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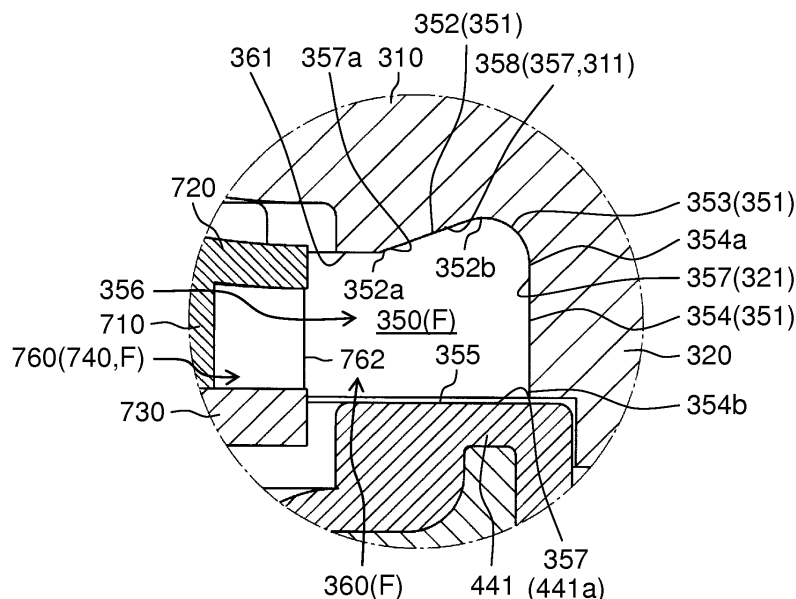
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(54) **CENTRIFUGAL PUMP WITH A VOLUTE HAVING A SLANTED WALL**

(57) A pump according to the present disclosure includes a pump body, an impeller stored in a pump chamber formed inside the pump body, and a shaft that supports the impeller such that the impeller is rotatable. A pump channel extending from a suction port to a first discharge port is formed inside the pump body. The pump channel includes a suction path, an impeller channel which is formed inside the impeller and into which liquid

in the suction path is introduced, a volute portion which is formed on a radially outer side of the impeller and into which liquid in the impeller channel is introduced, and a discharge path into which liquid in the volute portion is introduced. A liquid separation reduction structure that reduces separation of liquid flowing in the pump channel is provided in the pump channel.

FIG. 10



Description**BACKGROUND**

1. Technical Field

[0001] The present disclosure relates to a pump.

2. Description of the Related Art

[0002] For example, PTL 1 (Unexamined Japanese Patent Publication No. 2014-194190) discloses a pump which includes a rotation body provided with a rotor and an impeller formed integrally with each other, and a separation plate including a storage portion in which the rotor is stored.

[0003] According to PTL 1, a reduction unit is provided on an outer circumference of the impeller to reduce entrance of a foreign material contained in liquid into a space between the rotor and the separation plate. This reduction unit provided on the outer circumference of the impeller maintains a rotatable state of the rotor, and thus reduces a drop of pump efficiency.

[0004] The conventional structure noted above achieves reduction of a drop of pump efficiency. It is preferable, however, that a drop of pump efficiency more securely decreases.

SUMMARY

[0005] Accordingly, an object of the present disclosure is to provide a pump capable of more securely reducing a drop of pump efficiency.

[0006] For achieving the aforementioned object, a pump according to the present disclosure includes: a pump body that includes a suction path provided with a suction port through which liquid is sucked, and a discharge path provided with a first discharge port through which sucked liquid is discharged; an impeller stored in a pump chamber formed inside the pump body; and a shaft that supports the impeller such that the impeller is rotatable.

[0007] A pump channel extending from the suction port to the first discharge port is formed inside the pump body.

[0008] The pump channel includes the suction path, an impeller channel which is formed inside the impeller and into which liquid in the suction path is introduced, a volute portion which is formed on a radially outer side of the impeller and into which liquid in the impeller channel is introduced, and the discharge path into which liquid in the volute portion is introduced.

[0009] A liquid separation reduction structure that reduces separation of liquid flowing in the pump channel is provided in the pump channel.

[0010] This structure reduces separation or stay of liquid flowing in the pump channel, thereby securely reducing a drop of pump efficiency.

[0011] Provided according to the present disclosure is

a pump capable of securely reducing a drop of pump efficiency.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1A is a plan view illustrating a pump according to a first exemplary embodiment of the present disclosure;

FIG. 1B is a side view illustrating the pump according to the first exemplary embodiment of the present disclosure;

FIG. 2 is a partially exploded perspective view illustrating the pump according to the first exemplary embodiment of the present disclosure;

FIG. 3 is a cross-sectional view of FIG. 1A taken along a line 3-3;

FIG. 4 is a cross-sectional view of FIG. 1B taken along a line 4-4;

FIG. 5 is a perspective view illustrating a casing according to the first exemplary embodiment of the present disclosure;

FIG. 6 is a rear view illustrating the casing according to the first exemplary embodiment of the present disclosure;

FIG. 7 is a cross-sectional view taken along a line 7-7 in FIG. 6;

FIG. 8 is a cross-sectional view taken along a line 8-8 in FIG. 6;

FIG. 9 is a graph schematically showing a relationship between a position of a volute portion and a cross-sectional area according to the first exemplary embodiment of the present disclosure;

FIG. 10 is a cross-sectional view illustrating the enlarged volute portion according to the first exemplary embodiment of the present disclosure;

FIG. 11 is a side view of the pump according to the first exemplary embodiment of the present disclosure, illustrating a state that a discharge port faces a front;

FIG. 12 is a side view illustrating the enlarged discharge port according to the first exemplary embodiment of the present disclosure;

FIG. 13 is a rear view illustrating the casing according to the first exemplary embodiment of the present disclosure;

FIG. 14 is a cross-sectional view of FIG. 13 taken along a line 14-14;

FIG. 15 is a cross-sectional view of FIG. 13 taken along a line 15-15;

FIG. 16 is a cross-sectional view of FIG. 13 taken along a line 16-16;

FIG. 17 is a cross-sectional view of FIG. 13 taken along a line 17-17;

FIG. 18 is a cross-sectional view of FIG. 13 taken along a line 18-18;

FIG. 19 is a cross-sectional view of FIG. 13 taken

along a line 19-19;

FIG. 20 is a cross-sectional view of FIG. 13 taken along a line 20-20;

FIG. 21 is a cross-sectional view of FIG. 13 taken along a line 21-21;

FIG. 22 is a graph schematically illustrating a relationship between a position of a discharge path and a cross-sectional area according to the first exemplary embodiment of the present disclosure;

FIG. 23 is a cross-sectional view illustrating an enlarged flow direction change portion according to the first exemplary embodiment of the present disclosure;

FIG. 24 is a side view illustrating a rotation body according to the first exemplary embodiment of the present disclosure;

FIG. 25 is a cross-sectional view of FIG. 24 taken along a line 25-25;

FIG. 26 is a perspective view illustrating blades and a front surface shroud according to the first exemplary embodiment of the present disclosure;

FIG. 27 is a cross-sectional view illustrating enlarged centrifugal channels according to the first exemplary embodiment of the present disclosure;

FIG. 28 is a perspective view illustrating blades and a front surface shroud according to a modified example of the first exemplary embodiment of the present disclosure;

FIG. 29 is a plan view illustrating a pump according to a second exemplary embodiment of the present disclosure;

FIG. 30 is a cross-sectional view of FIG. 29 taken along a line 30-30;

FIG. 31 is a cross-sectional view illustrating an enlarged volute portion according to the second exemplary embodiment of the present disclosure;

FIG. 32 is a perspective view illustrating a casing according to the second exemplary embodiment of the present disclosure;

FIG. 33 is a rear view illustrating the casing according to the second exemplary embodiment of the present disclosure;

FIG. 34 is a cross-sectional view of FIG. 33 taken along a line 34-34; and

FIG. 35 is a cross-sectional view of FIG. 33 taken along a line 35-35.

DETAILED DESCRIPTION

[0013] A pump according to the present disclosure includes: a pump body that includes a suction path provided with a suction port through which liquid is sucked, and a discharge path provided with a first discharge port through which sucked liquid is discharged; an impeller stored in a pump chamber formed inside the pump body; and a shaft that supports the impeller such that the impeller is rotatable.

[0014] A pump channel extending from the suction port

to the first discharge port is formed inside the pump body.

[0015] The pump channel includes the suction path, an impeller channel which is formed inside the impeller and into which liquid in the suction path is introduced, a volute portion which is formed on a radially outer side of the impeller and into which liquid in the impeller channel is introduced, and the discharge path into which liquid in the volute portion is introduced.

[0016] A liquid separation reduction structure that reduces separation of liquid flowing in the pump channel is provided in the pump channel.

[0017] This structure reduces separation or stay of liquid flowing in the pump channel, thereby more securely reducing a drop of pump efficiency.

[0018] An opening is formed on a radially inner side of the volute portion. The opening faces a second discharge port formed on a radially outer side of the impeller channel. An inclined surface is formed in an inner surface of the volute portion. The inclined surface is inclined such that an axial length of the volute portion increases from an opening-side end edge of the volute portion toward a radially outer side of the volute portion. The liquid separation reduction structure includes the inclined surface.

[0019] According to this structure, liquid introduced into the volute portion flows along the inclined surface. In this case, the liquid is more smoothly introduced into the volute portion. Accordingly, separation or stay of liquid flowing in the volute portion decreases.

[0020] The inclined surface is configured such that a radial cross section of the volute portion constitutes a straight line.

[0021] According to this structure, the axial length of the volute portion linearly increases from an opening-side end edge of the volute portion toward a radially outer side of the volute portion. In this case, liquid in the impeller channel is more smoothly introduced into the volute portion. Accordingly, separation or stay of liquid more securely decreases.

[0022] The pump channel includes a straightening portion between the impeller channel and the volute portion. The liquid separation reduction structure includes the straightening portion.

[0023] According to this structure, liquid discharged from the impeller channel is introduced into the volute portion after straightened by the straightening portion. Accordingly, separation or stay of liquid more securely decreases.

[0024] The straightening portion is configured such that a radial cross section of the straightening portion constitutes a radially extending straight line.

[0025] According to this structure, liquid discharged from the impeller channel is straightened in the radial direction corresponding to the liquid introduction direction into the volute portion.

[0026] The discharge path is configured such that a contour shape of a channel cross section of the discharge path gradually changes into a perfect circle from an end point of the volute portion toward the first discharge port.

The liquid separation reduction structure includes the discharge path.

[0027] According to this structure, separation or stay of liquid flowing in the discharge path decreases.

[0028] A channel cross-sectional area of the discharge path linearly increases from the end point of the volute portion to the first discharge port.

[0029] According to this structure, liquid in the discharge path more smoothly flows toward the discharge port. Accordingly, separation or stay of liquid more securely decreases.

[0030] The impeller includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, a first shroud that covers axial one side of the blades, and a second shroud that covers an axial opposite side of the blades.

[0031] The impeller channel includes a centrifugal channel sectioned by two adjoining blades of the blades, the first shroud, and the second shroud, including an introduction port which is formed on a radially inner side of the centrifugal channel, and including a discharge port which is formed on a radially outer side of the centrifugal channel. The impeller channel further includes an introduction path which is formed on a radially inner side of the centrifugal channel and into which liquid is introduced from the suction path, and through which liquid introduced into the introduction path is introduced into the centrifugal channel via the introduction port.

[0032] The introduction path is formed such that the introduction path on the first shroud side corresponds to an upstream side, and that the introduction path on the second shroud side corresponds to a downstream side. The centrifugal channel is configured such that an inner surface of the centrifugal channel on the second shroud side constitutes a radially extending surface.

[0033] A direction in which liquid chiefly flows at a time of introduction into the introduction path, and a direction in which liquid chiefly flows at a time of introduction into the centrifugal channel from the introduction path cross each other.

[0034] A flow direction change portion formed inside the introduction path to change a flow of liquid includes a tapered tip, and is disposed in a state that the tip of the flow direction change portion faces the upstream side. A surface of the flow direction change portion constitutes a circular-arc line convex toward a center in a radial cross-sectional view.

[0035] The flow direction change portion is disposed inside the introduction path such that a virtual extension line of the circular-arc line makes contact with the inner surface of the centrifugal channel on the second shroud side. The liquid separation reduction structure includes the surface of the flow direction change portion.

[0036] This structure more smoothly changes a flow direction of liquid introduced into the introduction path from the suction path. In this case, liquid in the introduction path is easily introduced into the centrifugal channel. Accordingly, separation or stay of liquid flowing in the

impeller channel decreases.

[0037] The impeller includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, a first shroud that covers axial one side of the blades, and a second shroud that covers an axial opposite side of the blades.

[0038] The impeller channel includes a centrifugal channel sectioned by two adjoining blades of the blades, the first shroud, and the second shroud, including an introduction port which is formed on a radially inner side of the centrifugal channel, and including the second discharge port which is formed on a radially outer side of the centrifugal channel. The impeller channel further includes an introduction path which is formed on a radially inner side of the centrifugal channel and into which liquid is introduced from the suction path, and through which liquid introduced into the introduction path is introduced into the centrifugal channel via the introduction port.

[0039] The introduction path is formed such that the introduction path on the first shroud side corresponds to an upstream side, and that the introduction path on the second shroud side corresponds to a downstream side. A direction in which liquid chiefly flows at a time of introduction into the introduction path, and a direction in which liquid chiefly flows at a time of discharge from the second discharge port of the centrifugal channel cross each other.

[0040] An inner surface of the centrifugal channel on the first shroud side constitutes a contour line that protrudes toward the second shroud in a radial cross-sectional view.

[0041] The contour line is configured such that a direction of a tangential line at an end edge of the centrifugal channel on the introduction port side corresponds to the direction in which liquid chiefly flows at the time of introduction into the introduction path. The contour line is further configured such that a direction of a tangential line at an end edge of the centrifugal channel on the second discharge port side corresponds to the direction in which liquid chiefly flows at the time of discharge from the second discharge port of the centrifugal channel.

[0042] The liquid separation reduction structure includes the inner surface of the centrifugal channel on the first shroud side.

[0043] This structure more smoothly changes a flow direction of liquid flowing in the centrifugal channel. Accordingly, separation or stay of liquid flowing in the centrifugal channel decreases.

