion with the impeller rotation center point O at the blade thickness center) $\beta b1$.

[0033] FIG. 7 is a view for illustrating the end side coupling portion 8cd of the blade in a projective manner from the rotational axis direction. As illustrated in FIG. 4 and FIG. 7, the end side coupling portion 8cd is retreated more in the rotational direction as approaching to the center portion in the rotational axis direction. Further, a blade inclination deviation angle $\Delta 3$ at the cross-sectional portion 55 is smaller than the blade inclination deviation angle $\Delta 1$ at the cross-sectional portion 53, and a blade outlet angle $\beta b3$ at the cross-sectional portion 55 is larger than the blade outlet angle $\beta b1$ at the cross-sectional portion 53. In other words, in the end side coupling portion 8cd, the blade inclination deviation angle becomes smaller and the blade outlet angle becomes larger as approaching to the center portion in the rotational axis direction.

[0034] FIG. 8 is a view for illustrating the inter-blade portion 8cc of the blade in a projective manner from the rotational axis direction. As illustrated in FIG. 4 and FIG. 8, the inter-blade portion 8cc is retreated more in the rotational direction as approaching to the center portion in the rotational axis direction. Further, the inter-blade portion 8cc has the constant blade inclination deviation angle $\Delta 3$ and the constant blade outlet angle $\beta b3$.

[0035] FIG. 9 is a view for illustrating the center side coupling portion 8ce of the blade in a projective manner from the rotational axis direction. As illustrated in FIG. 4 and FIG. 9, most of the center side coupling portion 8ce except for a part on an outer peripheral end portion 15a side is retreated more in the rotational direction as approaching to the center portion in the rotational axis direction. Further, a blade inclination deviation angle $\Delta 2$ at the cross-sectional portion 59 is larger than the blade inclination deviation angle $\Delta 3$ at the cross-sectional portion 57, and a blade outlet angle $\beta b2$ at the cross-sectional portion 59 is smaller than the blade outlet angle $\beta b3$ at the cross-sectional portion 57. In other words, in the center side coupling portion 8ce, the blade inclination deviation angle becomes larger and the blade outlet angle becomes smaller as approaching to the center portion in the rotational axis direction. Further, the blade inclination deviation angle $\Delta 2$ at the cross-sectional portion 59 is larger than the blade inclination deviation angle $\Delta 1$ at the cross-sectional portion 53, and the blade outlet angle $\beta b2$ at the cross-sectional portion 59 is smaller than the blade outlet angle $\beta b1$ at the cross-sectional portion 53.

[0036] FIG. 10 is a view for illustrating the inter-blade-ring center portion 8cb of the blade in a projective manner from the rotational axis direction. As illustrated in FIG. 4 and FIG. 10, the inter-blade-ring center portion 8cb is retreated more in the rotational direction as approaching to the center portion in the rotational axis direction. Further, the inter-blade-ring center portion 8cb has the constant blade inclination deviation angle $\Delta 2$ and the constant blade outlet angle $\beta b2$.

[0037] In the entire blade, at a portion between a pair of rings, the blade 8c has an outer diameter and an inner diameter that are identical in the rotational axis direction, and has a cross-sectional shape and a blade outlet angle that are identical over the rotational axis direction. Further, the blade 8c includes aplurality of regions that are advanced or retreated in the rotational direction over the rotational axis direction and has, at the portion between the pair of rings, at least two different blade outlet angles. More specifically, the blade 8c is formed so that the blade outlet angles satisfy $\beta b2<\beta b1<\beta b3$ and the blade inclination deviation angles satisfy $\Delta 3<\Delta 1<\Delta 2$. Further, an inner peripheral end portion 15b of the blade 8c has a shape that advances again in the rotational direction after retreating in the rotational direction from one corresponding ring toward the other corresponding ring, and the outer peripheral end portion 15a also has a shape that advances again in the rotational direction after retreating in the rotational direction from one corresponding ring toward the other corresponding ring. In other words, as illustrated in FIG. 4, when the pressure surface of the blade 8c is viewed in a projective manner, the inner peripheral end portion 15b and the outer peripheral end portion 15a in each of the plurality of blades 8c have inverted V-shapes, respectively. Note that, the blade may include, at a portion further outside (side farther away from the central cross-sectional portion 51) of each of the pair of blade ring vicinity portions 8ca, a portion extending with the positions of the inner peripheral end portion 15b and the outer peripheral end portion 15a, the blade outlet angle, and the blade inclination deviation angle at the blade cross section maintained in the rotational axis direction.

[0038] Next, a cross-sectional shape of the blade 8c in a direction orthogonal to the rotational axis is described in detail. FIG. 11 to FIG. 13 are views for illustrating a blade shape in a cross section taken along the line A-A in FIG. 3.

[0039] AsillustratedinFIG. 11 to FIG. 13, the outer peripheral end portion 15a and the inner peripheral end portion 15b of the blade 8c are each formed into an arc shape. Further, the blade 8c is formed so that the outer peripheral endportion 15a side is inclined forward in the impeller rotational direction RO with respect to the inner peripheral end portion 15b side. That is, when the blade 8c is viewed in the vertical cross section, a blade pressure surface 13a and a blade suction surface 13b of the blade 8c are curved in the impeller rotational direction RO as approaching from the impeller rotation center (rotational axis) O of the impeller 8a toward the outer side of the blade 8c.

[0040] A center of a circle corresponding to the arc shape formed in the outer peripheral end portion 15a is represented by P1 (also referred to as "arc center P1"), and a center of a circle corresponding to the arc shape formed in the inner peripheral end portion 15b is represented by P2 (also referred to as "arc center P2"). Further, when a line segment connecting together the arc centers P1 and P2 is represented by a blade chord line (blade chord) L, as illustrated inFIG. 13, the length of the blade chord line L is set to Lo (hereinafter also referred to as "blade chord length Lo").

[0041] The blade 8c includes the blade pressure surface 13a, which is a surface on the rotational direction RO side of the impeller 8a, and the blade suction surface 13b, which is a surface on an opposite side to the rotational direction RO side of the impeller 8a. In the vicinity of the center of the blade chord line L, the blade 8c has a concave shape curved in a direction from the blade pressure surface 13a toward the blade suction surface 13b.

[0042] Further, in the blade 8c, a radius of a circle corresponding to the arc shape on the blade pressure surface 13a side is different between the outer peripheral side of the impeller 8a and the inner peripheral side of the impeller 8a. That is, as illustrated in FIG. 12, the surface of the blade 8c on the blade pressure surface 13a side is a multiple-arc curved surface and includes an outer peripheral curved surface Bp1 in which a radius (arc radius) corresponding to the arc shape on the outer peripheral side of the impeller 8a is Rp1, and an inner peripheral curved surface Bp2 in which a radius (arc radius) corresponding to the arc shape on the inner peripheral side of the impeller 8a is Rp2. Further, the surface of the blade 8c on the blade pressure surface 13a side includes a flat surface Qp having a planar shape, which is connected to an inner peripheral end portion of the end portions of the inner peripheral curved surface Bp2.

[0043] As described above, the surface of the blade 8c on the blade pressure surface 13a side is formed in a manner that the outer peripheral curved surface Bp1, the inner peripheral curved surface Bp2, and the flat surface Qp are continuously connected to one another. Note that, when the blade 8c is viewed in the vertical cross section, the straight line forming the flat surface Qp is a tangent at a point connected to the arc forming the inner peripheral curved surface Bp2.

[0044] On the other hand, the surface of the blade 8c on the blade suction surface 13b side is a surface corresponding to the surface on the blade pressure surface 13a side. Specifically, the surface of the blade 8c on the blade suction surface 13b side includes an outer peripheral curved surface Bs1 in which a radius (arc radius) corresponding to the arc shape on the outer peripheral side of the impeller 8a is Rs1, and an inner peripheral curved surface Bs2 in which a radius (arc radius) corresponding to the arc shape on the inner peripheral side of the impeller 8a is Rs2. Further, the surface of the blade 8c on the blade suction surface 13b side includes a flat surface Qs having a planar shape, which is connected to an inner peripheral end portion of the end portions of the inner peripheral curved surface Bs2.

[0045] As described above, the surface of the blade 8c on the blade suction surface 13b side is formed in a manner that the outer peripheral curved surface Bs1, the inner peripheral curved surface Bs2, and the flat surface Qs are continuously connected to one another. Note that, when the blade 8c is viewed in the vertical cross section, the straight line forming the flat surface Qs is a tangent at a point connected to the arc forming the inner peripheral curved surface Bs2.

[0046] Next, the blade thickness is described. When the blade 8c is viewed in the vertical cross section, and when a diameter of a circle inscribed in the blade surfaces is represented by a blade thickness (thickness) t, as illustrated in FIG. 12, a blade thickness (thickness) t1 at the outer peripheral end portion 15a is smaller than a blade thickness (thickness) t2 at the inner peripheral end portion 15b. Note that, the blade thickness t1 corresponds to 2 $\times$ radius R1 of the circle forming the arc of the outer peripheral end portion 15a, and the blade thickness t2 corresponds to 2 $\times$ radius R2 of the circle forming the arc of the inner peripheral end portion 15b.

[0047] In other words, when the diameter of the circle inscribed in the blade pressure surface 13a and the blade suction surface 13b of the blade 8c represents the blade thickness, the blade thickness is formed as follows. The blade thickness of the outer peripheral end portion 15a is smaller than that of the inner peripheral end portion

15b, and the blade thickness gradually increases as approaching from the outer peripheral end portion 15a toward the center to become maximum at a predetermined position in the vicinity of the center. Then, the blade thickness gradually decreases as approaching toward the inner side to become substantially the same thickness at a straight portion Q.

[0048] More specifically, in a range of the outer peripheral curved surface Bp1, the inner peripheral curved surface Bp2, the outer peripheral curved surface Bs1, and the inner peripheral curved surface Bs2 formed in the blade pressure surface 13a and the blade suction surface 13b excluding the outer peripheral end portion 15a and the inner peripheral end portion 15b, the blade thickness t of the blade 8c gradually increases as approaching from the outer peripheral end portion 15a toward the center of the blade 8c, becomes a maximum thickness t3 at the predetermined position in the vicinity of the center of the blade chord line L, and gradually decreases as approaching toward the inner peripheral end portion 15b. Then, in a range of the straight portion Q, that is, in a range between the flat surface Qp and the flat surface Qs, the blade thickness t is the inner peripheral end portion thickness t2 that is a substantially constant value.

[0049] In this case, a part of the blade 8c having the flat surfaces Qp and Qs of the inner peripheral end portion 15b as surfaces is referred to as the straight portion Q. That is, the blade suction surface 13b of the blade 8c is formed of the multiple arcs and the straight portion Q in a range from the outer peripheral side toward the inner peripheral side of the impeller.

[0050] The cross-flow fan having the above-mentioned configuration and the air conditioner having the cross-flow fan mounted thereon can achieve the following effects.