[0044] The impeller includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, a first shroud that covers axial one side of the blades, and a second shroud that covers an axial opposite side of the blades.

[0045] The impeller channel includes a centrifugal channel sectioned by two adjoining blades of the blades, the first shroud, and the second shroud, and including an introduction port which is formed on a radially inner side of the centrifugal channel and the second discharge

port which is formed on a radially outer side of the centrifugal channel.

[0046] A channel cross-sectional area of the centrifugal channel linearly increases from the introduction port of the centrifugal channel to the second discharge port. The liquid separation reduction structure includes the centrifugal channel.

[0047] According to this structure, liquid in the centrifugal channel more smoothly flows. Accordingly, separation or stay of liquid flowing in the centrifugal channel decreases.

[0048] The impeller is configured to extend from a radially inner side toward the radially outer side, and includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades.

[0049] Each of the blades is configured to include a tapered radially inner side tip. The liquid separation reduction structure includes the blades.

[0050] According to this structure, interference between radially inner side ends of the blades and liquid introduced into the centrifugal channel from the introduction path decreases. Accordingly, liquid is more smoothly introduced into the centrifugal channel.

[0051] Exemplary embodiments according to the present disclosure are hereinafter described with reference to the drawings. Note that the present disclosure is not limited to the exemplary embodiments described herein. It is assumed in the following description that a rotational axis direction of an impeller is defined as a front-rear direction, and that a suction side in the rotational axis direction is defined as a front side.

[0052] A plurality of the following exemplary embodiments described below includes similar constituent elements. Accordingly, similar constituent elements in the following description are given similar reference numbers, and the same explanation is not repeated.

(First Exemplary Embodiment)

[0053] As illustrated in FIGS. 1A, 1B, and 2, pump 1 according to a first exemplary embodiment includes pump body 10 constituting an outline, and rotation body 20 stored in rotation body storage chamber 510 formed inside pump body 10.

[0054] Pump body 10 is constituted by casing 30 including pump chamber 330 opened to a rear, and driving block 40 including storage portion 450 opened to a front (see FIG. 2). Accordingly, driving block 40 is located on the rear of casing 30.

[0055] Storage portion 450 (described below) of driving block 40 communicates with pump chamber 330 of casing 30. Storage portion 450 and pump chamber 330 form rotation body storage chamber 510 which stores a whole of rotation body 20.

[0056] As illustrated in FIG. 3, driving block 40 includes separation plate 410, magnetic driving unit 460, controller 470, and mold resin 480 constituting the outline.

[0057] Separation plate 410 is made of synthetic resin

such as polyphenylene sulfide (PPS) resin. Alternatively, the separation plate may be made of metal not affecting magnetic driving.

[0058] Separation plate 410 has a bottomed cylindrical container shape opened to the front, and is constituted by bottom portion 420, circumferential wall portion 430 extended from an outer circumference of bottom portion 420 toward the front, and flange 440 projected radially outward from a front edge of circumferential wall portion 430. Flange 440 in the first exemplary embodiment is provided throughout a circumference of circumferential wall portion 430 in a circumferential direction of circumferential wall portion 430.

[0059] Storage portion 450 defined by bottom portion 420 and circumferential wall portion 430 is opened to the front, and closed by bottom portion 420 on the rear side.

[0060] Accordingly, casing 30 and separation plate 410 in the first exemplary embodiment constitute housing 50 which contains rotation body storage chamber 510 for storing rotation body 20.

[0061] Cylindrical rib 421 (rear shaft fixing portion: shaft support portion) projects toward the front from a center of bottom portion 420 of storage portion 450 (inner center inside storage portion 450). Cylindrical rib 421 receives a rear end of shaft 60 which supports rotation body 20 such that rotation body 20 is rotatable. Shaft 60 may be made of ceramic, for example.

[0062] Shaft 60 is supported on separation plate 410 in a non-rotatable state. As illustrated in FIG. 2, a contour shape of the rear end of shaft 60 is a D-shape in the first exemplary embodiment. A D-shaped portion (not shown) corresponding to the rear end of shaft 60 is formed inside cylindrical rib 421. The D-shaped rear end of shaft 60 is fitted into cylindrical rib 421 to support shaft 60 on separation plate 410 in a non-rotatable state.

[0063] Magnetic driving unit 460 may be constituted by a stator which includes stator core 461 made of an electromagnetic steel sheet, coil 462 wound around stator core 461, and insulation portion 463 which insulates stator core 461 from coil 462, for example. Magnetic driving unit 460 provided on an outer circumference of circumferential wall portion 430 surrounds circumferential wall portion 430.

[0064] Controller 470 is a control board for controlling magnetic driving unit 460, and is located on the rear of separation plate 410 and magnetic driving unit 460. Controller 470 is electrically connected to coil 462 of magnetic driving unit 460. With energization of coil 462 of magnetic driving unit 460 by controller 470, a magnetic field is generated in magnetic driving unit 460 to rotate magnetic follower unit 80 (described below) of rotation body 20.

[0065] Mold resin 480 may be made of unsaturated polyester resin, for example, and is located outside separation plate 410 to accommodate separation plate 410, magnetic driving unit 460, and controller 470 as one piece body. Mold resin 480 has a function of radiating heat generated from magnetic driving unit 460 and controller 470 to the outside. Mold resin 480 also has a function of

protecting magnetic driving unit 460 and controller 470.

[0066] Rotation body 20 includes impeller 70 provided as a pump unit in a front region of rotation body 20, and magnetic follower unit 80 provided on the rear of impeller 70. Impeller 70 and magnetic follower unit 80 in the first exemplary embodiment are connected to each other via a neck portion 90 (connection portion) (see FIGS. 2 and 24). In addition, impeller 70, magnetic follower unit 80, and neck portion (connection portion) 90 in the first exemplary embodiment are combined into one piece body. In other words, impeller 70 is formed integrally with a front region of magnetic follower unit 80 (one end side in a direction of shaft 60).

[0067] Magnetic follower unit 80 of rotation body 20 is stored in storage portion 450, while impeller 70 is stored in pump chamber 330. According to the first exemplary embodiment, pump chamber 330 is constituted by impeller storage chamber 340 which has a circular shape in a plan view and accommodates impeller 70, and volute portion 350 which has a spiral shape in a plan view, resides on an outer circumference of impeller storage chamber 340, and provides an effect of increasing pressure of liquid.

[0068] Magnetic follower unit 80 is a rotor stored in storage portion 450, and rotatably supported by shaft 60.

[0069] Magnetic follower unit 80 is constituted by fixed member 810 made of synthetic resin, magnet unit 820 fixed to an outer circumferential side of fixed member 810, and bearing 830 fixed to an inner circumferential side of fixed member 810. Fixed member 810 may be made of polyphenylene ether (PPE) resin, for example. Magnet unit 820 may be constituted by a permanent magnet made of ferrite or Sm-Fe. Bearing 830 may be constituted by a resin sliding member containing carbon, or made of ceramic.

[0070] As illustrated in FIG. 3, fixed member 810 in the first exemplary embodiment is formed integrally with neck portion (connection portion) 90 and rear surface shroud (second shroud) 730.

[0071] Magnet unit 820 is constituted by magnet body 821, and magnet cover 822 made of stainless steel and covering an outer surface of magnet body 821. Magnet cover 822 may be eliminated. In this case, an outer circumferential surface of magnet body 821 is exposed to an outer circumference of magnetic follower unit (rotor) 80.

[0072] Through hole 831 is formed at a center of bearing 830. Shaft 60 is inserted into through hole 831 to support rotation body 20 such that rotation body 20 is rotatable.

[0073] In this case, magnetic follower unit (rotor) 80 is disposed in such a position that magnet unit 820 faces magnetic driving unit 460 via circumferential wall portion 430 of separation plate 410. Clearance d1 for allowing rotation of magnetic follower unit 80 is formed between magnet unit 820 and circumferential wall portion 430.

[0074] Impeller 70 functioning as a pump unit and located on the front of magnetic follower unit 80 includes

a plurality of blades 710 disposed substantially at equal intervals in a circumferential direction of impeller 70 to increase pressure of liquid by utilizing rotational centrifugal force of blades 710. Impeller 70 further includes front surface shroud (first shroud) 720 covering front sides (one side in axial direction) of respective blades 710, and rear surface shroud (second shroud) 730 covering rear sides (the other side in axial direction) of respective blades 710.

[0075] According to the first exemplary embodiment, front surface shroud 720 is constituted by a front surface shroud body 721 whose diameter decreases toward the front, and cylindrical portion 722 which includes rear end 722b connected to a front end of front surface shroud body 721 (inner circumferential side end 723), and projects toward the front.

[0076] On the other hand, rear surface shroud 730 has a substantially disk shape. Through hole 730a is formed at a central region of rear surface shroud 730. Fixed member 810 is connected via neck portion (connection portion) 90 to a circumferential edge of through hole 730a of rear surface shroud 730, i.e., to inner circumferential side end 731 of rear surface shroud 730. According to the first exemplary embodiment, front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760 described below) constitutes a radially extending flat surface.

[0077] Rear surface shroud 730 and magnetic follower unit 80 in the first exemplary embodiment are formed by insert molding. More specifically, in an inserted state of magnet unit 820 and bearing 830 into a metal mold (not shown), resin is injected into the metal mold to form rear surface shroud 730, neck portion (connection portion) 90, and fixed member 810, and combine rear surface shroud 730 and magnetic follower unit 80 into one piece body.

[0078] Each of blades 710 has a substantially plate shape, and is formed integrally with rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels 760 described below) in a state that a plate thickness crosses the axial direction. Moreover, each of blades 710 in the first exemplary embodiment has a smooth circular-arc shape convex to the front side in a rotation direction.

[0079] Respective blades 710 are provided within a range from inner circumferential side end 723 of front surface shroud body 721 to outer circumferential side end 724 of front surface shroud body 721.

[0080] On the other hand, rear ends of respective blades 710 are attached to front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760). In this case, respective blades 710 are provided within a range from inner circumferential side end 731 of rear surface shroud 730 to outer circumferential side end 732 of rear surface shroud 730.

[0081] According to the first exemplary embodiment, an inner circumferential edge of front surface shroud body 721 (inner circumferential side end 723 of front sur-

face shroud body 721) and inner circumferential edge of rear surface shroud 730 (inner circumferential side end 731 of rear surface shroud 730) are disposed at the same position in a radial direction of impeller 70.

[0082] More specifically, front surface shroud body 721 and rear surface shroud 730 are formed such that the inner circumferential edge of front surface shroud body 721 (inner circumferential side end 723 of front surface shroud body 721) and the inner circumferential edge of rear surface shroud 730 (inner circumferential side end 731 of rear surface shroud 730) are located substantially at the same position as viewed in the axial direction.

[0083] On the other hand, an outer circumferential edge of front surface shroud body 721 (outer circumferential side end 724 of front surface shroud body 721) and an outer circumferential edge of rear surface shroud 730 (outer circumferential side end 732 of rear surface shroud 730) are also disposed at the same position in the radial direction of impeller 70.

[0084] More specifically, front surface shroud body 721 and rear surface shroud 730 are formed such that the outer circumferential edge of front surface shroud body 721 (outer circumferential side end 724 of front surface shroud body 721) and the outer circumferential edge of rear surface shroud 730 (outer circumferential side end 732 of rear surface shroud 730) are located substantially at the same position as viewed in the axial direction.

[0085] A clearance is formed between inner circumferential side end 723 of front surface shroud body 721 and inner circumferential side end 731 of rear surface shroud 730. A clearance is also formed between outer circumferential side end 724 of front surface shroud body 721 and outer circumferential side end 732 of rear surface shroud 730.

[0086] According to the first exemplary embodiment, therefore, a plurality of spaces is formed in the circumferential direction between front surface shroud body 721 and rear surface shroud 730. Each of the spaces is sectioned by two adjoining blades 710, 710, front surface shroud 720, and rear surface shroud 730, and has an opened radially inner side, and an opened radially outer side.

[0087] Each of the plurality of spaces constitutes centrifugal channel 760 forming a part of impeller channel 740 provided inside impeller 70. The radially inner opening of each of centrifugal channels 760 corresponds to introduction port 761, while the radially outer opening of each of centrifugal channels 760 corresponds to discharge port 762.

[0088] Introduction path 750 constituting a part of impeller channel 740 is further provided on a radially inner side of centrifugal channels 760.

[0089] According to the first exemplary embodiment, introduction path 750 is configured to extend in the axial direction from front end 722a of cylindrical portion 722 to through hole 730a of rear surface shroud 730. Introduction ports 761 of respective centrifugal channels 760 communicate with introduction path 750.

[0090] With rotation of impeller 70 thus structured, pressure of liquid introduced into centrifugal channels 760 from introduction path 750 via introduction ports 761 is increased by centrifugal force of rotating impeller 70.

Thereafter, the liquid having high pressure is discharged from discharge ports 762 to the radially outer side.

[0091] The liquid discharged from discharge ports 762 to the outer circumferential side of impeller 70 is introduced into volute portion 350 to increase pressure of the liquid at volute portion 350.

[0092] Casing 30 may be made of synthetic resin, such as polyphenylene sulfide (PPS) resin. Casing 30 may be made of metal.

[0093] As illustrated in FIG. 2, casing 30 includes top wall 310, and circumferential wall 320 projecting rearward from a circumferential edge of top wall 310, and has a container-shape opened to the rear. Pump chamber 330 described above is sectioned by inner surface 311 of top wall 310, and inner surface 321 of circumferential wall 320.

[0094] According to the first exemplary embodiment, circumferential wall 320 of casing 30 is located outside circumferential wall portion 430 of separation plate 410, while an outer circumferential portion of pump chamber 330 expands radially outward from storage portion 450. An outer circumferential portion of impeller 70 projected radially outward from magnetic follower unit 80 is disposed at this expanded portion. In this case, impeller 70 is disposed in such a position that a rear surface of the outer circumferential portion of impeller 70 (outer circumferential side rear surface of rear surface shroud 720) faces a front surface of an inner circumferential portion of flange 440.

[0095] According to the first exemplary embodiment, storage portion 450 and pump chamber 330 of casing 30 communicate with each other in a state of contact between a rear surface of circumferential wall 320 and an outer circumferential side of front surface of flange 440.