[0051] First, in a case where air is blown out from inside to outside of the cross-flow fan 8 (that is, in the case of a flow in the cross-flow fan 8 at the blades 8c that are located at a lower right position in the drawing sheet in FIG. 2, in other words, in the case of a flow at the blades 8c that are positioned on the outlet-side air duct E2 side), the airflows from the inner peripheral end portion 15b toward the outer peripheral end portion 15a as indicated by the solid arrows in FIG. 4. In this case, at a portion between a corresponding pair of rings, each of the plurality of blades 8c has an outer diameter and an inner diameter that are identical in the rotational axis direction, and has a cross-sectional shape and a blade outlet angle that are identical over the rotational axis direction. Further, each of the plurality of blades 8c includes at least one region that is advanced or retreated in the rotational direction over the rotational axis direction, and has at least two different blade outlet angles. Therefore, unlike the case where the outer peripheral end portion of each blade is inclined uniformly from one ring toward the other ring, flows in each blade that are inclined in the rotation axis direction in a plurality of modes and are also inclined in the rotational direction in a plurality of modes are successively and repetitively blown out. Thus, the flows are blown out uniformly between the pair of rings, and an extremely uniform blowing-out distribution can be obtained as a successive flow state resulting from the rotation of the cross-flow fan. The flow can be suitably dispersed over the rotational axis direction in the entire fan. Further, when flowing over the inner peripheral end portion 15b, air is accompanied by a blade tip vortex with the inner peripheral end portion 15b as an end portion and flows across the blade 8c as a flow with suppressed separation. Therefore, the suppressed separation allows blowing-out at the outer peripheral end portion 15a to be suitably maintained, which also promotes the dispersion of the flow.

[0052] In addition, the following functions and effects can be obtained.

(1) The suction surface 13b of the blade 8c is formed of the multiple arcs and the straight portion Q in the range from the outer peripheral side toward the inner peripheral side of the impeller. Thus, when the blade 8c passes through the inlet-side air duct E1, the flow on the blade surface that is about to separate at the outer peripheral curved surface Bs1 reattaches onto the following inner peripheral curved surface Bs2 having a different arc radius.

(2) Further, the blade 8c has the flat surface Qs to generate a negative pressure. Therefore, the flow reattaches even when the flow is about to separate at the inner peripheral curved surface Bs2.

(3) Further, the blade thickness t is larger on the impeller inner peripheral side than on the impeller outer peripheral side, and hence the distance between the adjacent blades 8c is reduced.

(4) Further, the flat surface Qs is flat. Therefore, unlike the case of a curved surface, the blade thickness t does not abruptly increase as approaching toward the impeller outer periphery, and hence the frictional resistance can be suppressed.

(5) The pressure surface 13a of the blade 8c is also formed of the multiple arcs and the straight portion (flat surface) in the range from the outer peripheral side toward the inner peripheral side of the impeller. Thus, when air flows from the outer peripheral curved surface Bp1 toward the inner peripheral curved surface Bp2 having a different arc radius, the flow gradually accelerates to generate a pressure gradient on the suction surface 13b. Therefore, the separation is suppressed and no abnormal fluid noise is generated.

(6) Further, the flat surface Qp on the downstream side is a tangent to the inner peripheral curved surface Bs2. In other words, the blade 8c has the flat surface Qp on the downstream side, and hence the blade 8c is shaped so as to be bent by a predetermined angle with respect to the rotational direction RO. Therefore, unlike the case where the straight surface (flat surface Qp) is absent, the flow can be

directed toward the suction surface 13b even when the blade thickness t2 of the inner peripheral end portion 15b is large. Thus, the wake vortex can be suppressed when air flows into the impeller from the inner peripheral end portion 15b.

(7) The blade 8c has the thick inner peripheral end portion 15b. Thus, separation is less liable to occur in various inflow directions in the outlet-side air duct E2.

(8) Further, the blade 8c has the maximum thickness in the vicinity of the center of the blade chord, which is positioned on the downstream side of the flat surface Qs. Therefore, when the flow is about to separate after passing along the flat surface Qs, the air flows along the inner peripheral curved surface Bs2 because the blade thickness t is gradually increased toward the vicinity of the center of the blade chord, which can suppress the separation.

(9) Further, the blade 8c has the outer peripheral curved surface Bs1 having a different arc radius on the downstream side of the inner peripheral curved surface Bs2. Therefore, the separation of the flow is suppressed, the effective outlet-side air duct from the impeller can be increased, the outlet airflow velocity is reduced and equalized, and the load torque applied to the blade surface can be reduced.

(10) The blade outlet angle or the blade inclination deviation angle is set to at least two different values, and hence the separation of the flow can be suppressed to reduce the noise.

(11) The blade outlet angles at the blade ring-side portion 8ca, the inter-blade-ring center portion 8cb, and the inter-blade portion 8cc are different from each other, and the respective blade outlet angles $\beta b1$, $\beta 2b$, and $\beta b3$ are formed so as to satisfy $\beta b2<\beta b1<\beta b3$. Thus, the inter-blade-ring center portion 8cb has the minimum outlet angle $\beta 2b$ and projects forward in the blade rotational direction. Therefore, the flow does not concentrate excessively on the inter-ring center portion in the longitudinal direction. Further, in the inter-blade portion 8cc, the outlet angle is the largest, and air is blown out relatively in a radial direction as compared to the other regions. Further, the distance between blades adjacent to each other in the rotational direction is increased, thereby allowing the airflow velocity to be reduced. At the blade ring vicinity portion 8ca where the velocity is low, the outlet angle is reduced and the inter-blade distance is decreased. Thus, turbulence, which may be generated due to the instability of the flow, can be prevented, and the airflow velocity can be increased.

(12) In addition, the blade shape varies as each of the plurality of regions having different outlet angles extends to have a predetermined length in the rotational axis direction, and hence the distribution of the velocity of the airflow toward the downstream air outlet can be uniformized. In this manner, as compared to the case where the blade shape is the same in the rotational axis direction, an energy-saving and quiet air conditioner indoor unit having a higher-efficiency and lower-noise cross-flow fan mounted thereon can be obtained.

(13) The blade inclination deviation angles Δ at the blade ring-side portion 8ca, the inter-blade-ring center portion 8cb, and the inter-blade portion 8cc are different from each other, and the respective blade inclination deviation angles $\Delta 1$, $\Delta 2$, and $\Delta 3$ are formed so as to satisfy $\Delta 3<\Delta 1<\Delta 2$. Accordingly, the inter-blade-ring center portion 8cb has the maximum blade inclination deviation angle $\Delta 2$ and projects forward in the rotational direction. Therefore, the flow does not concentrate excessively on the inter-ring center portion in the longitudinal direction. The inter-blade portion 8cc has the minimum blade inclination deviation angle $\Delta 3$, and air is blown out relatively in the radial direction as compared to the other regions. Further, the distance between blades adjacent to each other in the rotational direction is also increased, thereby allowing the airflow velocity to be reduced. At the blade ring-side portion 8ca where the velocity is low, the blade inclination deviation angle $\Delta 1$ is reduced and the inter-blade distance is decreased. Thus, the turbulence, which may be generated due to the instability of the flow, can be prevented, and the airflow velocity can be increased.

Further, according to this embodiment, advantageous effects are obtained over the related-art configurations disclosed in Patent Literature 1 to Patent Literature 3. First, in the configuration disclosed in Patent Literature 1, the blade becomes thinner in accordance with the position in the impeller rotational axis direction. Further, in the configuration disclosed in Patent Literature 2, the blade is formed into a tapered shape in which the blade has a smaller outer diameter and a larger inner diameter as the blade extends from the base on the blade ring side. Further, the blade tip portion is inclined in the rotational axis direction, and the blade outer diameter varies in the impeller longitudinal direction. Therefore, a flow directed from one ring toward the other ring in the impeller rotational axis direction is generated. Further, the space between the impeller and the stabilizer or the casing facing the impeller is enlarged in the rotational axis direction to increase the leakage loss of the flow, and the space varies in the impeller rotational axis direction to cause a flow from a region having a narrow space to a region having a wide space, thus further increasing the leakage loss. Further, the efficiency deterioration increases the motor power consumption. Further, two components are necessary in the configuration disclosed in Patent Literature 3. Further, the orientation of the blade inclination is alternately changed for each impeller element. Thus, regions where the flow concentrates in the vicinity of the ring and regions where the flow separates from the vicinity of the ring are alternately formed on a ring basis, and the blowing-out airflow velocity distribution varies from a sparse state to a dense state or vice versa at wide intervals on a two-ring basis. When dust and the like are deposited on the filter installed at the air inlet of the air conditioner to increase the pressure loss, the sparseness and denseness become significant to cause back flow in a wide sparse region in the worst case. Therefore, high-humidity air flows back during the cooling, which may cause dew condensation to discharge dew condensation water to the outside.

(14) In connection with those problems, according to this embodiment, the blade 8c is formed so that the inter-blade-ring center portions are retreated (or advanced) in the impeller rotational direction in the impeller rotational direction while the blade cross section orthogonal to the impeller rotational axis is the same. Thus, the space between the impeller and the stabilizer 9 facing the impeller is the same, and hence the flow leakage can be prevented from increasing due to a circular vortex g1 caused by a difference in the space in the longitudinal direction, though this increase of the flow leakage has been a problem in the above-mentioned related-art configuration. Accordingly, the power consumption of the motor to be driven can be reduced while achieving high efficiency.

(15) Further, the blade is retracted in the impeller rotational direction and each blade tip portion has a region that is inclined with respect to the impeller rotational axis. Therefore, when the blade passes in the vicinity of the stabilizer 9 facing the impeller, the flow is dispersed in the entire region of each blade tip portion in the impeller longitudinal direction without pressure variations, thus reducing harsh rotational noise (NZ noise) due to the number of rotations and the number of blades. Accordingly, the noise can be reduced. As a result, the separation of the flow from the blade surface can be suppressed on the inlet side and the outlet side of the impeller. Therefore, the noise can be reduced, and further the power consumption of the fan motor can be reduced. In other words, an indoor unit 100 having a quiet and energy-saving cross-flow fan 8 mounted thereon can be obtained.

Second Embodiment

[0053] Next, a second embodiment of the present invention is described with reference to FIG. 14 and FIG. 15. FIG. 14 is a view for illustrating the second embodiment of the present invention in the same manner as in FIG. 3, and FIG. 15 is a view for illustrating a blade shape in a cross section taken along the line B-B in FIG. 14. The configuration in the second embodiment is the same as that in the above-mentioned first embodiment except for portions to be described below.

[0054] According to the second embodiment, each of a plurality of blades 108c has an outer diameter and an inner diameter that are identical in the rotational axis direction, and only includes a region that is advanced or retreated in the rotational direction between a pair of rings. The blade portion on one ring side is deviated from the blade portion on the other ring side by an angle δ.

[0055] The second embodiment configured as described above can also achieve the same effects as in the first embodiment.

Third Embodiment

[0056] Next, a third embodiment of the present invention is described with reference to FIG. 16, FIG. 17, and FIG. 18. FIG. 16 is a view for illustrating the third embodiment of the present invention in the same manner as in FIG. 3, FIG. 17 is a view for illustrating the third embodiment of the present invention in the same manner as in FIG. 4, and FIG. 18 is a view for illustrating a blade shape in a cross section taken along the line C-C in FIG. 16. The configuration in the third embodiment is the same as that in the above-mentioned first embodiment except for portions to be described below.

[0057] According to the third embodiment, each of a plurality of blades 208c has an outer diameter and an inner diameter that are identical in the rotational axis direction, and includes only a region that is advanced in the rotational direction between a pair of rings or a region that is retreated in the rotational direction between the pair of rings, and a pair of ring-side portions 220 that are positioned on both sides of the above-mentioned region and extend along the rotational axis direction without being advanced or retreated in the rotational direction, respectively. The portion on one ring side is deviated from the portion on the other ring side by the angle δ.

[0058] The third embodiment configured as described above can also achieve the same functions as in the first embodiment regarding the air flow. Further, according to the third embodiment, each of the plurality of blades achieves the following advantages due to the pair of ring-side portions that extend along the rotational axis direction without being advanced or retreated in the rotational direction. In other words, when the plurality of impeller elements are stacked together and blades of one impeller element are welded to the ring of another stacked impeller element, the blade tips are upright and hence come into contact with the ring surface in an upright state. Accordingly, the weldability is improved while achieving good assembling workability. Further, the blade parallel portions (ring-side portions) at both ends have no inclination to suppress concentration or dispersion of the flow on or from the ring surface, thus stabilizing the flow in the vicinity of the ring. In this way, a uniform airflow velocity distribution can be achieved and back flow can be prevented from occurring even when dust and the like are deposited on the filter installed at the air inlet of the air conditioner to increase the pressure loss. Therefore, a high-quality air conditioner causing no dew condensation also during the cooling can be obtained.

[0059] The details of the present invention have been described above specifically with reference to the preferred embodiments, but it is apparent that a person skilled in the art may employ various modifications based on the basic technical thoughts and teachings of the present invention.

[0060] For example, the above-mentioned first embodiment may also be carried out by reversing the relationship of advance and retreat in each portion and using a blade formed into a V-shape instead of the inverted V-shape.

Reference Signs List

[0061]

1 main body, 8 cross-flow fan, 8a impeller, 8b ring (support plate), 8c, 108c, 208c, 308c blade, 8ca blade ring vicinity portion, 8cb inter-blade-ring center portion, 8cc inter-blade portions 8, 9 stabilizer, 15a outer peripheral end portion, 15b inner peripheral end portion, 100 air conditioner

Claims

1. A cross-flow fan, comprising:

   an impeller; and
   a shaft configured to support the impeller in a rotatable manner,
   the impeller comprising:

      a plurality of support plates; and
      a plurality of blades arranged between a corresponding pair of support plates at intervals in a circumferential direction,

   each of the plurality of blades having an outer diameter and an inner diameter that are identical in a rotational axis direction between the pair of support plates, and including at least one region that is advanced or retreated in a rotational direction.

2. A cross-flow fan according to claim 1, wherein the each of the plurality of blades has at least two different blade outlet angles between a corresponding pair of support plates.

3. A cross-flow fan according to claim 1 or 2, wherein at a portion between the corresponding pair of the support plates, the each of the plurality of blades may have an outer diameter and an inner diameter that are identical in the rotational axis direction, have a cross-sectional shape and a blade outlet angle that are identical over the rotational axis direction, and include a plurality of the regions that are advanced or retreated in the rotational direction over the rotational axis direction.

4. A cross-flow fan according to claim 3,
   wherein the each of the plurality of blades is formed bilaterally symmetrically across a central cross-sectional portion, and comprises, in an order of increasing a distance from the central cross-sectional portion, a pair of inter-blade-ring center portions (8cb), a pair of inter-blade portions (8cc), and a pair of blade ring vicinity portions (8ca), and
   wherein, as for a blade outlet angle ($\beta b2$) and a blade inclination deviation angle ($\Delta 2$) at the inter-blade-ring center portions , a blade outlet angle ($\beta b3$) and a blade inclination deviation angle ($\Delta 3$) at the inter-blade portions, and a blade outlet angle ($\beta b1$) and a blade inclination deviation angle ($\Delta 1$) at the blade ring vicinity portions, the each of the plurality of blades is formed so that the blade outlet angles satisfy $\beta b2<\beta b1<\beta b3$ and the blade inclination deviation angles satisfy $\Delta 3<\Delta 1<\Delta 2$.

5. An air conditioner, comprising:

      a stabilizer configured to partition an inlet-side air duct and an outlet-side air duct inside a main body;
      a cross-flow fan arranged between the inlet-side air duct and the outlet-side air duct;
      a ventilation resistor arranged inside the main body; and
      a guide wall configured to guide air discharged from the cross-flow fan to an air outlet of the main body,

   the cross-flow fan comprising the cross-flow fan of any one of claims 1 to 4.