[0096] Casing 30 is attached to driving block 40 by attachment between circumferential wall 320 and an outer circumferential portion of driving block 40 via a plurality of screws 130.

[0097] More specifically, casing 30 is fixed to driving block 40 by inserting screws 130 from the front into through holes 322 formed in circumferential wall 320, through holes 442b formed in flange 440 of separation plate 410, and screw holes 481 formed in mold resin 480 in a state that respective holes 322, 442b, and 481 communicate with each other.

[0098] In this case, seal member 100 such as packing is provided at a connection portion between casing 30 and flange 440 to secure water-tightness of rotation body storage chamber 510.

[0099] According to the first exemplary embodiment, a step is formed in flange 440. Flange 440 includes inner circumferential side flange portion 441, and outer circumferential side flange portion 442 located on the rear of inner circumferential side flange portion 441. Groove

442a receiving seal member 100 is formed on an inner circumferential side (outside the step) of outer circumferential side flange portion 442 (see FIG. 2).

[0100] In addition, press projection 323 is formed on circumferential wall 320 to press seal member 100 stored in groove 442a.

[0101] When casing 30 is fixed to driving block 40, seal member 100 stored in groove 442a is pressed by press projection 323 formed on circumferential wall 320.

[0102] This structure secures water-tightness of rotation body storage chamber 510 formed in housing 50 (in pump body 10).

[0103] Moreover, a rear surface of circumferential wall 320 also makes contact with an outer circumferential portion of inner circumferential side flange portion 441 when casing 30 is fixed to driving block 40 according to the first exemplary embodiment. In this case, an outer circumferential edge of pump chamber 330 is located inside with respect to an outer circumferential edge of inner circumferential side flange portion 441. A rear region of volute portion 350 is sectioned by front surface 441a of inner circumferential side flange portion 441.

[0104] Suction pipe 380 connected to not-shown piping or the like is provided in a central region of top wall 310 of casing 30. Suction path 381 through which liquid is introduced into pump chamber 330 is formed inside suction pipe 380. On the other hand, discharge pipe 390 connected to not-shown piping or the like is provided on circumferential wall 320 of casing 30. Discharge path 391 through which liquid in pump chamber 330 is discharged to the outside (connected piping or the like) is formed inside discharge pipe 390.

[0105] Suction pipe 380 projects toward the front from the central region of top wall 310. Suction port 381a is formed at a tip of suction pipe 380. Suction port 381a opened to the front is an opening through which liquid is sucked into suction path 381. Suction path 381 communicates, via suction port 381a formed on an upstream side, with channels such as piping connected to suction pipe 380.

[0106] According to the first exemplary embodiment, suction path 381 communicates with introduction path 750 of impeller channel 740 in a state that impeller 70 is disposed in pump chamber 330.

[0107] More specifically, rear end 380a of suction pipe 380 is projected into pump chamber 330. Flow-out port 381b opened to the rear is formed at rear end 380a thus projected. Suction path 381 is communicatively connected to introduction path 750 by insertion of flow-out port 381b of rear end 380a into introduction path 750. Flow-out port 381b of suction path 381 also constitutes an introduction port of introduction path 750.

[0108] Moreover, annular groove 312 is formed in an outer circumference of rear end 380a projected into pump chamber 330 in the first exemplary embodiment. Rotation of impeller 70 is guided in a state that front end 722a of cylindrical portion 722 is inserted into groove 312.

[0109] According to the first exemplary embodiment,

both suction path 381 and introduction path 750 are so disposed as to extend in a front-rear direction. Accordingly, liquid in suction path 381 and liquid in introduction path 750 chiefly flow from the front to the rear in the axial direction. In this case, suction path 381 and introduction path 750 are formed such that the axial front corresponds to an upstream side, and that the axial rear corresponds to a downstream side.

[0110] On the other hand, discharge pipe 390 projects outward from a side portion of circumferential wall 320. Discharge port 391b is formed at a tip of discharge pipe 390. Discharge port 391b opened outward is an opening through which liquid is discharged from discharge path 391 to the outside. Discharge path 391 communicates, via discharge path 391b formed on the downstream side, with channels such as piping connected to discharge pipe 390.

[0111] Introduction port 391a is formed on the upstream side of discharge path 391. Discharge path 391 communicates with end point 350b of volute portion 350 via introduction port 391a. Discharge port 391b is opened in a direction crossing the axial direction (direction perpendicular to the axial direction in the first exemplary embodiment).

[0112] According to the first exemplary embodiment, discharge path 391 is so formed as to extend in a tangential direction from a position close to end point 350b of volute portion 350 formed in a spiral shape. Accordingly, liquid in discharge path 391 chiefly flows in the tangential direction from the position close to end point 350b of volute portion 350.

[0113] A portion of discharge path 391 communicating with end point 350b of volute portion 350 and extending in the tangential direction from the position close to end point 350b of volute portion 350 constitutes tongue portion 324 on circumferential wall 320 of casing 30 in a vicinity of end point 350b of volute portion 350. Tongue portion 324 separates volute portion 350 from discharge path 391. Start point 350a of volute portion 350 is provided between a tip of tongue portion 324 and the outer circumference of impeller 70.

[0114] Front shaft fixing portion (shaft support portion) 370 is provided on casing 30. Front shaft fixing portion 370 is located in a central region of rotation body storage chamber 510. A front end of shaft 60 is fixed to a rear region of front shaft fixing portion 370.

[0115] As described above, shaft 60 is held on separation plate 410 in a non-rotatable state. Casing 30 and separation plate 410 are fixed to each other via screws 130. In this case, rotation of shaft 60 relative to casing 30 is regulated without a necessity of holding the front end of shaft 60 on casing 30 in a non-rotatable state. Accordingly, holding of the front end of shaft 60 on casing 30 in a non-rotatable state is not required. However, the front end of shaft 60 may be held on casing 30 in a non-rotatable state.

[0116] Front shaft fixing portion 370 according to the first exemplary embodiment is formed integrally with cas-

ing 30 via a plurality of support ribs 373 extended toward pump chamber 330 from rear end 380a located on an inner surface 311 side of top wall 310 of casing 30. Front shaft fixing portion 370 is constituted by cone-shaped projection portion 371 projecting toward the front, and cylindrical bearing portion 372 connected to a rear region of projection portion 371 and supporting the front end of shaft 60.

[0117] A component to which a reference number 110 is given in FIG. 3 is a bearing plate which receives a load from bearing 830 in a thrust direction. Bearing plate 110 reduces abrasion of casing 30 at a portion facing magnetic follower unit 80 (rear end of cylindrical bearing portion 372) caused during rotation of magnetic follower unit 80. In addition, a component to which a reference number 120 is given in FIG. 23 is a cushioning member for absorbing vibration or the like of shaft 60.

[0118] Cone-shaped projection portion 371 according to the first exemplary embodiment is positioned in introduction path 750 of impeller channel 740 in a state that impeller 70 is disposed in pump chamber 330. In this case, a tapered tip of projection portion 371 faces the upstream side so that projection portion 371 changes a flow route of liquid introduced into introduction path 750.

[0119] Accordingly, projection portion 371 has a function of changing a flow direction of liquid. According to the first exemplary embodiment, projection portion 371 corresponds to a flow direction change portion.

[0120] In the first exemplary embodiment, impeller channel 740 is configured to discharge liquid received from the axial front toward the radially outer side.

[0121] More specifically, a direction in which liquid introduced into introduction path 750 chiefly flows (axial direction), and a direction in which liquid discharged from discharge ports 762 of centrifugal channels 760 (radial direction) cross each other.

[0122] According to the first exemplary embodiment, therefore, projection portion 371 is provided as the flow direction change portion in introduction path 750 to change a flow direction of liquid flowing in the axial direction into a direction closer to the radial direction. This structure more smoothly introduces liquid from introduction portion 761 into centrifugal channels 760.

[0123] Operation of pump 1 thus structured starts in response to energization of coil 462 by controller 470. A flow of current in coil 462 generates a magnetic field in magnetic driving unit 460. In this case, magnet unit 820 of rotation body 20 is attracted to or repulsed from magnetic driving unit 460. As a result, magnetic follower unit 80 rotates around shaft 60 in a direction of arrow a in FIG. 4 (forward in rotational direction), whereby impeller 70 rotates around shaft 60 extending in the front-rear direction.

[0124] With rotation of impeller 70, liquid introduced into impeller channel 740 from suction port 381a via suction path 381 is discharged from discharge ports 762 toward the outer circumferential side of impeller 70. The liquid discharged toward the outer circumferential side

of impeller 70 is basically introduced into volute portion 350 to increase pressure of the liquid at volute portion 350. Thereafter, the liquid in a state of high pressure at volute portion 350 is introduced into discharge path 391, and discharged to the outside of pump 1 via discharge port 391b.

[0125] Accordingly, pump channel F extending from suction port 381a to discharge port 391b is formed inside pump body 10 to allow liquid introduced into pump body 10 from suction port 381a to pass through an inside of pump channel F, and flow out from discharge port 391b.

[0126] According to the first exemplary embodiment, pump channel F includes suction path 381, impeller channel 740 (introduction path 750 and centrifugal channels 760), volute portion 350, and discharge path 391 described above.

[0127] Reduction of a drop of pump efficiency is more securely achieved in the first exemplary embodiment.

[0128] More specifically, a liquid separation reduction structure which reduces separation of liquid flowing in pump channel F is provided inside pump channel F to more securely reduce a drop of pump efficiency.

[0129] A specific structure of the liquid separation reduction structure provided in pump channel F is herein after described.

[0130] The liquid separation reduction structure provided on volute portion 350 is initially explained.

[0131] As described above, volute portion 350 disposed on the outer circumferential side of impeller 70 is configured to revolve around impeller 70 in a state that impeller 70 is positioned in pump chamber 330.

[0132] Liquid discharged from discharge ports 762 formed on a radially outer side of impeller channel 740 (radially outer side of centrifugal channels 760) is configured to flow into volute portion 350. More specifically, opening 356 which faces discharge ports 762 formed on a radially outer side of impeller channel 740 is provided on a radially inner side of volute portion 350. Opening 356 according to the first exemplary embodiment is formed in a range from start point 350a of volute portion 350 to end point 350b of volute portion 350 (whole of volute portion 350).

[0133] An axially rear side of volute portion 350 is sectioned by front surface 441a of inner circumferential side flange portion 441 of separation plate 410. According to the first exemplary embodiment, front surface 441a of inner circumferential side flange portion 441 constitutes a flat surface extending in the radial direction.

[0134] Outer circumferential side (radially outer side) of volute portion 350 is sectioned by inner surface 321 of circumferential wall 320, while axially front side of volute portion 350 is sectioned by inner surface 311 of top wall 310.

[0135] According to the first exemplary embodiment, therefore, volute portion 350 is constituted by a space opened to the radially inner side.

[0136] Liquid introduced into volute portion 350 flows in the circumferential direction from start point 350a to

end point 350b to be introduced from end point 350b into discharge port 391 via introduction port 391a.

[0137] Volute portion 350 in the first exemplary embodiment is configured such that a width (radial length) of volute portion 350 gradually increases from the upstream side to the downstream side (from start point 350a to end point 350b). In other words, volute portion 350 is configured such that a channel cross-sectional area of volute portion 350 gradually increases from the upstream side to the downstream side.

[0138] This structure allows liquid flowing in volute portion 350 to flow into discharge channel 391 in a state of high pressure of the liquid by passage through volute portion 350.

[0139] According to the first exemplary embodiment, inclined surface 358 is formed in inner surface 357 of volute portion 350. Inclined surface 358 is inclined such that an axial length of volute portion 350 increases from end edge 357a on opening 356 side toward the radially outer side.

[0140] More specifically, as illustrated in FIG. 10, contour line 351 of radial cross section (cross section in radial and axial directions) of volute portion 350 includes linear portion 352 corresponding to an inclined side inclined frontward from radially inner side end 352a to radially outer side end 352b. Linear portion 352 is a radial cross-sectional line of inclined surface 358. Accordingly, inclined surface 358 in the first exemplary embodiment is configured such that the radial cross section of volute portion 350 constitutes a straight line.

[0141] According to the first exemplary embodiment, contour line 351 of the radial cross section of volute portion 350 is constituted by linear portion 352, curved line 353, vertical line portion 354, and horizontal line 355.

[0142] Vertical line portion 354 is a straight line located on a radially outer side, and extending in the axial direction from front side end 354a to rear side end 354b.

[0143] Curved line 353 is a circular-arc line smoothly connecting radially outer side end 352b of linear portion 352 and front side end 354a of vertical line portion 354. Methods for smoothly connecting radially outer side end 352b of linear portion 352 and front side end 354a of vertical line portion 354 by a circular-arc line include a method which positions linear portion 352 on a tangential line of the circular-arc line at radially outer side end 352b, and positions vertical line portion 354 on a tangential line of the circular-arc line at front side end 354a, for example.

[0144] According to the first exemplary embodiment, linear portion 352, curved line 353, and vertical line portion 354 correspond to radial cross-sectional lines of surfaces which constitute inner surfaces 311 and 321 sectioning pump chamber 330 in casing 30, and section the front side and the radially outer side of volute portion 350. On the other hand, horizontal line 355 is a radial cross-sectional line of front surface 441a of inner circumferential side flange portion 441 sectioning the axial rear side of volute portion 350.

[0145] According to the first exemplary embodiment,

therefore, a shape of volute portion 350 includes, on the axial front side, a substantially sectorial cross-sectional shape which gradually expands frontward toward a radially outer side in a radial cross-sectional view.

[0146] Inclined surface 358 according to the first exemplary embodiment has a function of the liquid separation reduction structure.

[0147] More specifically, an angle formed by inclined surface 358 and the horizontal direction (elevation angle) is set to approximately 20 degrees so as to allow liquid introduced into volute portion 350 from opening 356 to smoothly flow on inclined surface 358.

[0148] When the angle formed by inclined surface 358 and the horizontal direction (elevation angle) is excessively large, liquid introduced into volute portion 350 from opening 356 may be difficult to flow on inclined surface 358, and may separate from inclined surface 358.

[0149] Accordingly, it is preferable that the angle formed by inclined surface 358 and the horizontal direction (elevation angle) is set to 45 degrees or smaller.