FIG. 1

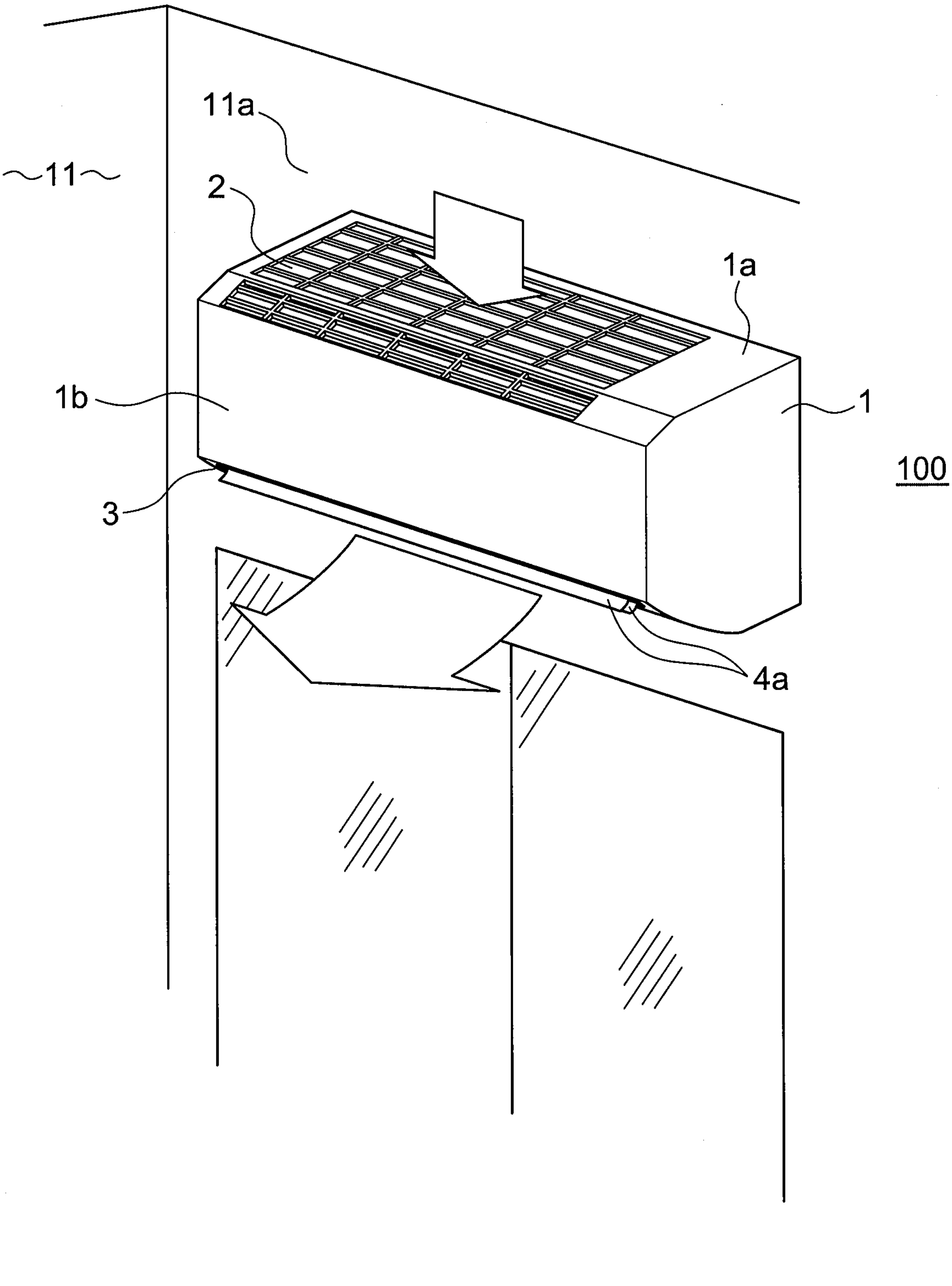

FIG. 2

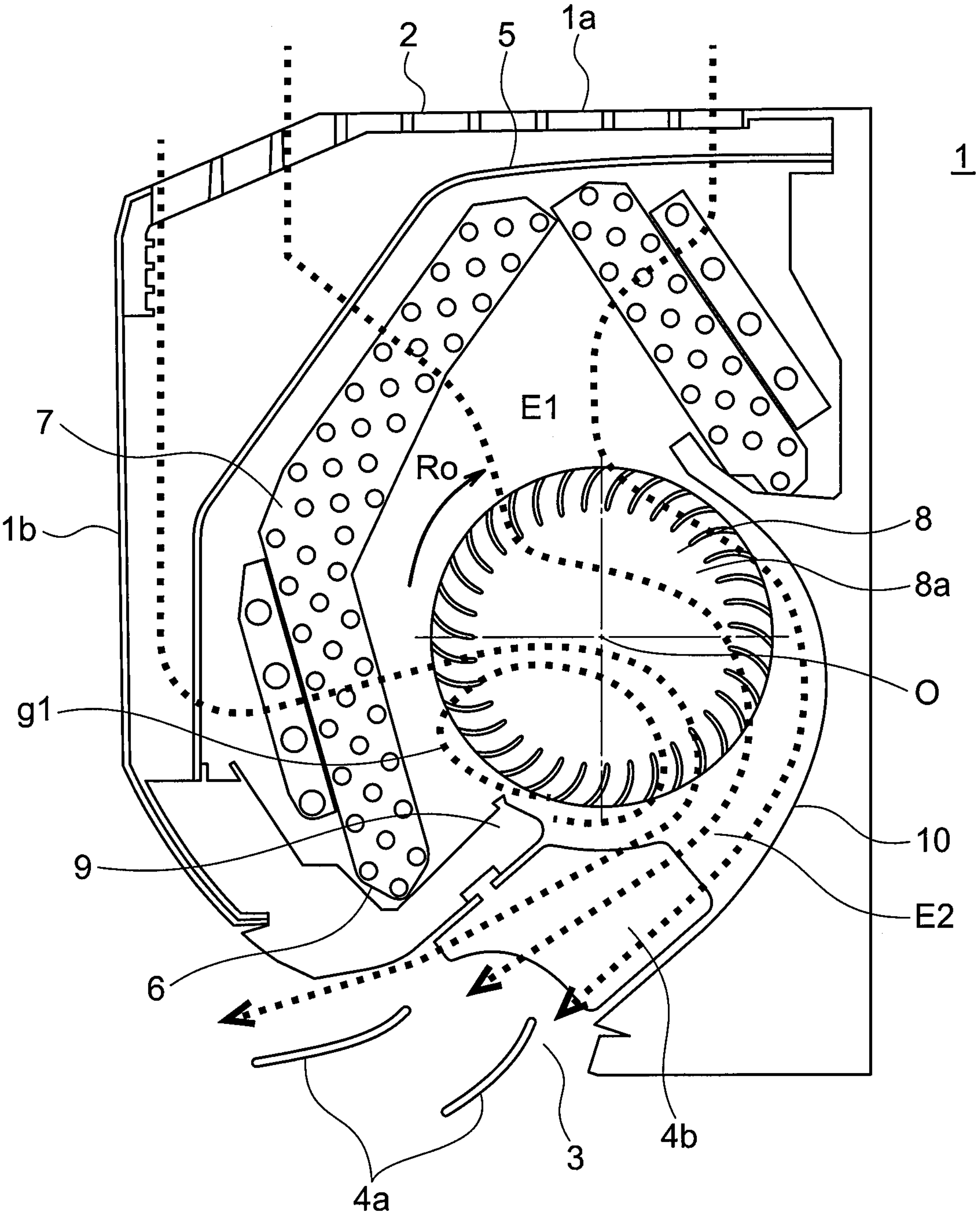

FIG. 3

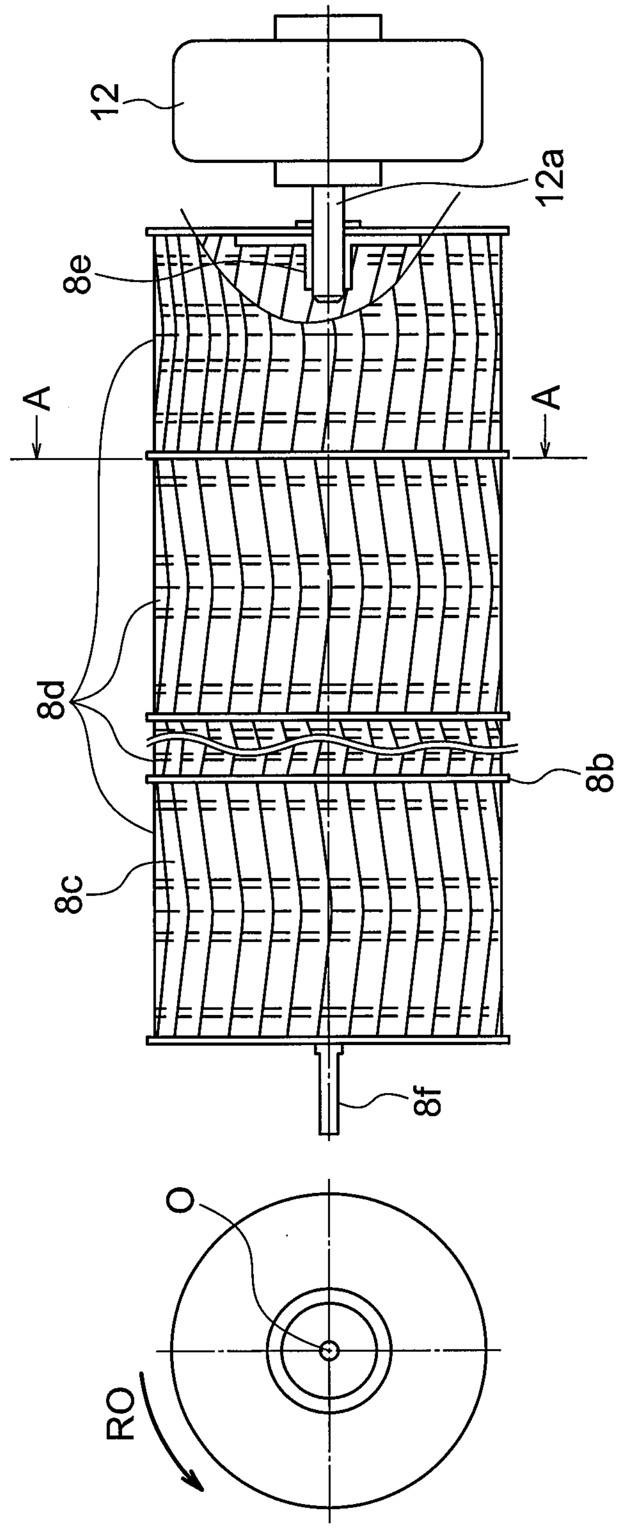

FIG. 4

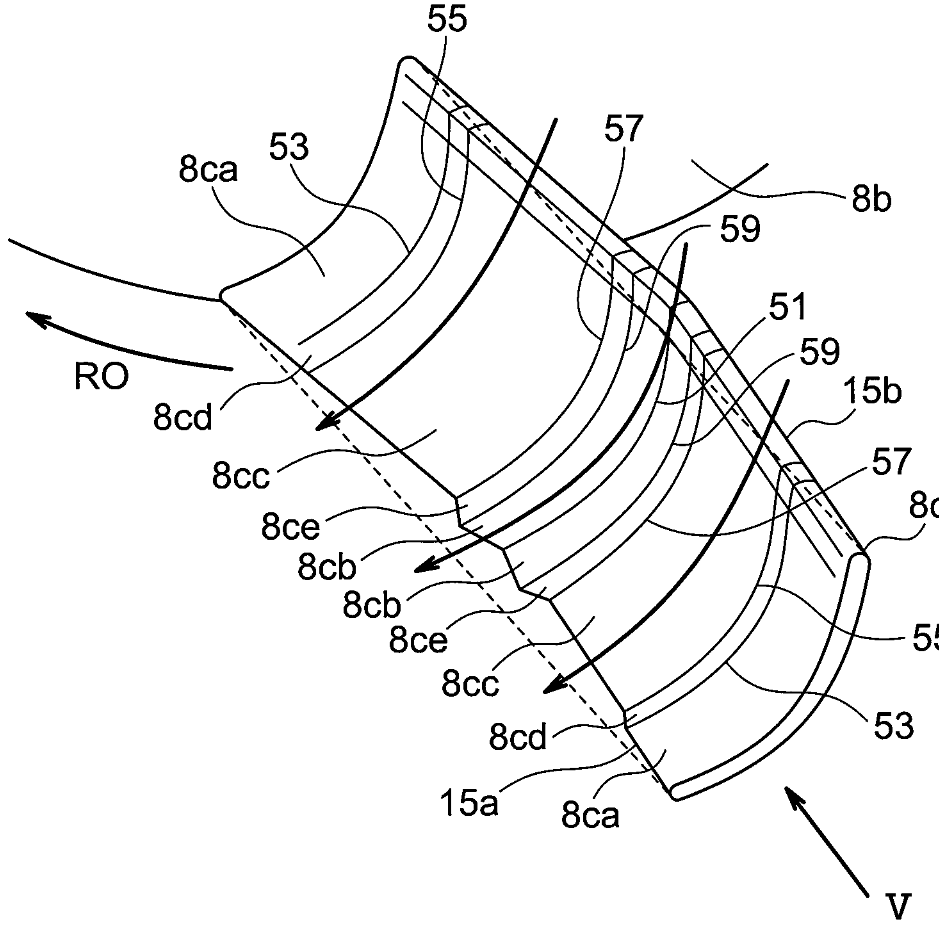
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FIG. 5