[0150] As illustrated in FIGS. 6 through 8, inclined surface 358 is configured such that a radial length of inclined surface 358 increases from the upstream side to the downstream side.

[0151] In this case, as shown in FIG. 9, the radial lengths of inclined surface 358 at respective positions are preferably set such that a channel cross-sectional area of volute portion 350 increases substantially linearly from start point 350a to end point 350b. In FIG. 9, a1 and S1 correspond to volute portion 350 shown in a left part in FIG. 8, a2 and S2 correspond to volute portion 350 shown in a left part in FIG. 7, and a3 and S3 correspond to volute portion 350 shown in a right part in FIG. 8, and a4 and S4 correspond to volute portion 350 shown in a right part in FIG. 7.

[0152] According to the first exemplary embodiment, an outside radius of impeller 70 is set to approximately 40 mm, while a height (axial length) of discharge ports 762 of impeller 70 is set to approximately 3.5 mm.

[0153] On the other hand, a minimum radius of volute portion 350 (radius at start point 350a) from a center of impeller 70 (center of shaft 60) is set to approximately 45 mm, while a maximum radius of volute portion 350 (radius at end point 350b) is set to approximately 58 mm.

[0154] In addition, a minimum height (axial length) of volute portion 350 is set to approximately 5.25 mm. According to the first exemplary embodiment, volute portion 350 has a minimum height at opening 356 which is formed on a radially inner side of volute portion 350.

[0155] According to the first exemplary embodiment, therefore, the height at opening 356 of volute portion 350 is larger than the height of discharge ports 762 of impeller 70. Impeller 70 is disposed in pump chamber 330 in a state that a whole of discharge ports 762, i.e., from front ends to rear ends of discharge ports 762, faces opening 356. This structure more efficiently introduces liquid discharged from discharge ports 762 into volute portion 350.

[0156] According to the first exemplary embodiment,

curved line 353 smoothly connects radially outer side end 352b of linear portion 352 and front side end 354a of vertical line portion 354. This structure reduces separation or stay of liquid in a radially outer side front region of volute portion 350.

[0157] According to the first exemplary embodiment, straightening portion 360 is provided between impeller channel 740 and volute portion 350 (see FIG. 10).

[0158] Straightening portion 360 is formed between centrifugal channels 760 and volute portion 350 to straighten liquid before introducing the liquid discharged from discharge ports 762 of centrifugal channels 760 into volute portion 350. Straightening portion 360 also constitutes a part of pump channel F.

[0159] Straightening portion 360 in the first exemplary embodiment extends substantially horizontally from the radially inner side to the radially outer side, and communicates with volute portion 350 on the radially outer side. In other words, straightening portion 360 is configured such that a radial cross section of straightening portion 360 constitutes a radially extending straight line.

[0160] More specifically, a front region of straightening portion 360 is sectioned by horizontal surface 361 horizontally extending from a radially inner side end edge of volute portion 350 (radially inner side end 352a) toward the radial inner side. According to the first exemplary embodiment, horizontal surface 361 is formed in inner surface 311 of top wall 310, and connected to inclined surface 358.

[0161] On the other hand, a rear region of straightening portion 360 is sectioned by horizontally extending front surface 441a of inner circumferential side flange portion 441. Accordingly, a rear side of straightening portion 360 is also configured to connect to inner surface 357 of volute portion 350.

[0162] Accordingly, straightening portion 360 in the first exemplary embodiment is configured to extend radially outward from discharge ports 762 along a discharge direction of liquid (radial direction). Moreover, straightening portion 360 has a substantially constant height (axial length), and is configured to connect to volute portion 350.

[0163] Straightening portion 360 has a function of the liquid separation reduction structure. According to the first exemplary embodiment, a length (radial length) of straightening portion 360 is set to approximately 1.5 mm.

[0164] The liquid separation reduction structure provided in discharge path 391 is now described.

[0165] According to the first exemplary embodiment, discharge path 391 is configured such that a contour shape of a channel cross section of discharge path 391 gradually changes into a perfect circle from end point 350b to discharge port 391b of volute portion 350.

[0166] More specifically, introduction port 391a of discharge path 391 communicates with end point 350b of volute portion 350, wherefore the contour shape of the channel cross section of introduction port 391a has a substantially trapezoidal shape. On the other hand, it is

preferable that discharge port 391b of discharge path 391, which port is connected to piping or the like, has a circular shape corresponding to a contour shape of a typical channel inside piping.

[0167] In this case, resistance produced in liquid flowing in discharge path 391 increases when the contour shape of the channel cross section rapidly changes in a course of discharge path 391.

[0168] According to the first exemplary embodiment, therefore, the contour shape of the channel cross section of discharge path 391 gradually changes into a perfect circle from end point 350b to discharge port 391b of volute portion 350 to allow smooth flow of liquid in discharge path 391 as illustrated in FIGS. 14 through 21.

[0169] This structure allows discharge path 391 to perform the function of the liquid separation reduction structure.

[0170] Moreover, according to the first exemplary embodiment, a channel cross-sectional area of discharge path 391 is configured to linearly increase from end point 350b of volute portion 350 to discharge port 391b as illustrated in FIG. 22. In this case, E through L in FIG. 22 correspond to respective cross-sectional lines shown in FIG. 13 (respective cross-sectional lines of equal divisions of discharge path 391), while SE through SL correspond to channel cross-sectional areas of discharge path 391 taken along the respective cross-sectional lines.

[0171] The foregoing shape of discharge path 391 is produced by a method which determines one or a plurality of reference lines extending from introduction port 391a to discharge port 391b, and defines a contour shape which becomes closer to a perfect circle while passing through the reference lines at respective positions from introduction port 391a to discharge port 391b, and increasing a cross-sectional area.

[0172] According to the first exemplary embodiment, a channel cross-sectional area at end point 350b of volute portion 350 is set to approximately 50 mm², a diameter of discharge port 391b is set to approximately 14.5 mm, and a channel cross-sectional area of discharge port 391b is set to approximately 165 mm².

[0173] A length of a line segment from end point 350b to discharge port 391b of volute portion 350 is set to approximately 50 mm.

[0174] The liquid separation reduction structure provided on cone-shaped projection portion 371 corresponding to the flow direction change portion is now described.

[0175] As described above, the direction in which liquid chiefly flows at the time of introduction into introduction path 750 (axial direction), and the direction in which liquid chiefly flows at the time of introduction from introduction path 750 into centrifugal channels 760 (direction more inclined to radial direction than to axial direction, i.e., substantially radial direction) cross each other in impeller channel 740.

[0176] Accordingly, projection portion 371 as a flow direction change portion is provided in introduction path

750 to change a flow direction of liquid flowing in the axial direction to a direction closer to the radial direction by utilizing projection portion 371.

[0177] According to the first exemplary embodiment, surface 371a of projection portion 371 (flow direction change portion) is formed in a concave shape concave toward the radially inner side. In other words, surface 371a of projection portion (flow direction change portion) 371 constitutes circular-arc line 371b convex toward the center in a radial cross-sectional view.

[0178] Moreover, projection portion (flow direction change portion) 371 in the first exemplary embodiment is disposed in introduction path 750 such that virtual extension line (virtual circular-arc line) C1 of circular-arc line 371b makes contact with front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760).

[0179] More specifically, front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760) constitutes a radially extending flat surface. Point of contact T1 is formed between an inner circumferential side end edge (inner circumferential side end 731 of rear surface shroud 730) and outer circumferential side end edge (outer circumferential side end 732 of rear surface shroud 730) of the flat surface.

[0180] Projection portion 371 (flow direction change portion) is provided to perform the function of more smoothly introducing liquid from introduction port 761 into centrifugal channels 760. Accordingly, it is preferable that point of contact T1 is formed at a position close to inner circumferential side end 731. Moreover, as illustrated in FIG. 23, it is preferable that projection portion 371 (flow direction change portion) is disposed such that the outer circumferential side end edge of surface 371a is located on an axially front side of front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760).

[0181] This structure allows surface 371a of projection portion 371 (flow direction change portion) to perform the function of the liquid separation reduction structure.

[0182] According to the first exemplary embodiment, a height of a tip of projection portion 371 (flow direction change portion) from a reference point of front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760) is set to approximately 8.5 mm. A maximum outer circumferential diameter of projection portion 371 (flow direction change portion) is set to approximately 14.8 mm. Radius of curvature of circular-arc line 371b is set to approximately 7.4 mm.

[0183] The liquid separation reduction structure provided on centrifugal channels 760 is now described.

[0184] As noted above, the direction in which liquid chiefly flows at the time of introduction into introduction path 750 (axial direction), and the direction in which liquid chiefly flows at the time of discharge from discharge ports 762 of centrifugal channels 760 (radial direction) cross each other in impeller channel 740.

[0185] In this case, liquid introduced into impeller chan-

nel 740 flows while changing the flow direction from the axial direction to the radial direction.

[0186] According to the first exemplary embodiment, therefore, rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels 760) is configured to constitute contour line 726 convex toward rear surface surround 730 (second shroud) in a radial cross-sectional view.

[0187] More specifically, contour line 726 has a shape smoothly connecting upstream side first circular-arc line 727 and downstream side second circular-arc line 728 as illustrated in FIG. 27.

[0188] In addition, contour line 726 is defined such that a tangential line of contour line 726 at start end 727a of first circular-arc line 727 (end edges of centrifugal channels 760 on introduction port 761 side) extends in the axial direction (direction in which liquid chiefly flows at the time of introduction into introduction path 750).

[0189] Moreover, contour line 726 is defined such that a tangential line of contour line 726 at final end 728b of second circular-arc line 728 (end edges of centrifugal channels 760 on discharge port 762 side) extends in the radial direction (direction in which liquid chiefly flows at the time of discharge from discharge ports 762 of centrifugal channels 760).

[0190] First circular-arc line 727 and second circular-arc line 728 have a common tangential line at final end 727b of first circular-arc line 727 and at start end 728a of second circular-arc line 728, respectively, to smoothly connect to each other.

[0191] This structure more smoothly changes the flow direction of liquid introduced into impeller channel 740 from the axial direction to the radial direction.

[0192] This structure therefore allows rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels 760) to perform the function of the liquid separation reduction structure.

[0193] According to the first exemplary embodiment, an inside opening diameter of front surface shroud body 721 is set to approximately 19 mm, while outside opening diameter of front surface shroud body 721 is set to approximately 40 mm. In addition, a radius of curvature of first circular-arc line 727 is set to 2.0 mm, while a radius of curvature of second circular arc line 728 is set to 25 mm.

[0194] Contour line 726 of rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels 760) is not limited to a shape smoothly connecting the two circular-arc lines. For example, this contour shape may be a shape illustrated in FIG. 28. The contour line of rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels 760) in FIG. 28 is constituted by one circular-arc line. A radius of curvature of this circular-arc line is set to 25 mm, for example.

[0195] In addition, a linear portion may be formed at an intermediate position of contour line 726. In this case, it is preferable that an area surrounded by contour line

726, and lines connecting both ends of contour line 726 becomes a convex set.

[0196] According to the first exemplary embodiment, the channel cross-sectional area of centrifugal channels 760 linearly increases from introduction port 761 to discharge ports 762 of centrifugal channels 760.

[0197] This structure allows centrifugal channels 760 to perform the function of the liquid separation reduction structure.

[0198] According to the first exemplary embodiment, an inside diameter height of respective blades 710 (axial length of radially inner side end 711) is set to approximately 5.8 mm, while an outside diameter height of respective blades 710 (axial length of radially outer side end 712) is set to approximately 3.5 mm. Each of blades 710 has a thickness of approximately 1.2 mm. Each of blades 710 is disposed such that an inside diameter blade angle (angle formed by blade 710 and tangential line of inner circumferential side end 731 of rear surface shroud 730 at tip 711a of radially inner side end 711) becomes approximately 35 degrees. Each of blades 710 is disposed such that an outside diameter blade angle (angle formed by blade 710 and tangential line of outer circumferential side end 731 of rear surface shroud 730 at tip 712a of radially outer side end 712) becomes approximately 35 degrees.

[0199] The liquid separation reduction structure provided on blades 710 is now described.

[0200] According to the first exemplary embodiment, each of blades 710 has tapered tip 711a of radially inner side end 711.

[0201] Sharpened tip 711a of radially inner side end 711 thus formed more smoothly branches liquid flowing toward tip 711a of radially inner side end 711 into opposite sides of blades 710.

[0202] This structure allows respective blades 710 to perform the function of the liquid separation reduction structure.

[0203] According to the first exemplary embodiment, a radius of curvature of tip 711a of radially inner side end 711 of each of blades 710 is set to 0.1 mm or smaller.

[0204] According to the first exemplary embodiment, tip 712a of radially outer side end 712 of each of blades 710 also has a tapered shape.

[0205] As described above, pump 1 according to the first exemplary embodiment includes pump body 10 that includes suction path 381 provided with suction port 381a through which liquid is sucked, and discharge path 391 provided with discharge port 391b through which sucked liquid is discharged. Pump 1 further includes impeller 70 stored in pump chamber 330 formed inside pump body 10, and shaft 60 that supports impeller 70 such that impeller 70 is rotatable.

[0206] Pump channel F extending from suction port 381a to discharge port 391b is formed inside pump body 10.

[0207] Pump channel F includes suction path 381, impeller channel 740 which is formed inside impeller 70 and

into which liquid in suction path 381 is introduced, volute portion 350 which is formed on a radially outer side of impeller 70 and into which liquid in impeller channel 740 is introduced, and discharge path 391 into which liquid in volute portion 350 is introduced.

[0208] A liquid separation reduction structure that reduces separation of liquid flowing in pump channel F is provided in pump channel F.

[0209] This structure reduces separation or stay of liquid flowing in pump channel F, thereby more securely reducing a drop of pump efficiency.

[0210] Opening 356 is formed on a radially inner side of volute portion 350. Opening 356 faces discharge port 762 formed on a radially outer side of impeller channel 740. Inclined surface 358 is formed in inner surface 357 of volute portion 350. Inclined surface 358 is inclined such that an axial length of volute portion 350 increases from end edge 357a on opening 356 side toward a radially outer side. The liquid separation reduction structure includes inclined surface 358.