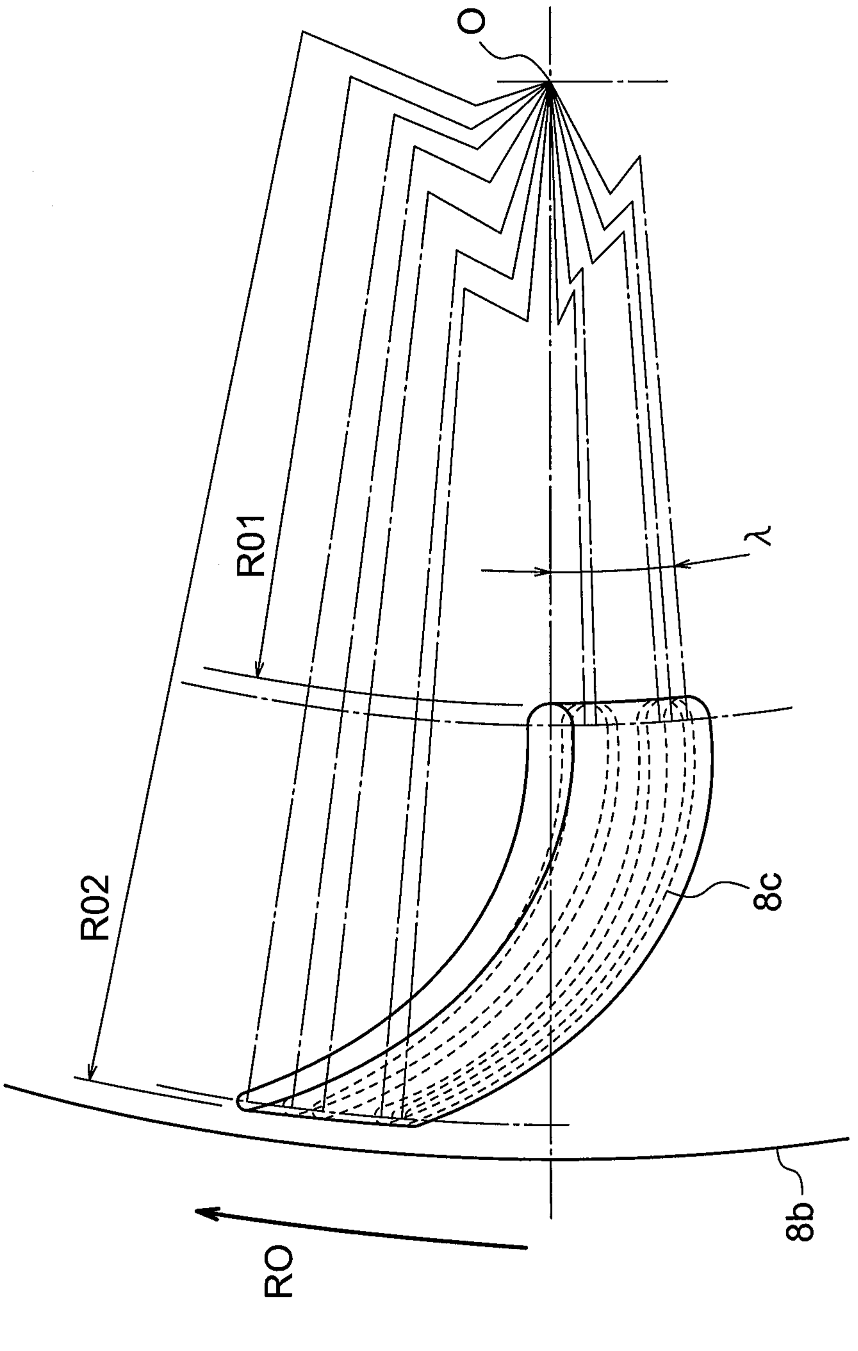


FIG. 6

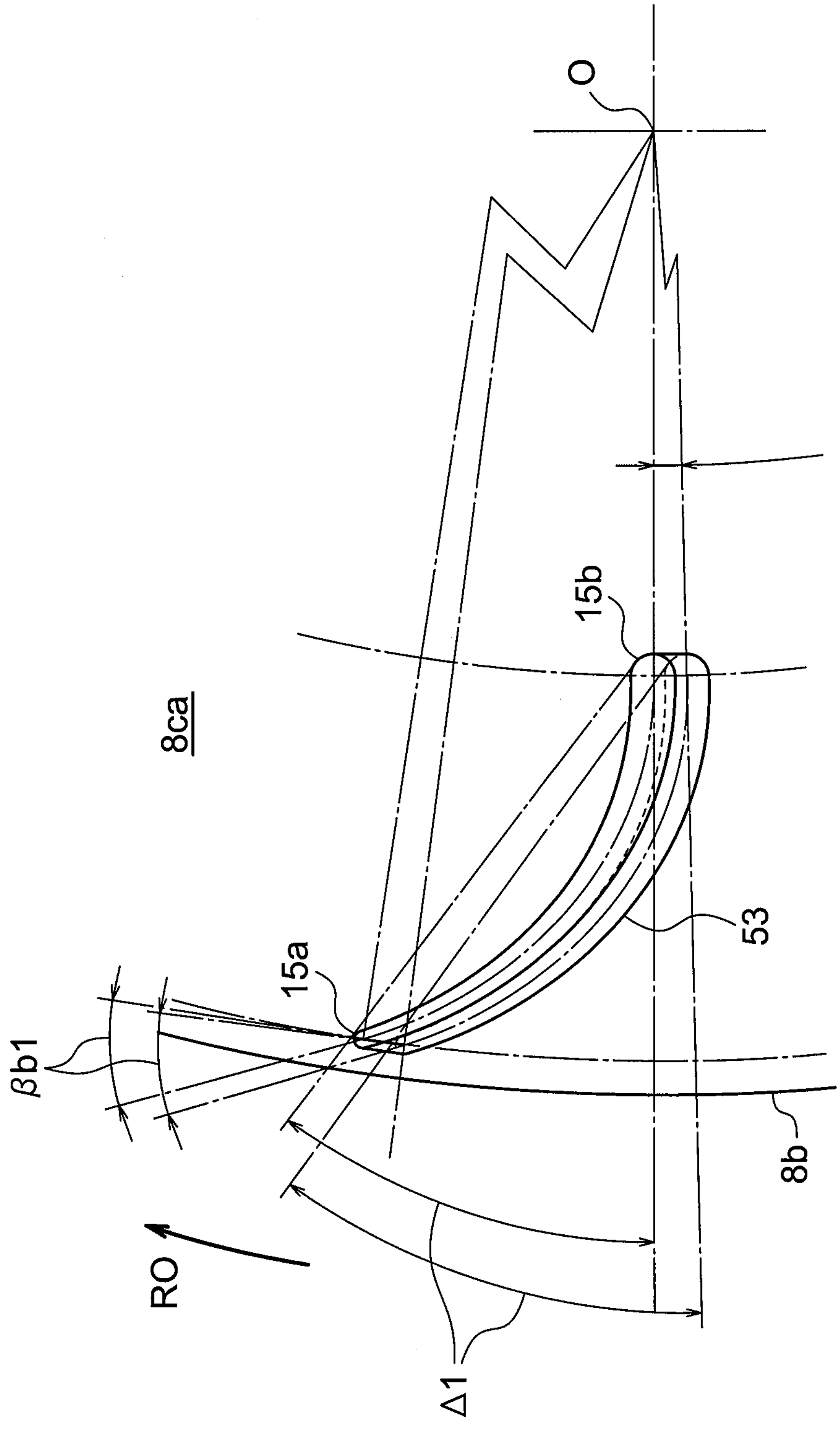


FIG. 7

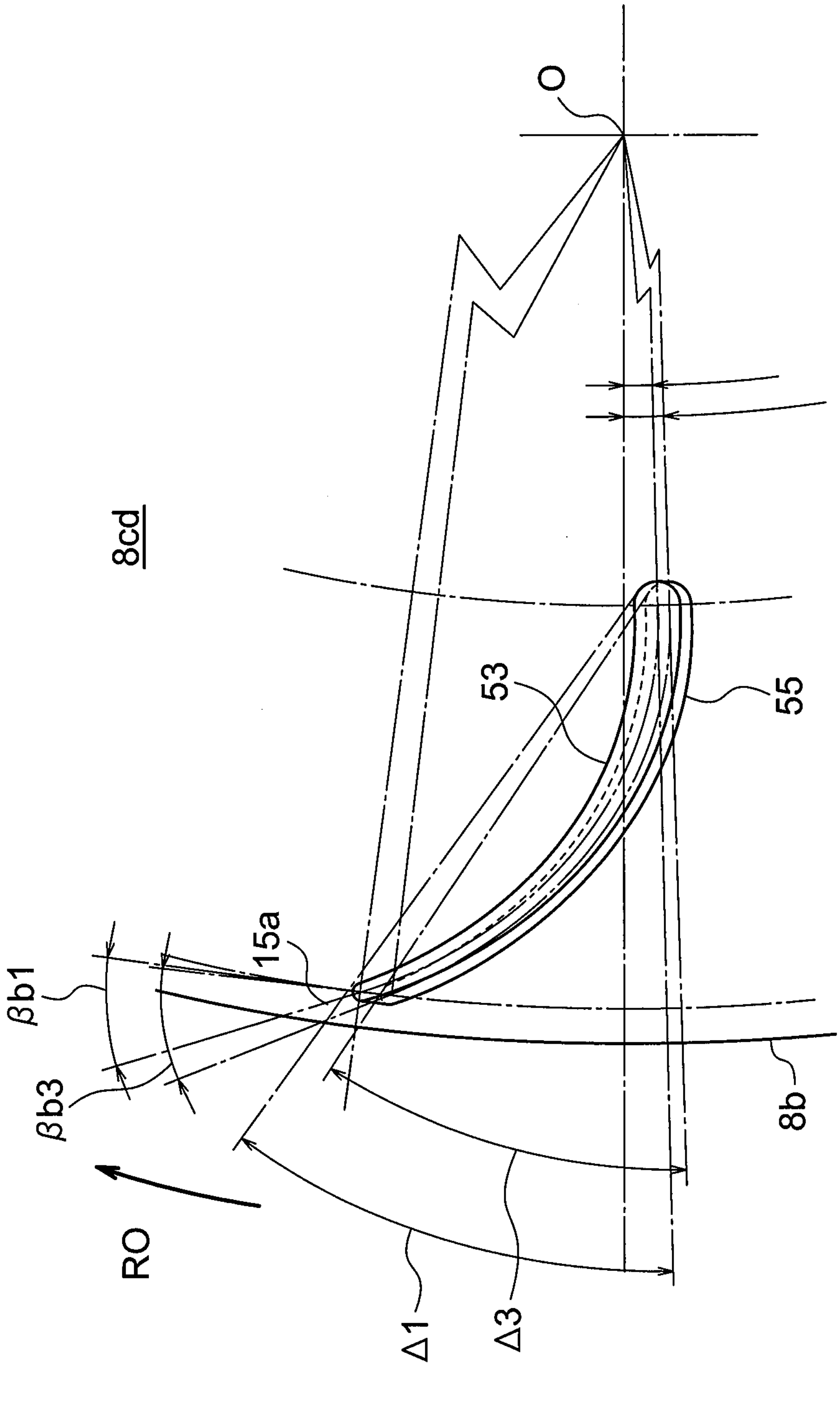


FIG. 8

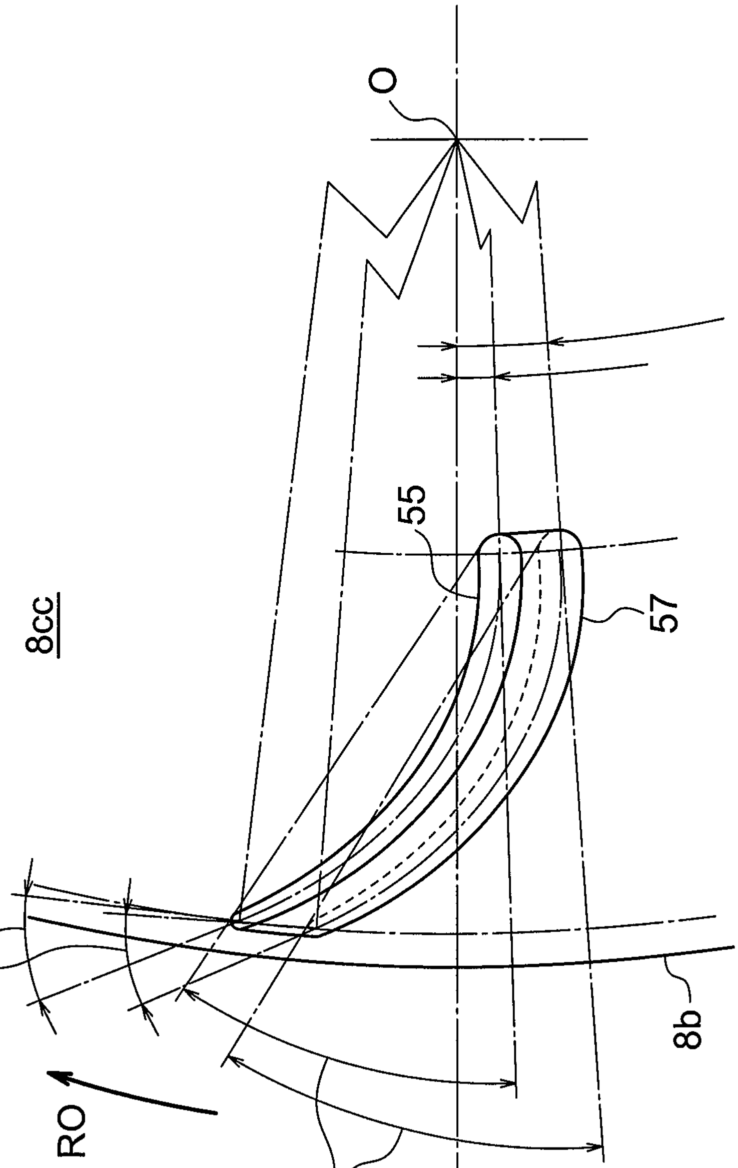


FIG. 9

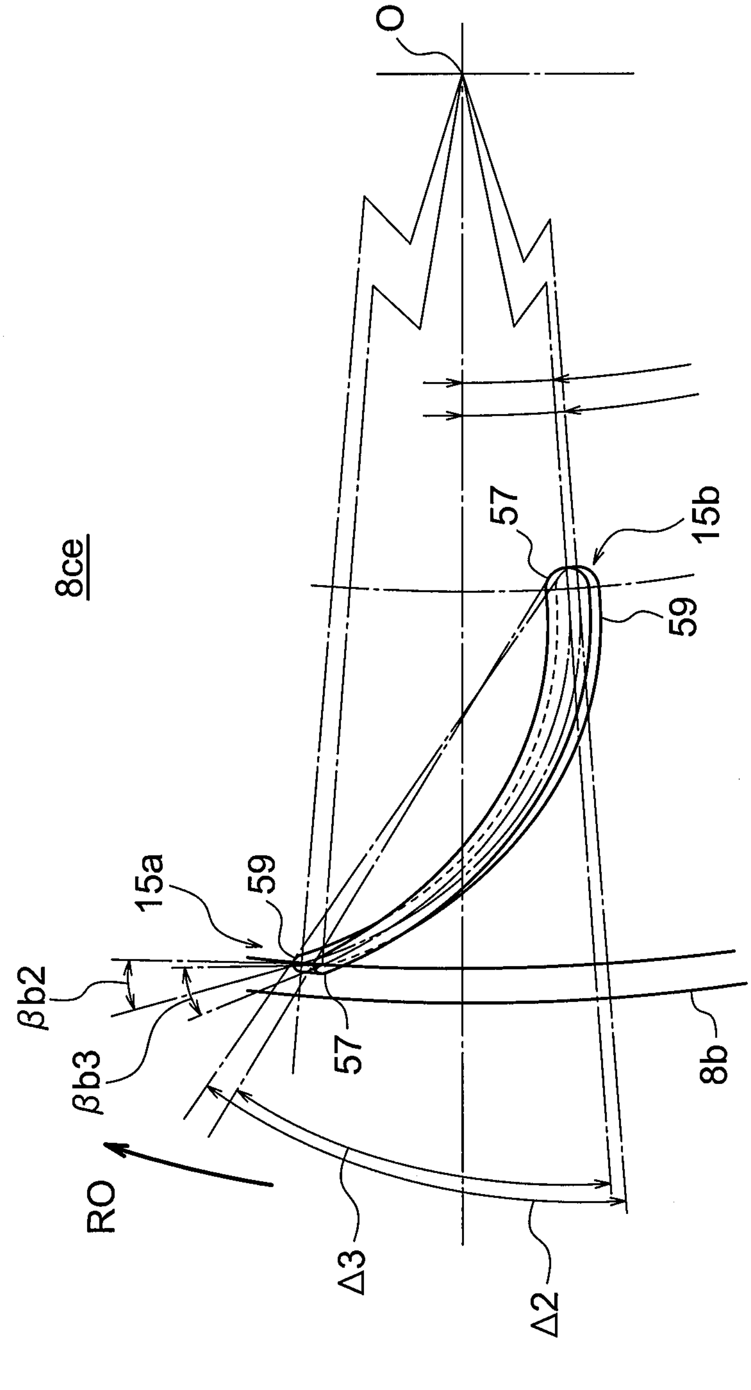