[0211] According to this structure, liquid introduced into volute portion 350 flows along inclined surface 358. In this case, the liquid more smoothly flows into volute portion 350. Accordingly, separation or stay of liquid flowing in volute portion 350 decreases.

[0212] Inclined surface 358 is configured such that a radial cross section of volute portion 350 constitutes a straight line.

[0213] According to this structure, the axial length of volute portion 350 linearly increases from end edge 357a on opening 356 side toward the radially outer side. In this case, liquid in impeller channel 740 is more smoothly introduced into volute portion 350. Accordingly, separation or stay of liquid more securely decreases.

[0214] Pump channel F includes straightening portion 360 between impeller channel 740 and volute portion 350. The liquid separation reduction structure includes straightening portion 360.

[0215] According to this structure, liquid discharged from impeller channel 740 is introduced into volute portion 350 after straightened by straightening portion 360. Accordingly, separation or stay of liquid more securely decreases.

[0216] Straightening portion 360 is configured such that a radial cross section of the straightening portion 360 constitutes a radially extending straight line.

[0217] According to this structure, liquid discharged from impeller channel 360 is straightened in the radial direction corresponding to the liquid introduction direction into volute portion 350.

[0218] Discharge path 391 is configured such that a contour shape of a channel cross section of discharge path 391 gradually changes into a perfect circle from end point 350b of volute portion 350 toward discharge port 391b. The liquid separation reduction structure includes discharge path 391.

[0219] According to this structure, separation or stay of liquid flowing in discharge path 391 decreases.

[0220] A channel cross-sectional area of discharge path 391 linearly increases from end point 350b of volute portion 350 to discharge port 391b.

[0221] According to this structure, liquid in discharge path 391 more smoothly flows toward discharge port 391b. Accordingly, separation or stay of liquid more securely decreases.

[0222] Impeller 70 includes the plurality of blades 710 that increases pressure of liquid by rotational centrifugal force of blades 710, front surface shroud (first shroud) 720 that covers a front (axial one side) of blades 710, and rear surface shroud (second shroud) 730 that covers a rear (axial opposite side) of blades 710.

[0223] Impeller channel 740 includes centrifugal channels 760 each of which is sectioned by two adjoining blades 710, 710, front surface shroud (first shroud) 720, and rear surface shroud (second shroud) 730, includes introduction port 761 which is formed on a radially inner side of the centrifugal channels 760, and includes discharge port 762 which is formed on a radially outer side of the centrifugal channels 760. Impeller channel 740 further includes introduction path 750 which is formed on a radially inner side of centrifugal channels 760 and into which liquid is introduced from suction path 381, and through which liquid introduced into introduction path 750 is introduced into centrifugal channels 760 via introduction port 761.

[0224] Introduction path 750 is formed such that introduction path 750 on the front side (front surface shroud 720 side) corresponds to an upstream side, and that introduction path 750 on the rear side (rear surface shroud 730 side) corresponds to a downstream side. Each of centrifugal channels 760 is configured such that front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760) constitutes a radially extending surface.

[0225] A direction in which liquid chiefly flows at the time of introduction into introduction path 750 (axial direction), and a direction in which liquid chiefly flows at the time of introduction into centrifugal channels 760 from introduction path 750 (direction more inclined to the radial direction than to the axial direction, or substantially radial direction) cross each other.

[0226] Projection portion (flow direction change portion) 371 formed inside introduction path 750 to change a flow of liquid includes a tapered tip, and is disposed in a state that the tip of the flow direction change portion faces the upstream side. Surface 371a of projection portion (flow direction change portion) 371 constitutes circular-arc line 371b convex toward a center in a radial cross-sectional view.

[0227] Projection portion (flow direction change portion) 371 is disposed inside introduction path 750 such that virtual extension line C1 of circular-arc line 371b contacts front surface 733 of rear surface shroud 730 (second shroud side inner surfaces of centrifugal channels 760). The liquid separation reduction structure includes surface 371a of projection portion (flow direction change

portion) 371.

[0228] This structure more smoothly changes a flow direction of liquid introduced into introduction path 750 from suction path 381. In this case, liquid in introduction path 750 easily flows into centrifugal channels 760. Accordingly, separation or stay of liquid flowing in impeller channel 740 decreases.

[0229] Impeller 70 includes the plurality of blades 710 that increases pressure of liquid by rotational centrifugal force of blades 710, front surface shroud (first shroud) 720 that covers a front (axial one side) of blades 710, and rear surface shroud (second shroud) 730 that covers a rear (axial opposite side) of blades 710.

[0230] Impeller channel 740 includes centrifugal channels 760 each of which is sectioned by two adjoining blades 710, 710, front surface shroud (first shroud) 720, and rear surface shroud (second shroud) 730, includes introduction port 761 which is formed on a radially inner side of the centrifugal channels 760, and includes discharge port 762 which is formed on a radially outer side of the centrifugal channels 760. Impeller channel 740 further includes introduction path 750 which is formed on a radially inner side of centrifugal channels 760 and into which liquid is introduced from suction path 381, and through which liquid introduced into introduction path 750 is introduced into centrifugal channels 760 via introduction port 761.

[0231] Introduction path 750 is formed such that introduction path 750 on the front side (front surface shroud 720 side) corresponds to an upstream side, and that introduction path 750 on the rear side (rear surface shroud 730 side) corresponds to a downstream side. A direction in which liquid chiefly flows at the time of introduction into introduction path 750 (axial direction), and a direction in which liquid chiefly flows at the time of discharge from discharge port 762 of centrifugal channels 760 cross each other.

[0232] Rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels 760) constitutes contour line 726 that protrudes toward rear surface shroud (second shroud) 730 in a radial cross-sectional view.

[0233] Contour line 726 is configured such that a direction of a tangential line at start end 727a of first circular-arc line 727 (introduction port 761 side end edges of centrifugal channels 760) corresponds to the axial direction (direction in which liquid chiefly flows at the time of introduction into introduction path 750).

[0234] Contour line 726 is further configured such that a direction of a tangential line at final end 728b of second circular-arc line 728 (discharge port 762 side end edges of centrifugal channels 760) corresponds to the radial direction (direction in which liquid chiefly flows at the time of discharge from discharge port 762 of centrifugal channels 760).

[0235] The liquid separation reduction structure includes rear surface 725 of front surface shroud body 721 (first shroud side inner surfaces of centrifugal channels

760).

[0236] This structure more smoothly changes a flow direction of liquid flowing in centrifugal channels 760. Accordingly, separation or stay of liquid flowing in centrifugal channels 760 decreases.

[0237] Impeller 70 includes the plurality of blades 710 that increases pressure of liquid by rotational centrifugal force of blades 710, front surface shroud (first shroud) 720 that covers a front (axial one side) of blades 710, and rear surface shroud (second shroud) 730 that covers a rear (axial opposite side) of blades 710.

[0238] Impeller channel 740 includes centrifugal channels 760 each of which is sectioned by two adjoining blades 710, 710, front surface shroud (first shroud) 720, and rear surface shroud (second shroud) 730, and includes introduction port 761 which is formed on a radially inner side of the centrifugal channels 760 and discharge port 762 which is formed on a radially outer side of the centrifugal channels 760.

[0239] A channel cross-sectional area of each of centrifugal channels 760 linearly increases from introduction port 761 of centrifugal channel 760 to discharge port 762. The liquid separation reduction structure includes centrifugal channels 760.

[0240] According to this structure, liquid in centrifugal channels 760 more smoothly flows. Accordingly, separation or stay of liquid flowing in centrifugal channels 760 decreases.

[0241] Impeller 70 is configured to extend from a radially inner side toward a radially outer side, and includes the plurality of blades 710 that increases pressure of liquid by rotational centrifugal force of blades 710.

[0242] Each of blades 710 is configured to include tip 711a of tapered radially inner side end 711 (radially inner side tip). The liquid separation reduction structure includes blades 710.

[0243] According to this structure, interference between tip 711a of radially inner side ends 711 (radially inner side tip) of blades 710 and liquid introduced into centrifugal channels 760 from introduction path 750 decreases. Accordingly, liquid is more smoothly introduced into centrifugal channels 760.

(Second Exemplary Embodiment)

[0244] As illustrated in FIGS. 29 through 35, pump 1A according to a second exemplary embodiment basically has a configuration similar to the configuration of pump 1 presented in the first exemplary embodiment described above.

[0245] More specifically, pump 1A includes pump body 10 that includes suction path 381 provided with suction port 381a through which liquid is sucked, and discharge path 391 provided with discharge port 391b through which sucked liquid is discharged. Pump 1A further includes impeller 70 stored in pump chamber 330 formed inside pump body 10, and shaft 60 that supports impeller 70 such that impeller 70 is rotatable.

[0246] Pump channel F extending from suction port 381a to discharge port 391b is formed inside pump body 10.

[0247] Pump channel F includes suction path 381, impeller channel 740 which is formed inside impeller 70 and into which liquid in suction path 381 is introduced, volute portion 350 which is formed on a radially outer side of impeller 70 and into which liquid in impeller channel 740 is introduced, and discharge path 391 into which liquid in volute portion 350 is introduced.

[0248] A liquid separation reduction structure that reduces separation of liquid flowing in pump channel F is provided in pump channel F.

[0249] Pump 1A according to the second exemplary embodiment is chiefly different from pump 1 according to the first exemplary embodiment described above in that straightening portion 360 is not provided between impeller channel 740 and volute portion 350.

[0250] In this case, liquid discharged from discharge port 762 to the outer circumferential side of impeller 70 is directly introduced into volute portion 350, whereat pressure of the liquid is increased.

[0251] Pump 1A includes the liquid separation reduction structures provided in the first exemplary embodiment other than the straightening portion.

[0252] According to pump 1A thus structured, operations and effects similar to those of first exemplary embodiment are similarly offered.

[0253] While preferred exemplary embodiments of the present disclosure have been described herein, various modifications may be made to the foregoing exemplary embodiments.

[0254] For example, all of the plurality of liquid separation reduction structures provided in the respective exemplary embodiments are not necessarily required. Similar operations and effects are offered as long as at least one of these liquid separation reduction structures is equipped. In other words, the pump may include only a part of the plurality of liquid separation reduction structures.

[0255] Moreover, detailed specifications (such as shape, size, and layout) of the casing, the driving block, and others may be arbitrarily changed.

[0256] As described above, the pump according to the present disclosure is capable of reducing separation, stay and the like of liquid, and increasing pump efficiency. Accordingly, the pump of the present disclosure is applicable to a pump for a hot water heater, a heat pump, and other purposes.

Claims

1. A pump comprising:

a pump body that includes a suction path provided with a suction port through which liquid is sucked, and a discharge path provided with a

first discharge port through which sucked liquid is discharged;
 an impeller stored in a pump chamber formed inside the pump body; and
 a shaft that supports the impeller such that the impeller is rotatable,

wherein

a pump channel extending from the suction port to the first discharge port is formed inside the pump body, the pump channel includes the suction path, an impeller channel which is formed inside the impeller and into which liquid in the suction path is introduced, a volute portion which is formed on a radially outer side of the impeller and into which liquid in the impeller channel is introduced, and the discharge path into which liquid in the volute portion is introduced, and

a liquid separation reduction structure that reduces separation of liquid flowing in the pump channel is provided in the pump channel.

2. The pump according to claim 1, wherein
 an opening is formed on a radially inner side of the volute portion, the opening facing a second discharge port formed on a radially outer side of the impeller channel,
 an inclined surface is formed in an inner surface of the volute portion, the inclined surface being inclined such that an axial length of the volute portion increases from an opening-side end edge of the volute portion toward a radially outer side of the volute portion, and
 the liquid separation reduction structure includes the inclined surface.
3. The pump according to claim 2, wherein the inclined surface is configured such that a radial cross section of the volute portion constitutes a straight line.
4. The pump according to any one of claims 1 to 3, wherein
 the pump channel includes a straightening portion formed between the impeller channel and the volute portion, and
 the liquid separation reduction structure includes the straightening portion.
5. The pump according to claim 4, wherein the straightening portion is configured such that a radial cross section of the straightening portion constitutes a radially extending straight line.
6. The pump according to any one of claims 1 to 5, wherein
 the discharge path is configured such that a contour shape of a channel cross section of the discharge

path gradually changes into a perfect circle from an end point of the volute portion toward the first discharge port, and
 the liquid separation reduction structure includes the discharge path.

7. The pump according to claim 6, wherein a channel cross-sectional area of the discharge path linearly increases from the end point of the volute portion to the first discharge port.
8. The pump according to any one of claims 1 to 7, wherein
 the impeller includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, a first shroud that covers axial one side of the blades, and a second shroud that covers an axial opposite side of the blades,
 the impeller channel includes a centrifugal channel sectioned by two adjoining blades of the blades, the first shroud, and the second shroud, including an introduction port which is formed on a radially inner side of the centrifugal channel, and including the second discharge port which is formed on a radially outer side of the centrifugal channel, and includes an introduction path which is formed on a radially inner side of the centrifugal channel and into which liquid is introduced from the suction path, and through which introduced liquid is introduced into the centrifugal channel via the introduction port,
 the introduction path is formed such that the introduction path on the first shroud side corresponds to an upstream side, and that the introduction path on the second shroud side corresponds to a downstream side,
 the centrifugal channel is configured such that an inner surface of the centrifugal channel on the second shroud side constitutes a radially extending surface,
 a direction in which liquid chiefly flows at a time of introduction into the introduction path, and a direction in which liquid chiefly flows at a time of introduction into the centrifugal channel from the introduction path cross each other,
 a flow direction change portion formed inside the introduction path to change a flow of liquid includes a tapered tip, and is disposed in a state that the tip of the flow direction change portion faces the upstream side,
 a surface of the flow direction change portion constitutes a circular-arc line convex toward a center in a radial cross-sectional view,
 the flow direction change portion is disposed inside the introduction path such that a virtual extension line of the circular-arc line makes contact with the inner surface of the centrifugal channel on the second shroud side, and
 the liquid separation reduction structure includes the

surface of the flow direction change portion.