FIG. 10

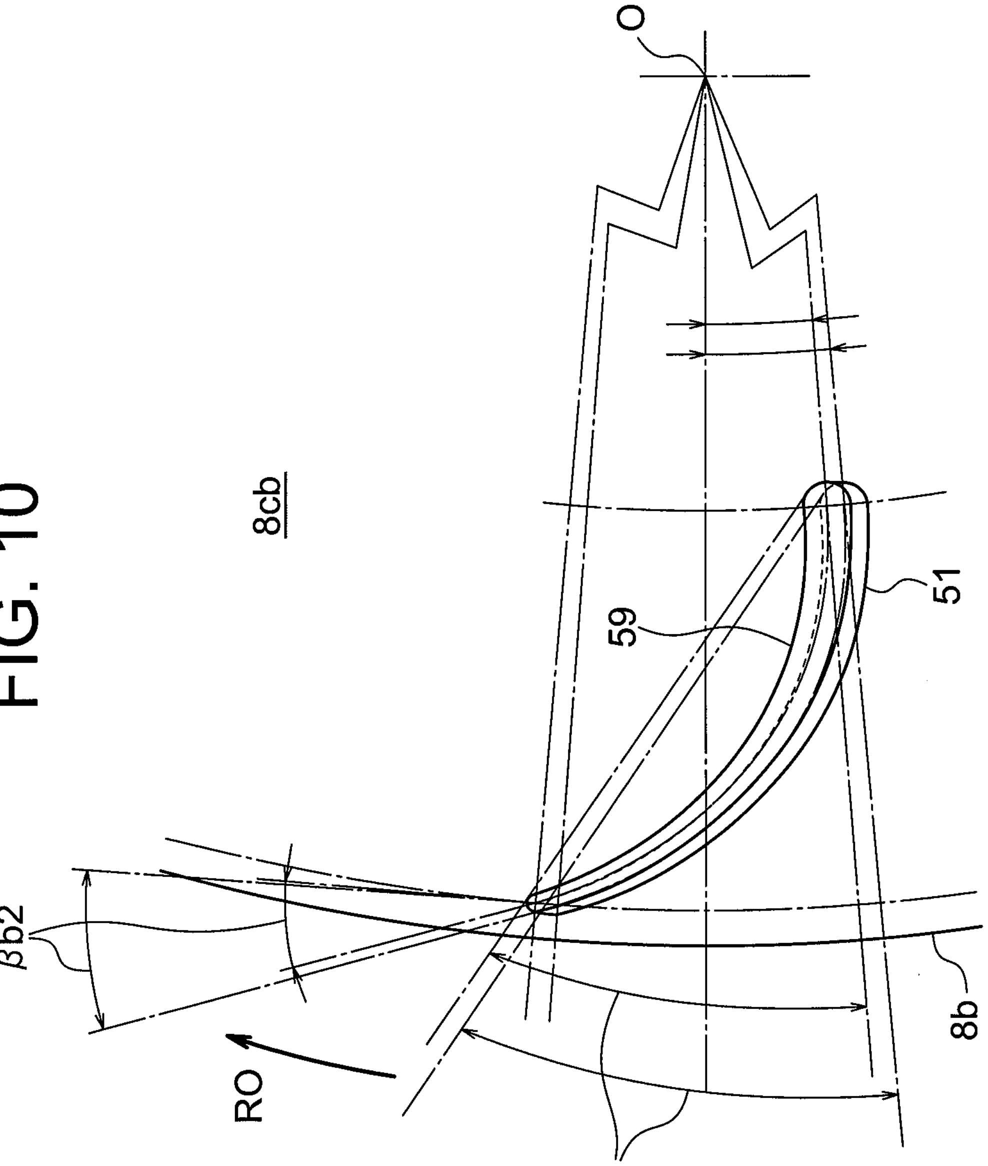
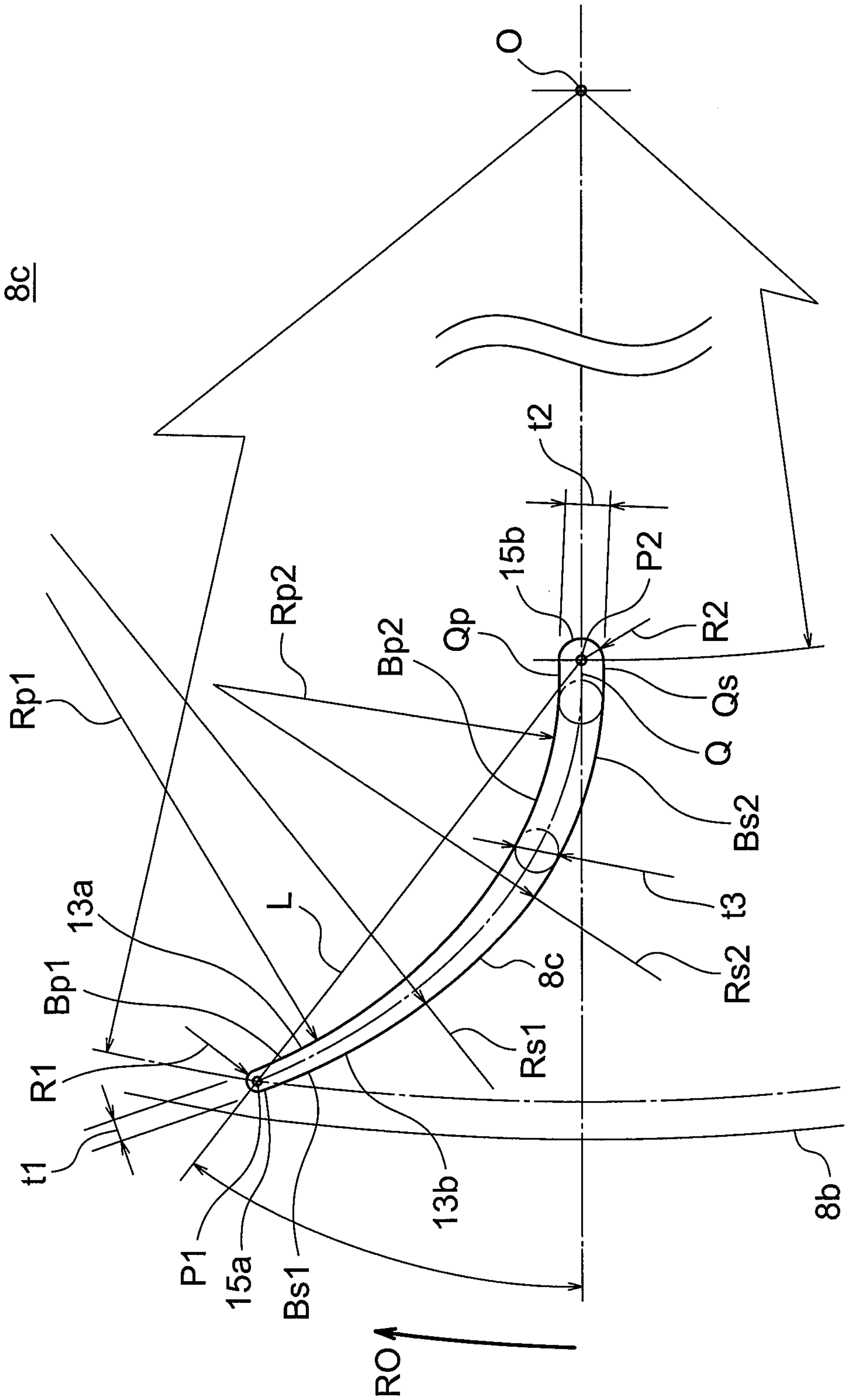


FIG. 11


8c
O
t2
15b
P2
Rp2
Qp
R2
Bp2
Qs
Rp1
Q
Bs2
t3
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15a
Bs1
RO