9. The pump according to any one of claims 1 to 7, wherein
 the impeller includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, a first shroud that covers axial one side of the blades, and a second shroud that covers an axial opposite side of the blades, the impeller channel includes a centrifugal channel sectioned by two adjoining blades of the blades, the first shroud, and the second shroud, including an introduction port which is formed on a radially inner side of the centrifugal channel, and including the second discharge port which is formed on a radially outer side of the centrifugal channel, and includes an introduction path which is formed on a radially inner side of the centrifugal channel and into which liquid is introduced from the suction path, and through which introduced liquid is introduced into the centrifugal channel via the introduction port, the introduction path is formed such that the introduction path on the first shroud side corresponds to an upstream side, and that the introduction path on the second shroud side corresponds to a downstream side, a direction in which liquid chiefly flows at a time of introduction into the introduction path, and a direction in which liquid chiefly flows at a time of discharge from the second discharge port of the centrifugal channel cross each other, an inner surface of the centrifugal channel on the first shroud side constitutes a contour line that protrudes toward the second shroud in a radial cross-sectional view, the contour line is configured such that a direction of a tangential line at an end edge of the centrifugal channel on the introduction port side corresponds to the direction in which liquid chiefly flows at the time of introduction into the introduction path, and that a direction of a tangential line at an end edge of the centrifugal channel on the second discharge port side corresponds to the direction in which liquid chiefly flows at the time of discharge from the second discharge port of the centrifugal channel, and the liquid separation reduction structure includes the inner surface of the centrifugal channel on the first shroud side.
10. The pump according to any one of claims 1 to 7, wherein
 the impeller includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, a first shroud that covers axial one side of the blades, and a second shroud that covers an axial opposite side of the blades, the impeller channel includes a centrifugal channel sectioned by two adjoining blades of the blades, the

first shroud, and the second shroud, and including an introduction port which is formed on a radially inner side of the centrifugal channel and the second discharge port which is formed on a radially outer side of the centrifugal channel, a channel cross-sectional area of the centrifugal channel linearly increases from the introduction port of the centrifugal channel to the second discharge port, and the liquid separation reduction structure includes the centrifugal channel.

11. The pump according to any one of claims 1 to 10, wherein
 the impeller is configured to extend from a radially inner side toward a radially outer side, and includes a plurality of blades that increases pressure of liquid by rotational centrifugal force of the blades, each of the blades is configured to include a tapered radially inner side tip, and the liquid separation reduction structure includes the blades.

FIG. 1A

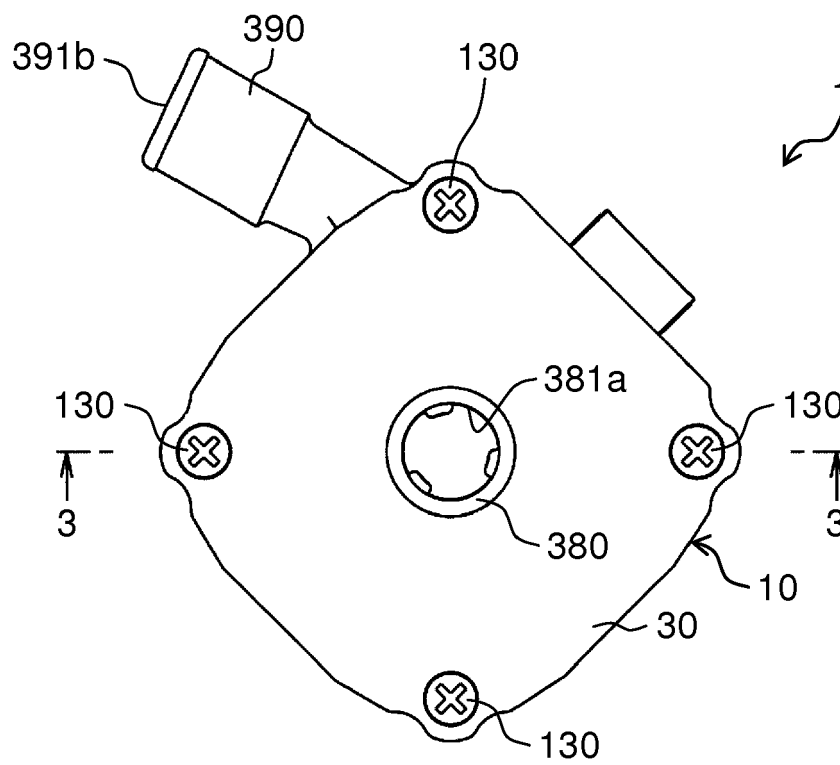


FIG. 1B

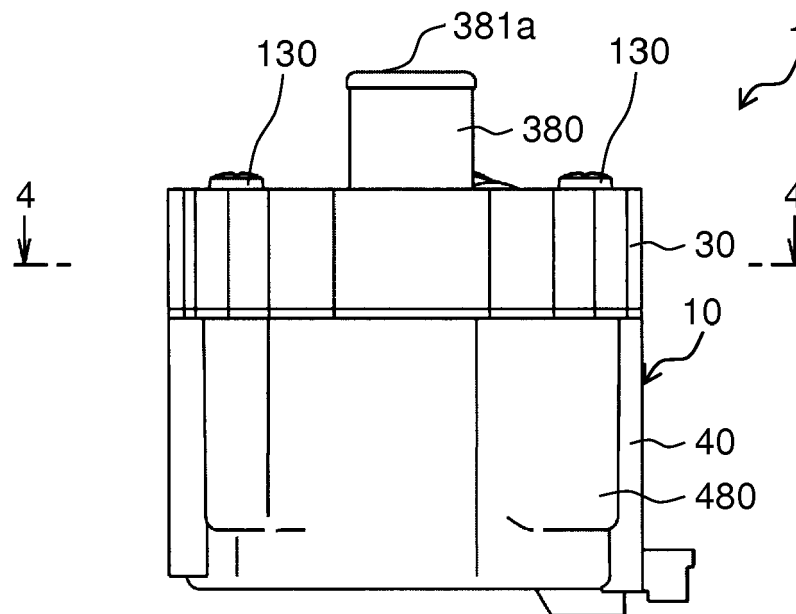


FIG. 2

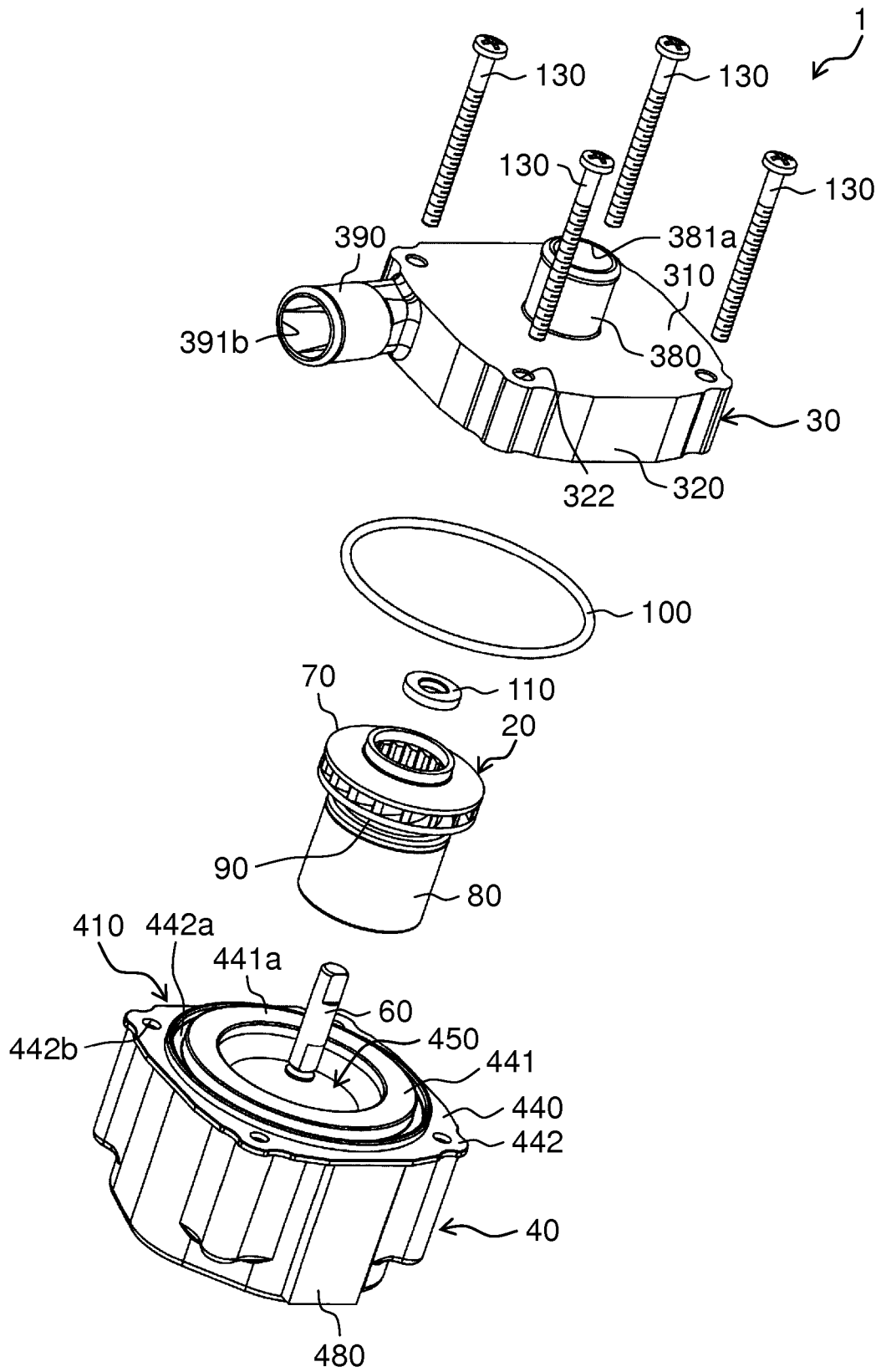


FIG. 3

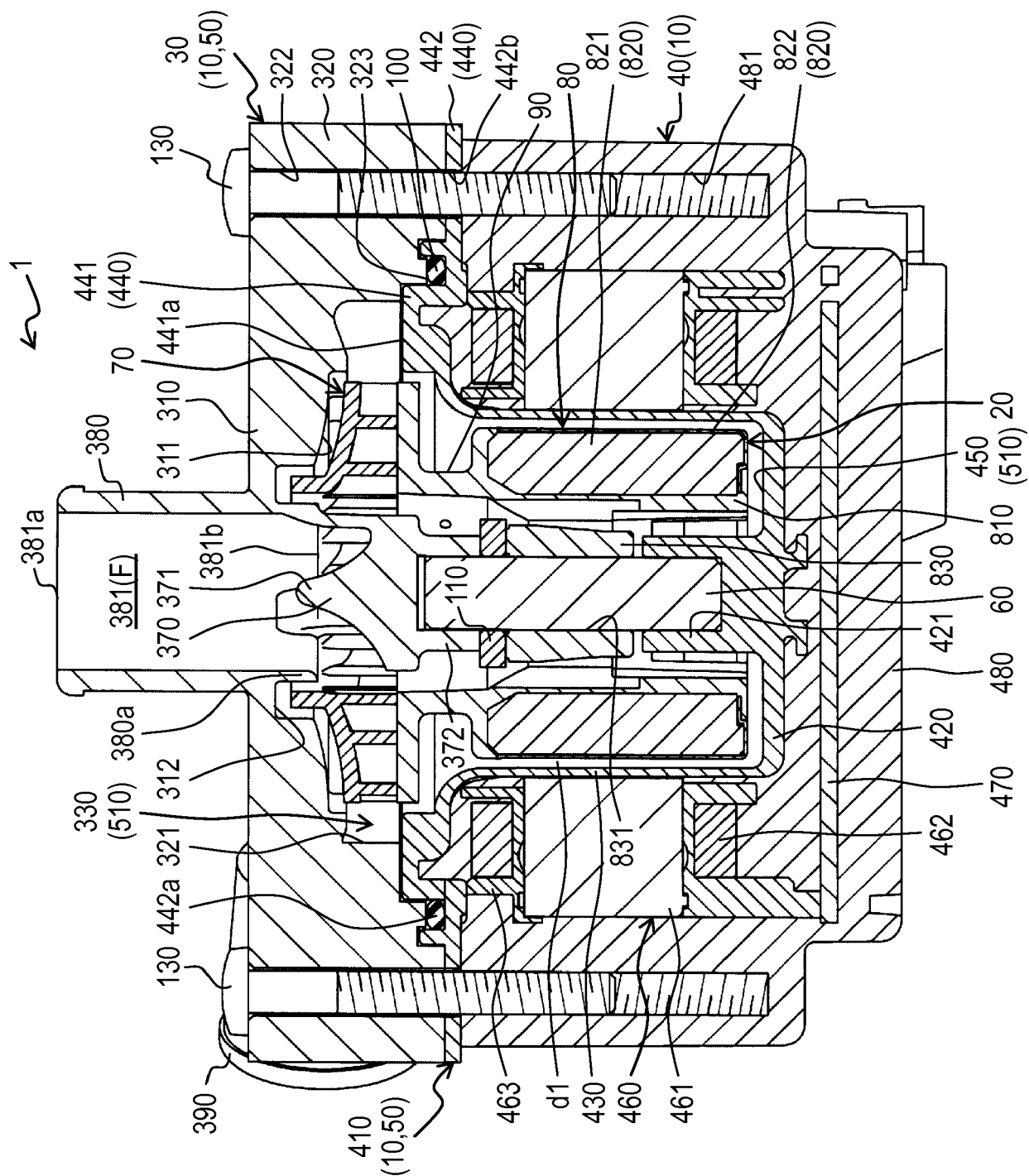


FIG. 4

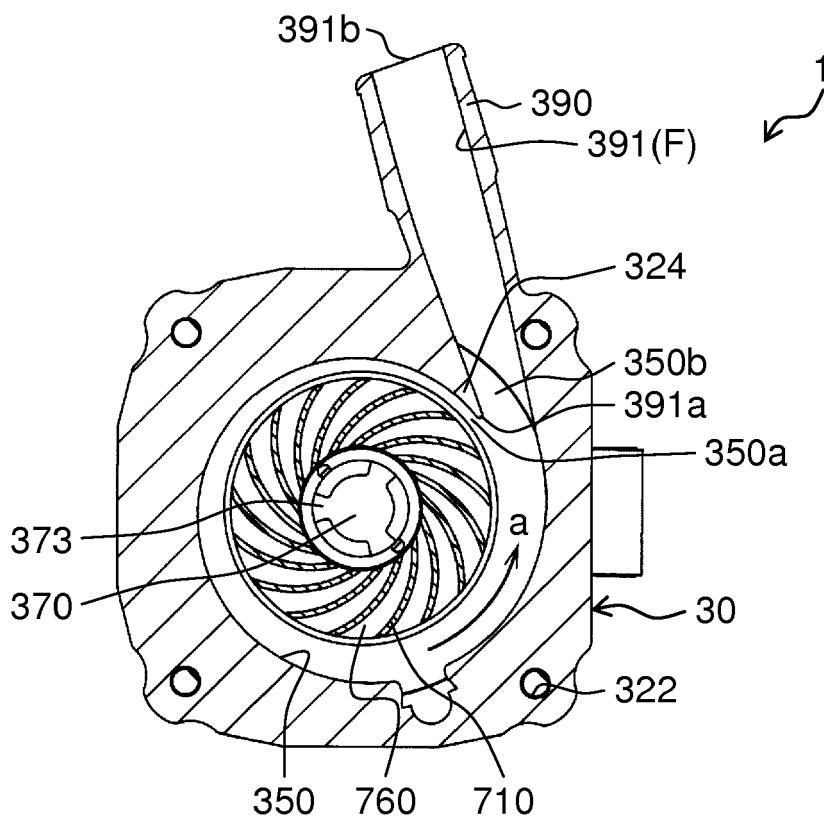


FIG. 5

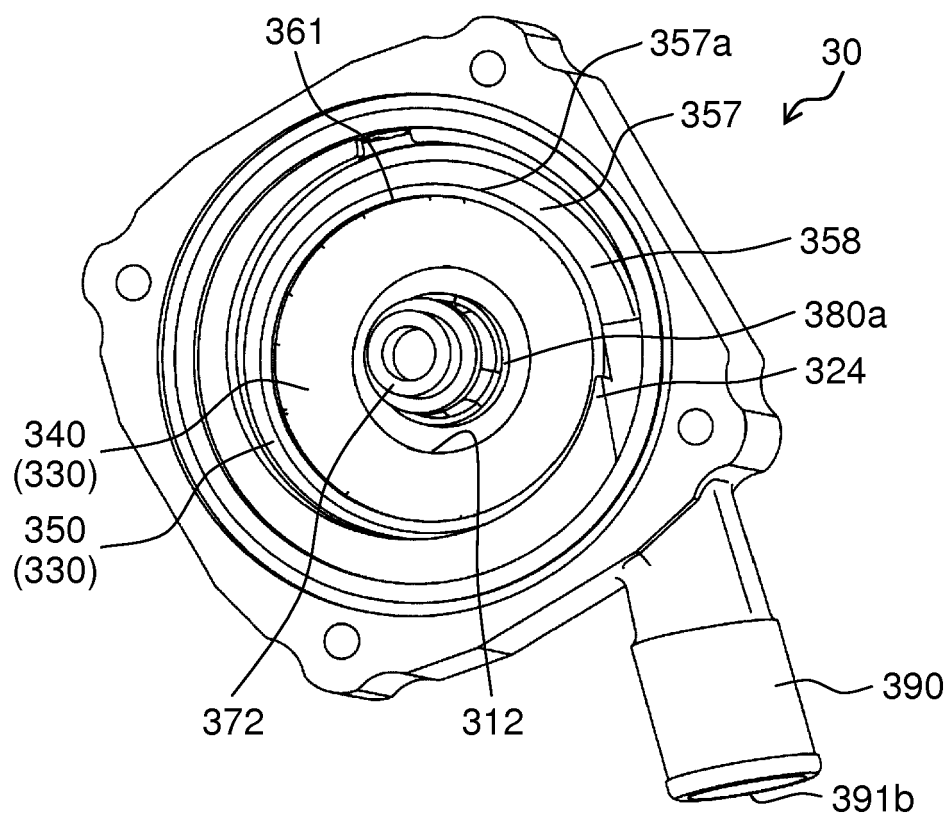


FIG. 6

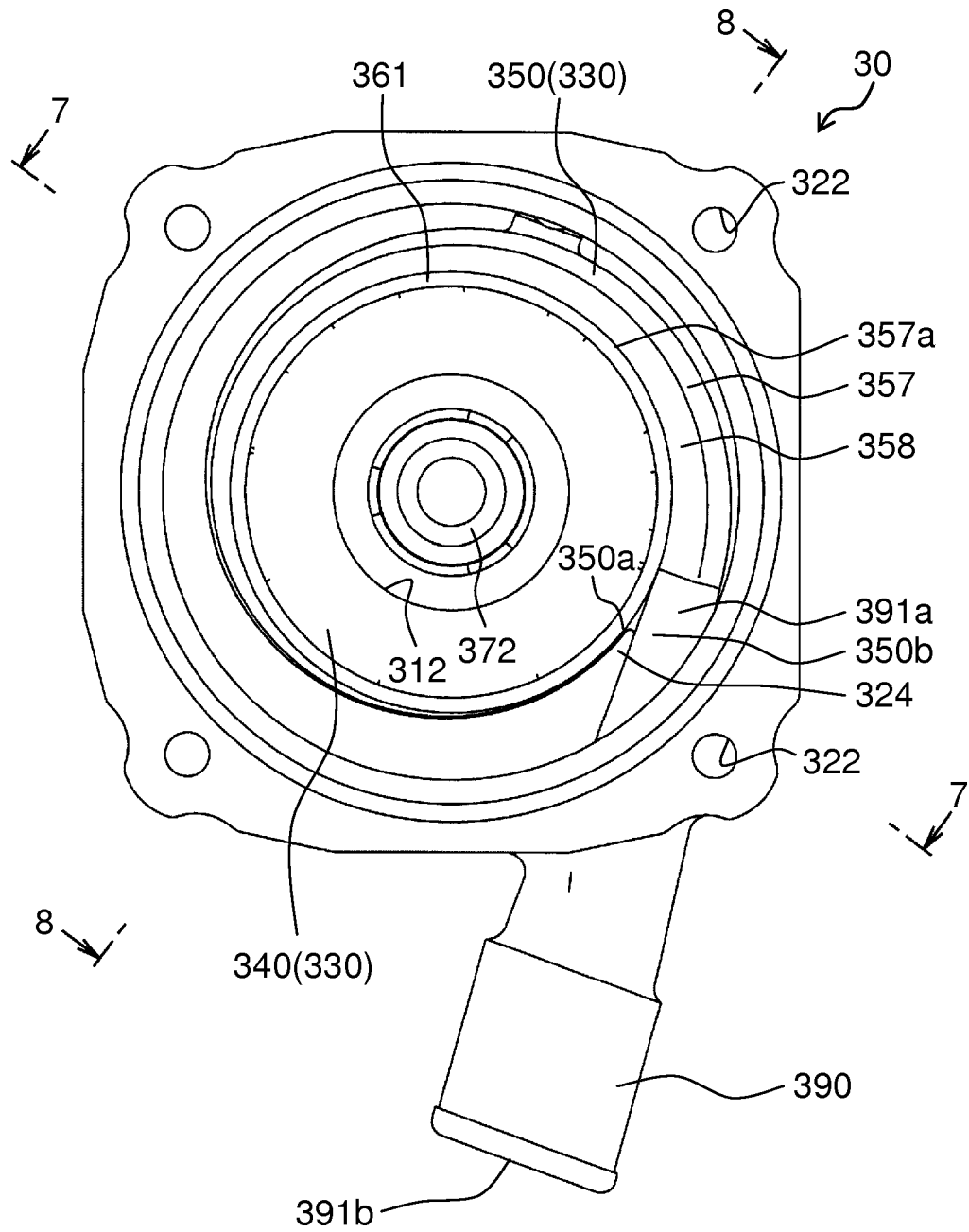


FIG. 7

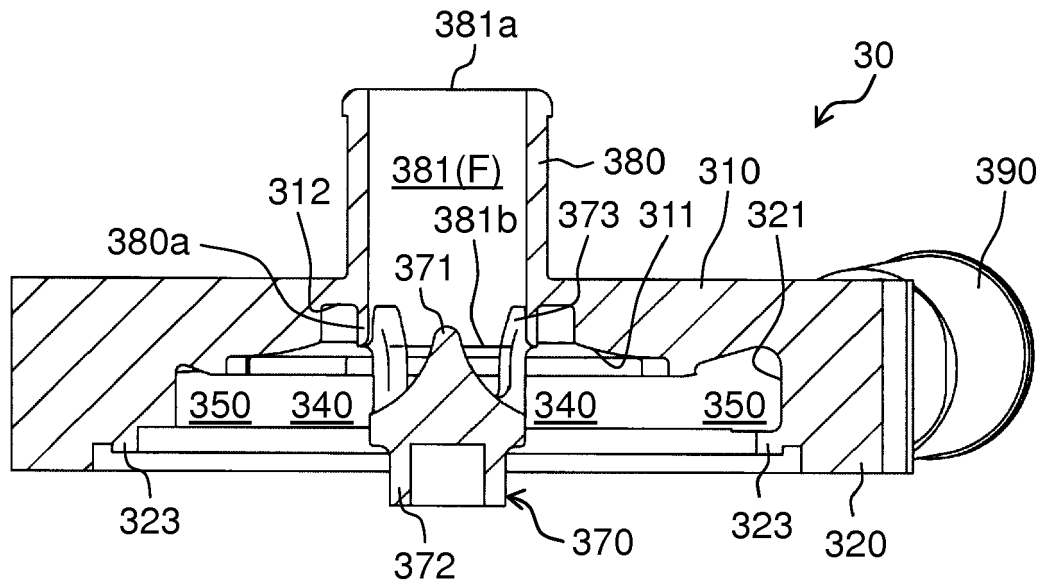


FIG. 8

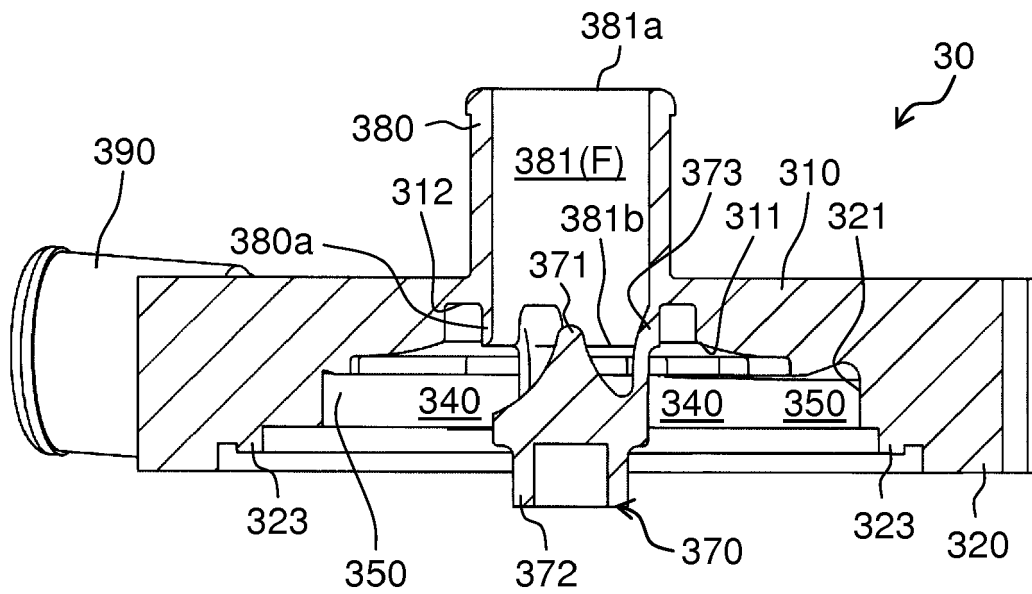


FIG. 9

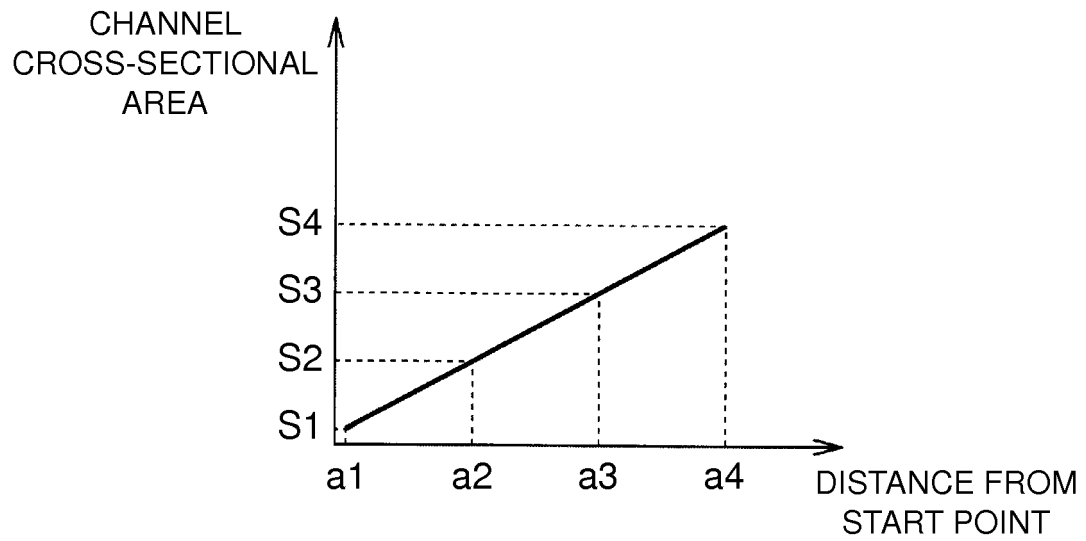


FIG. 10