FIG. 12

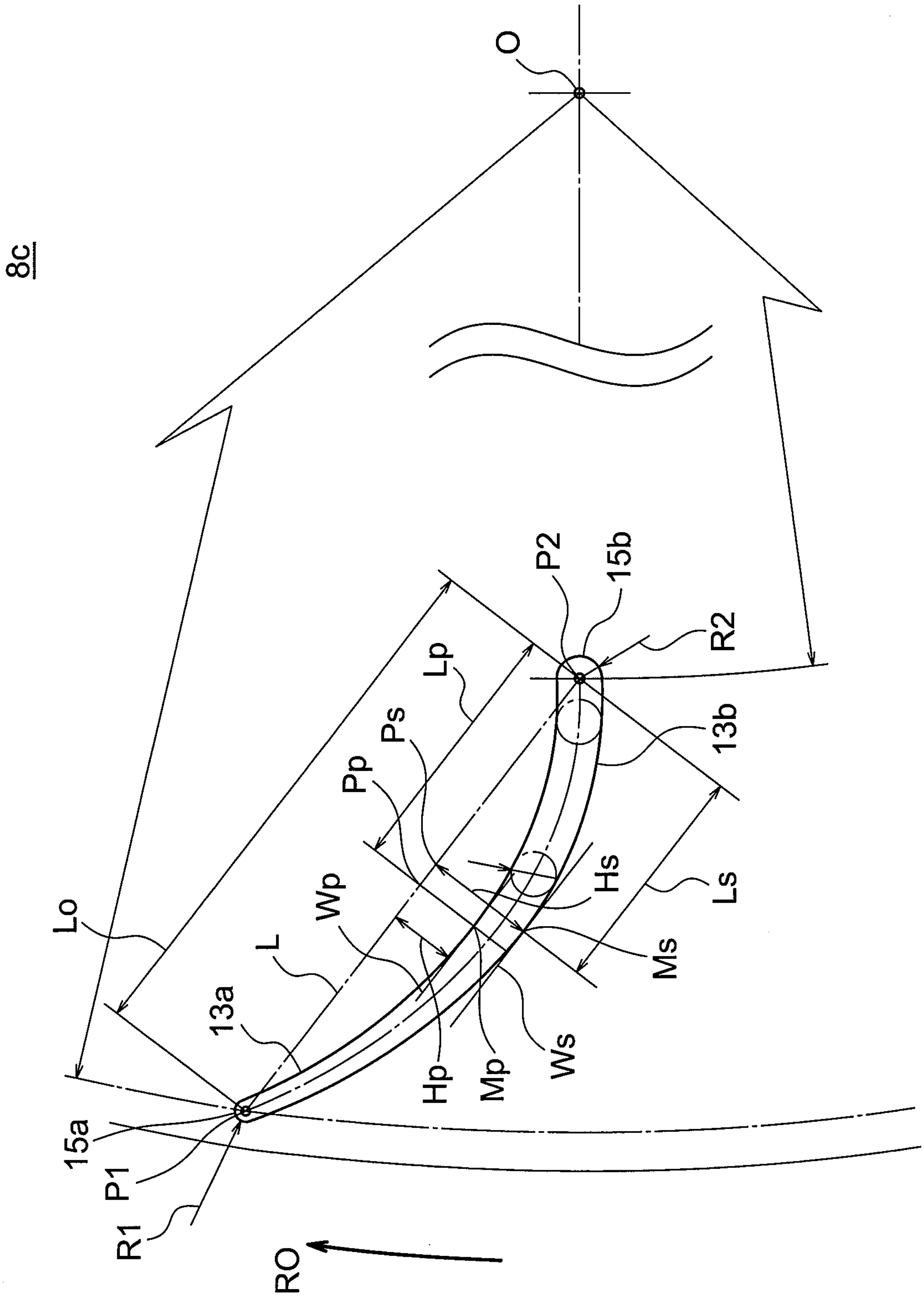


FIG. 13

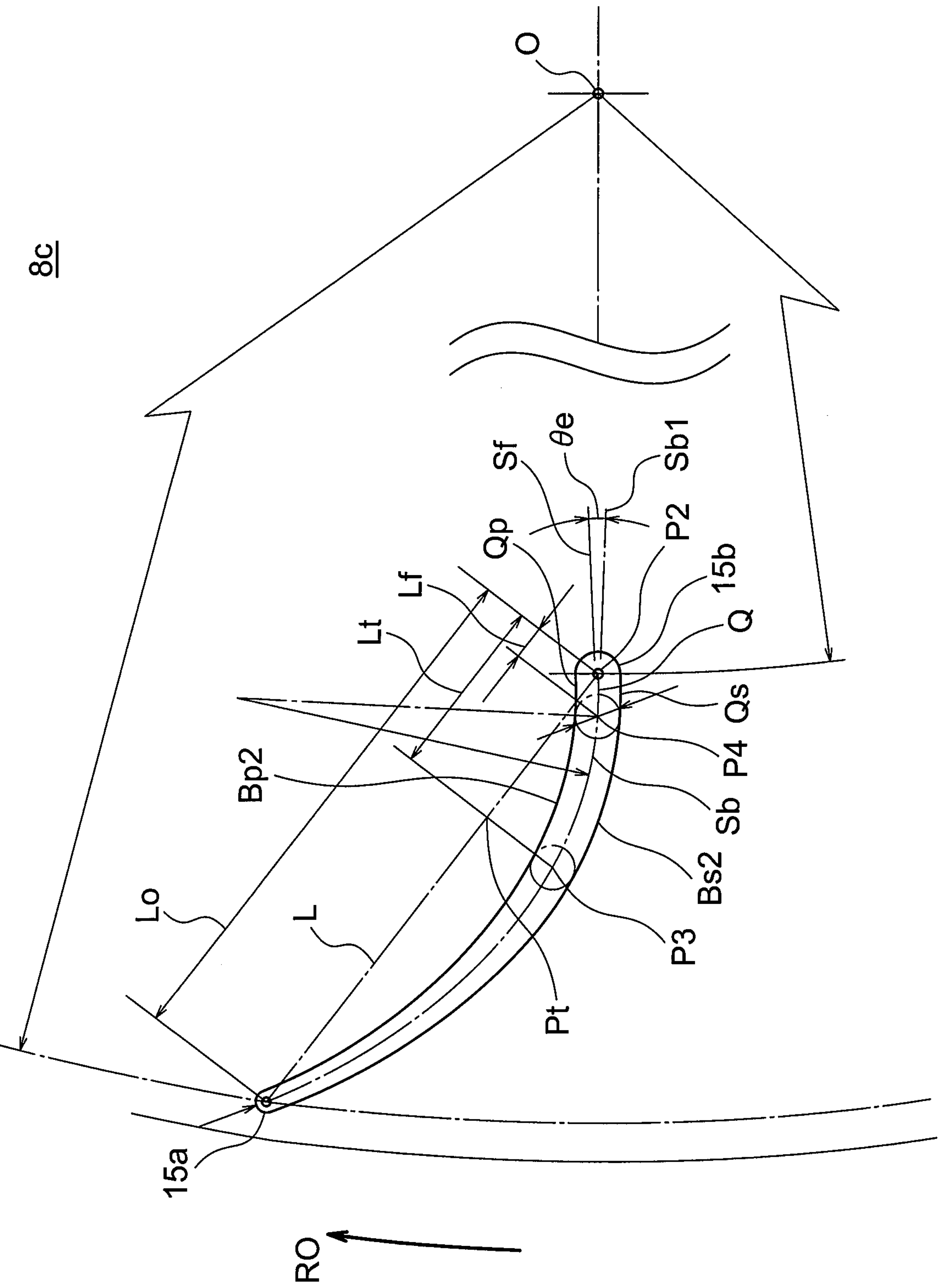


FIG. 14

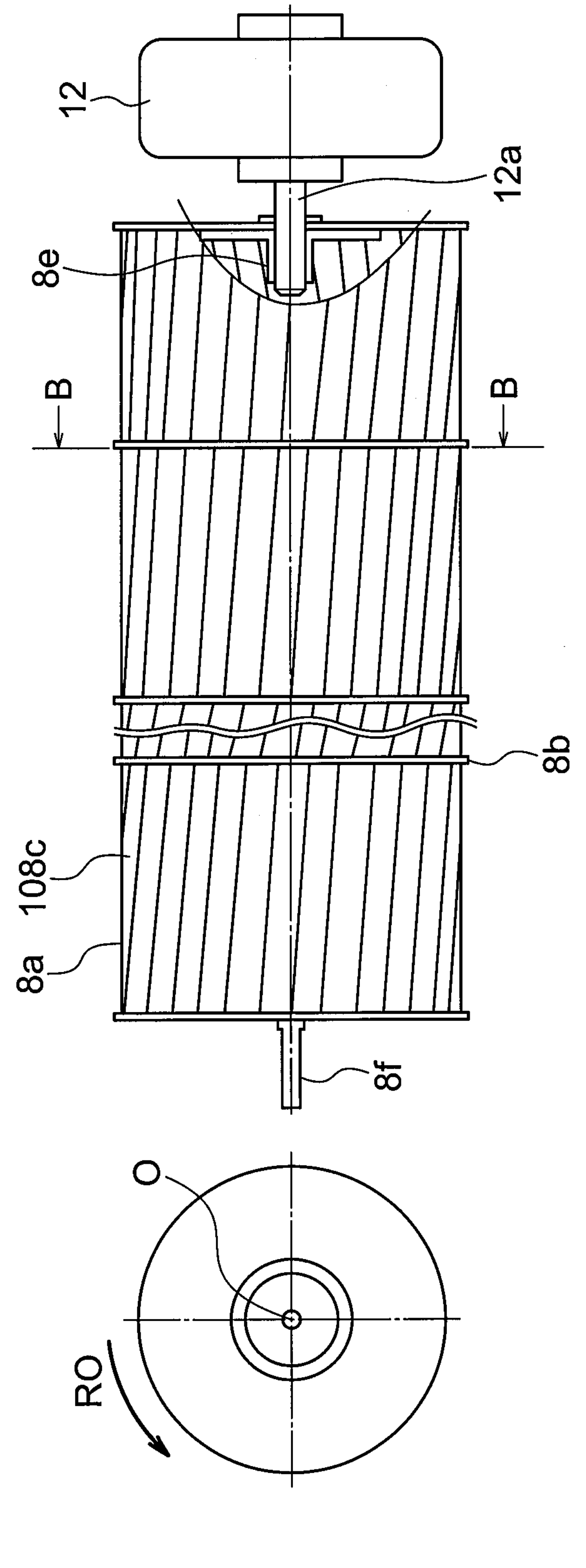


FIG. 15

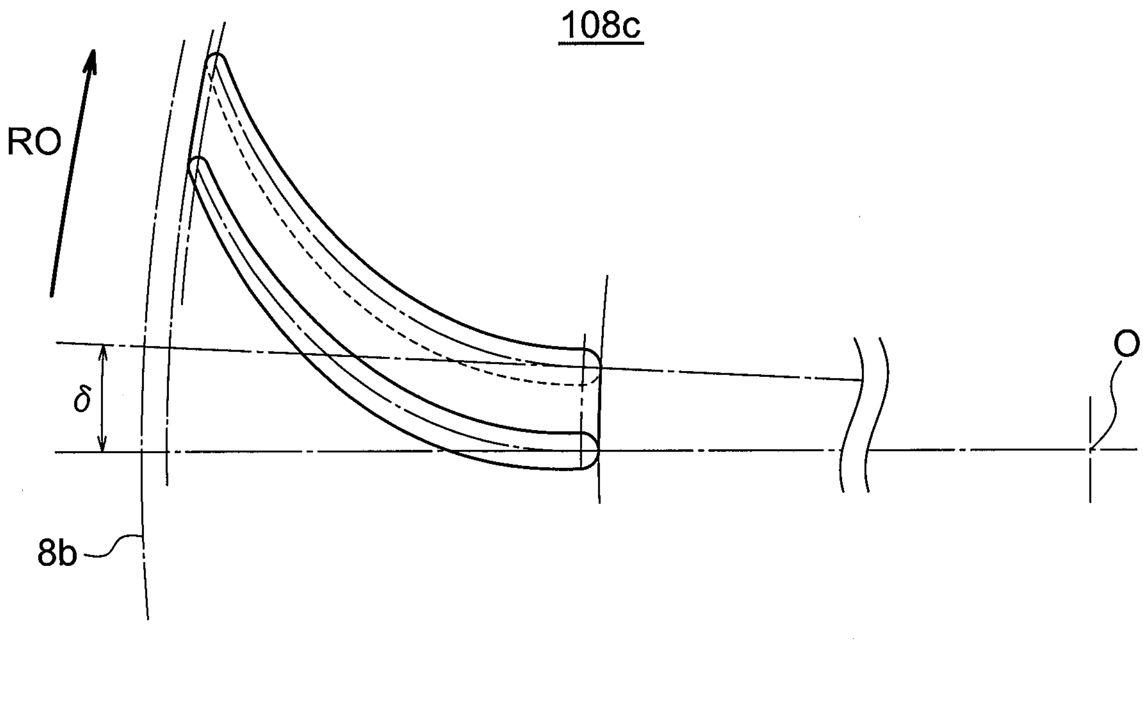


FIG. 16

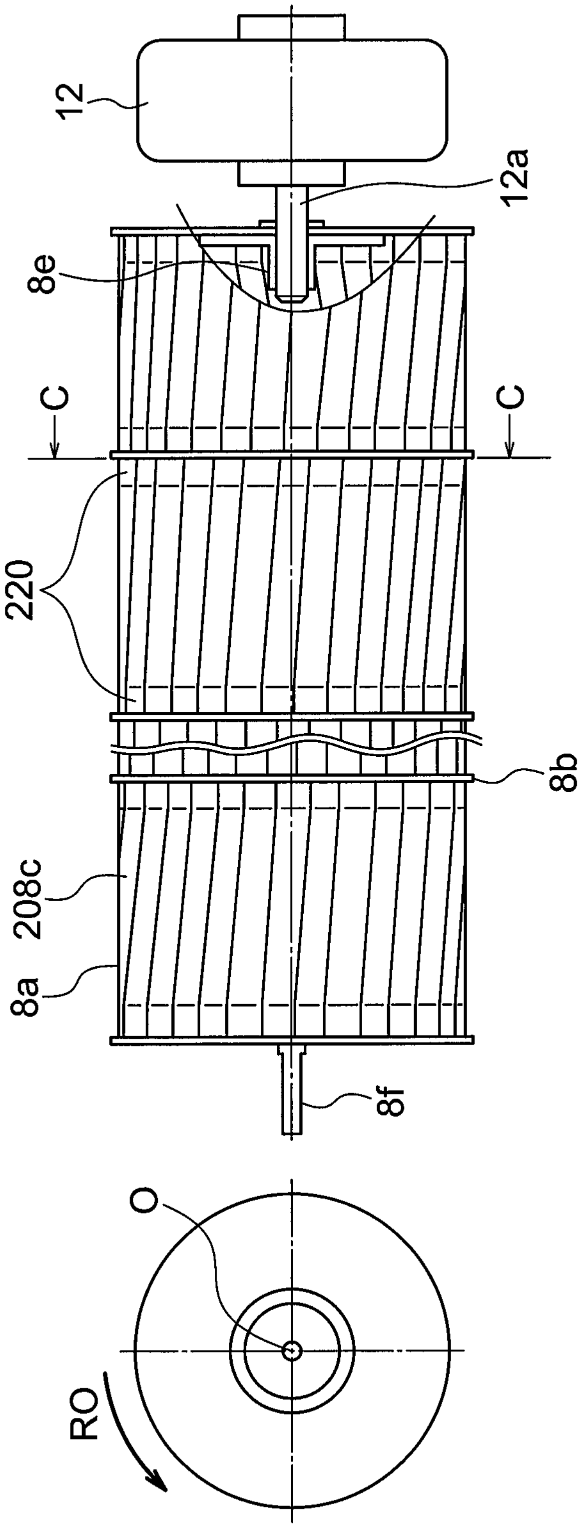


FIG. 17

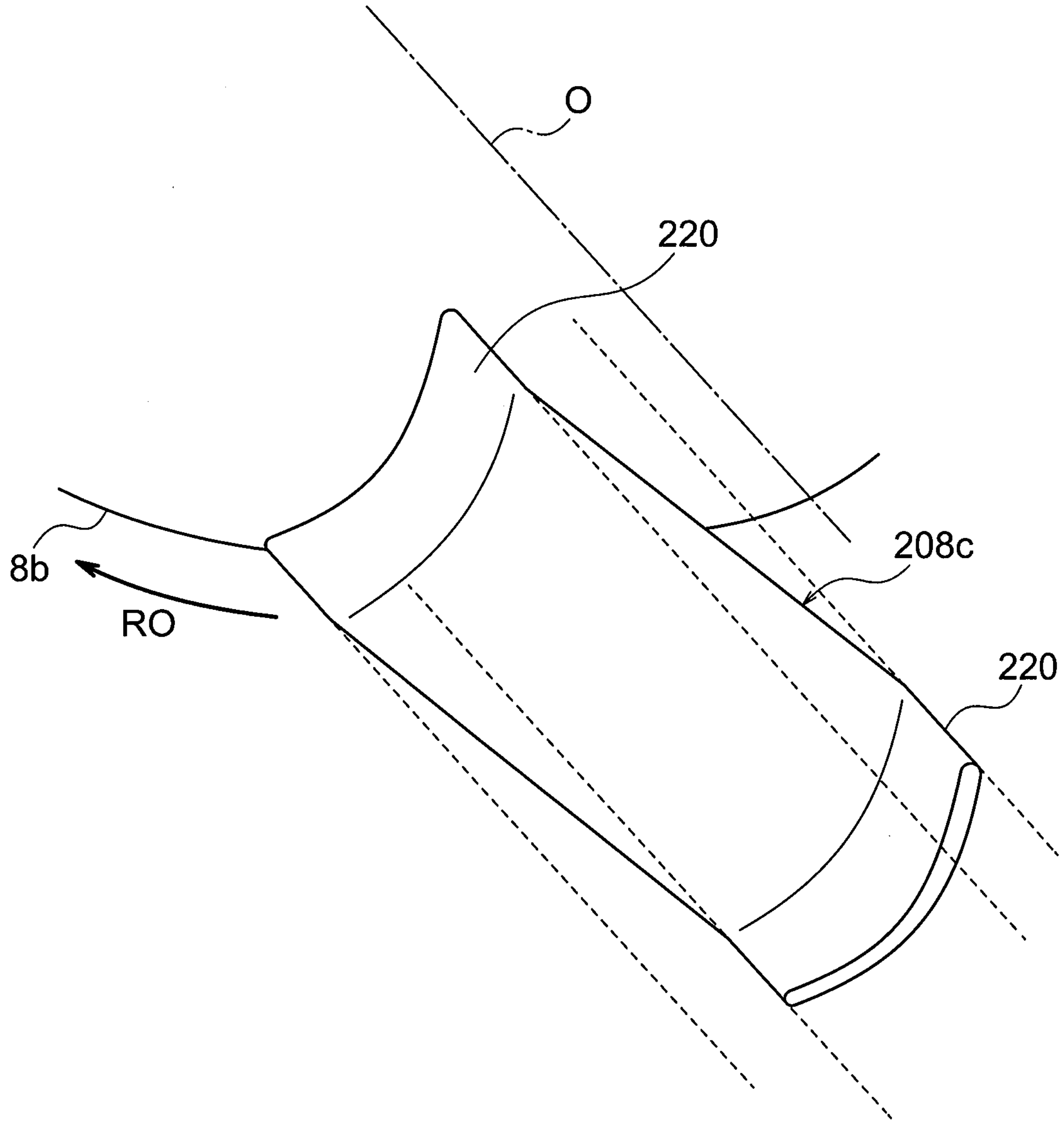
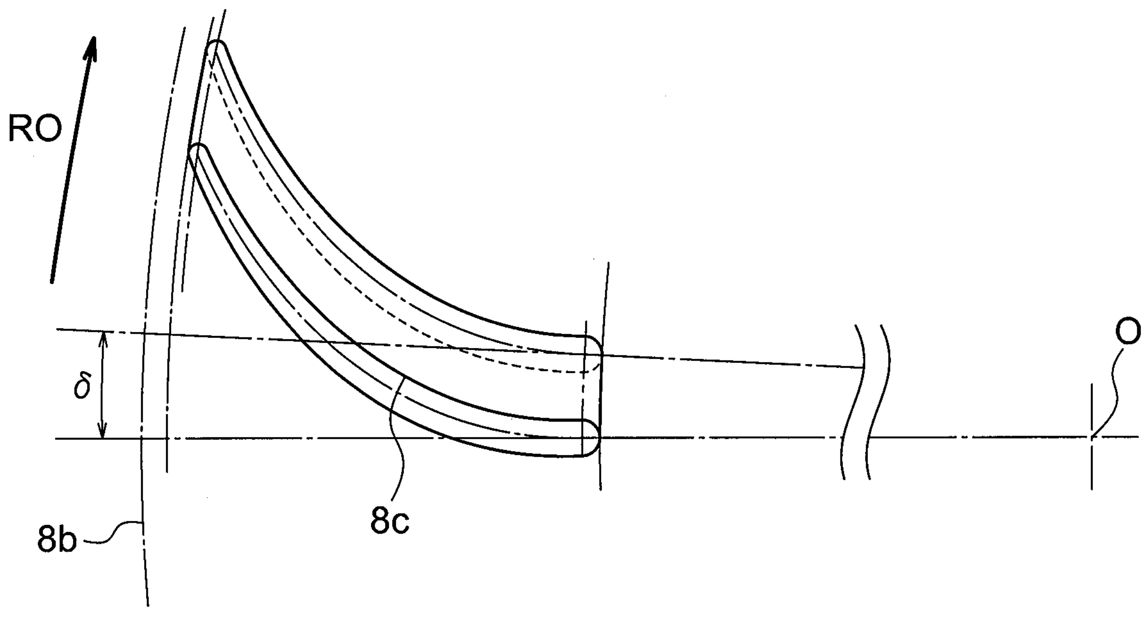


FIG. 18



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2014/078719

A. CLASSIFICATION OF SUBJECT MATTER
F04D17/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04D17/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2015
Kokai Jitsuyo Shinan Koho	1971-2015	Toroku Jitsuyo Shinan Koho	1994-2015

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 9-250493 A (Hitachi, Ltd.), 22 September 1997 (22.09.1997), paragraphs [0045] to [0049]; fig. 6 (Family: none)	1,3 2-5
Y	WO 2013/150673 A1 (Mitsubishi Electric Corp.), 10 October 2013 (10.10.2013), claims 5 to 6 (Family: none)	2-5
A	EP 2345814 A2 (LG ELECTRONICS INC.), 20 July 2011 (20.07.2011), entire text; all drawings & KR 10-2011-0083043 A & CN 102128172 A	1-5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
05 January 2015 (05.01.15)	03 February 2015 (03.02.15)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/078719

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2009/0104017 A1 (Jeong Taek PARK), 23 April 2009 (23.04.2009), entire text; all drawings & EP 2201253 A1 & WO 2009/054587 A1	1-5
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 27103/1985(Laid-open No. 144294/1986) (Toshiba Corp.), 05 September 1986 (05.09.1986), entire text; all drawings (Family: none)	1-5
A	JP 2011-122522 A (Mitsubishi Electric Corp.), 23 June 2011 (23.06.2011), entire text; all drawings (Family: none)	1-5
A	JP 2012-255628 A (Mitsubishi Electric Corp.), 27 December 2012 (27.12.2012), entire text; all drawings & WO 2012/169100 A1	1-5

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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- JP 4549416 B **[0005]**
- JP 9158890 A **[0005]**