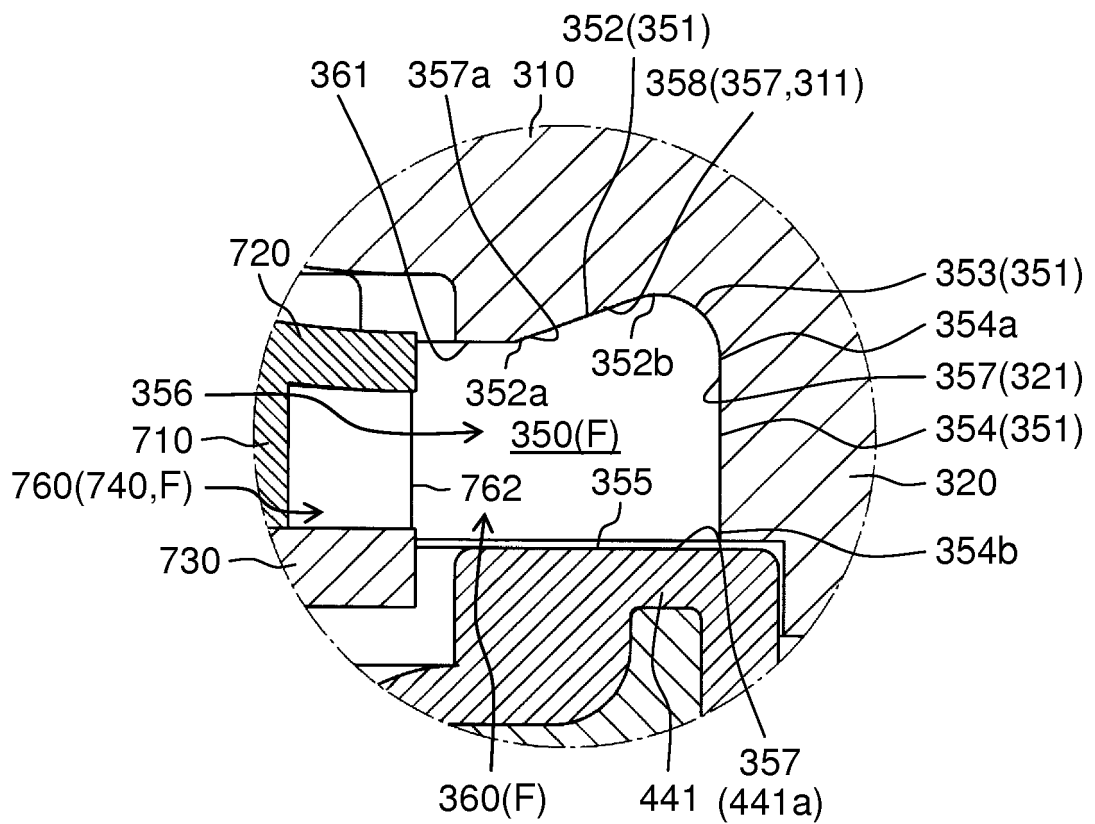


FIG. 11

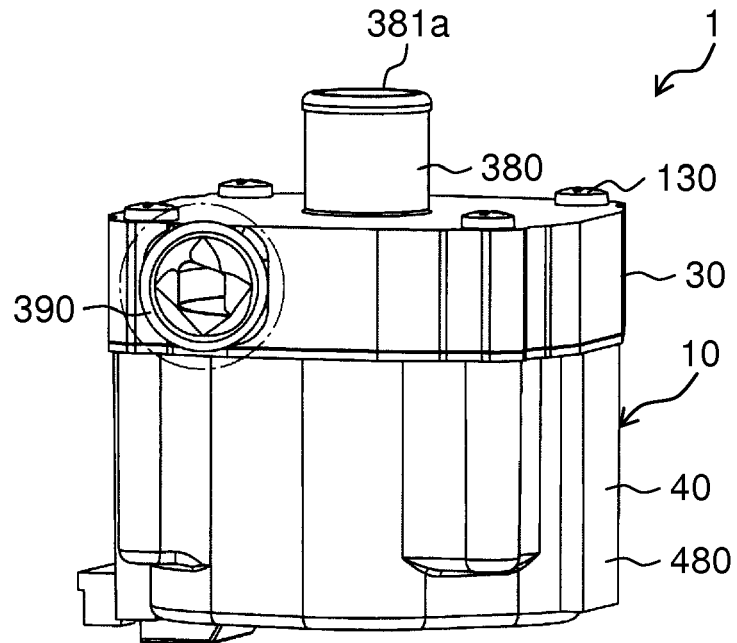


FIG. 12

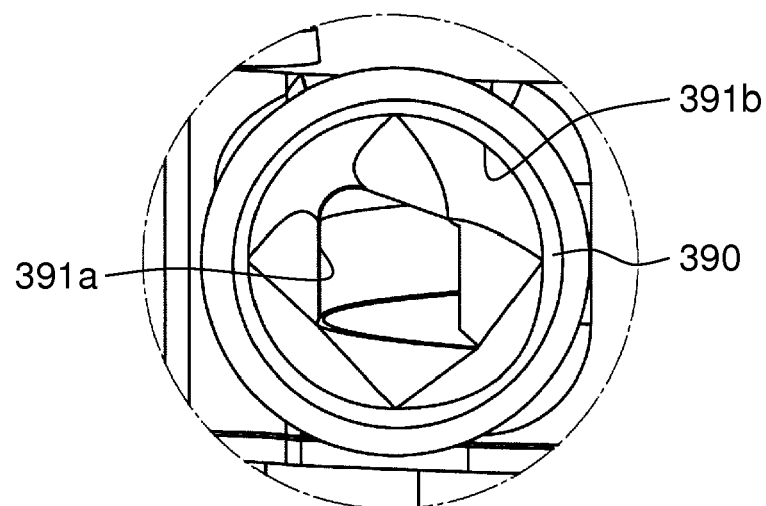


FIG. 13

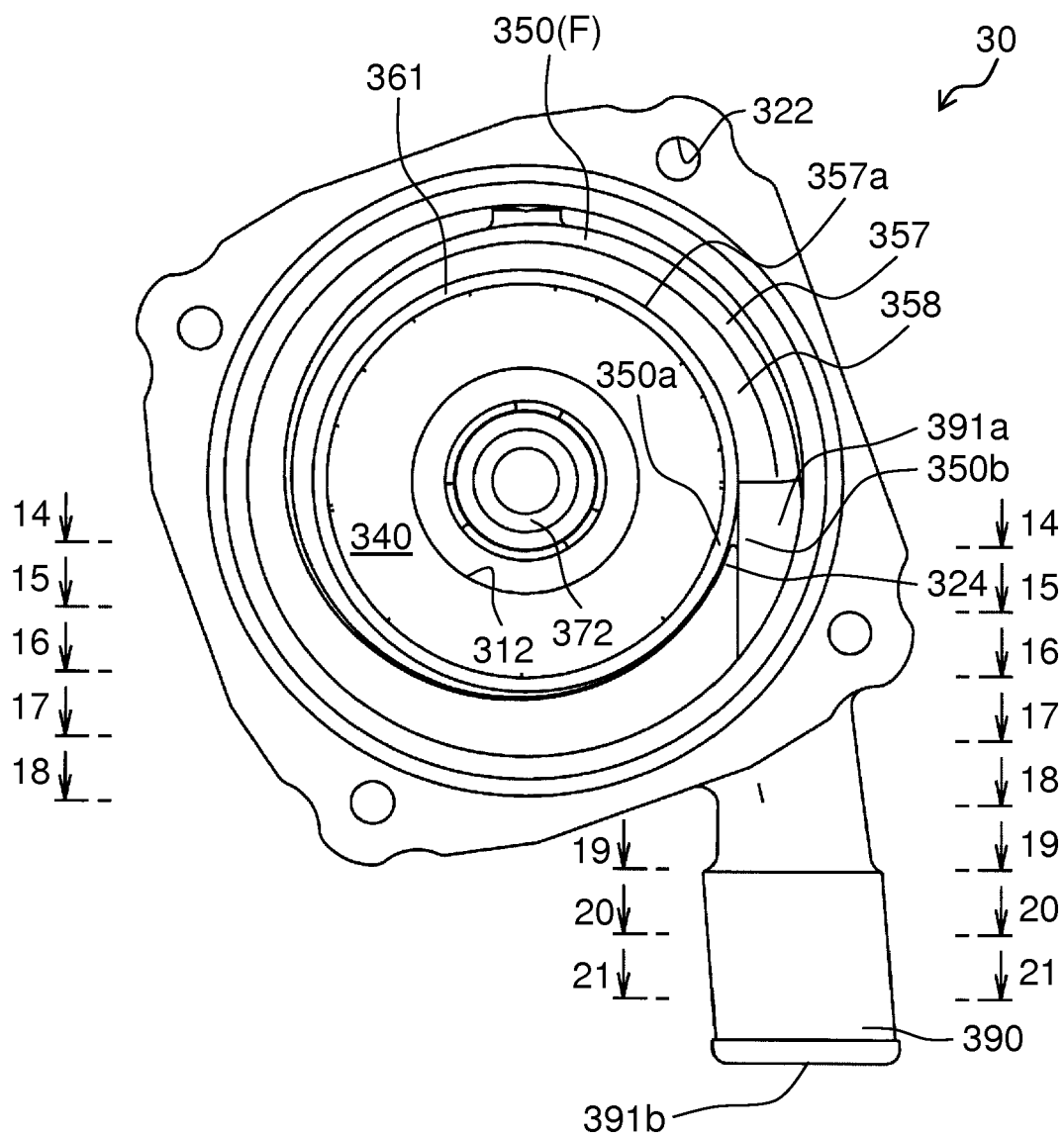


FIG. 14

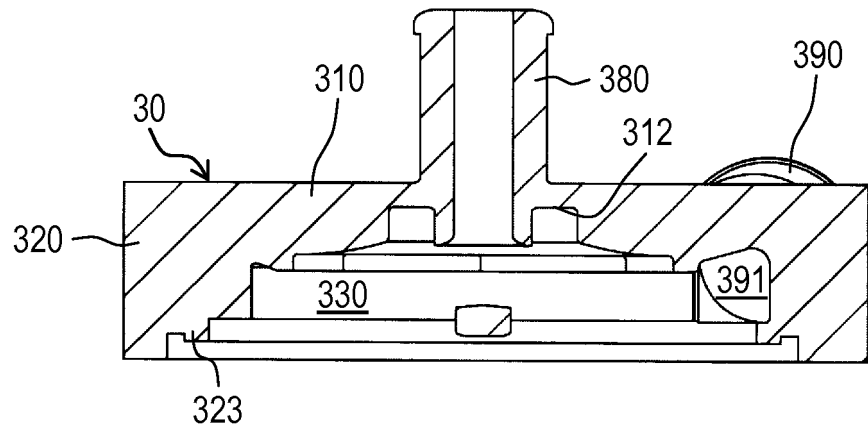


FIG. 15

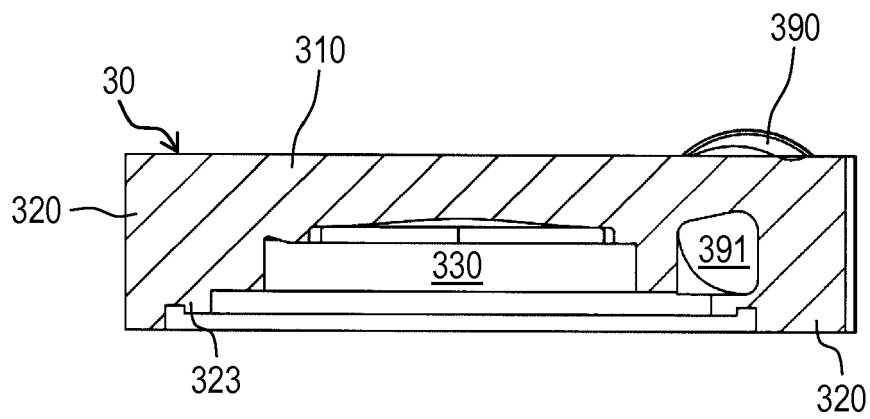


FIG. 16

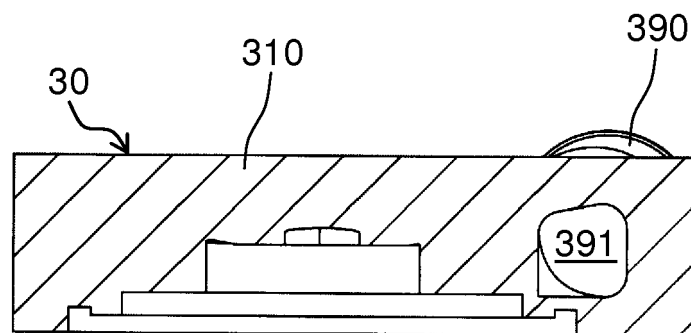


FIG. 17

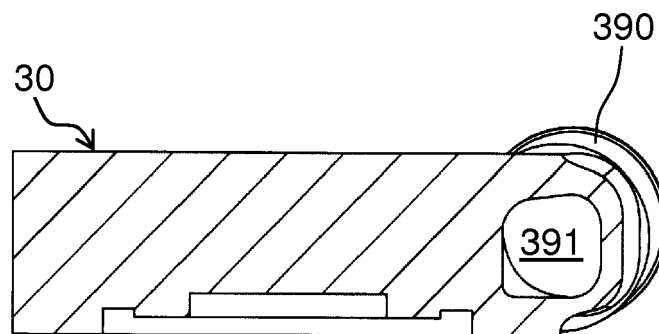


FIG. 18

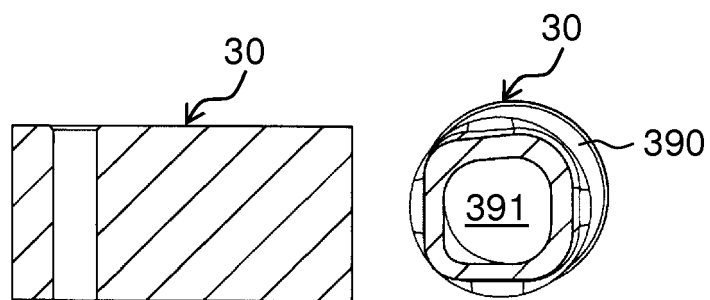


FIG. 19

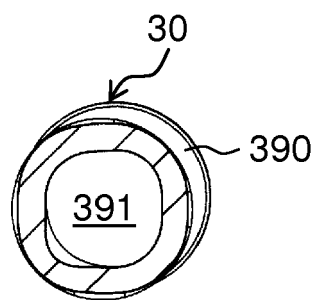


FIG. 20

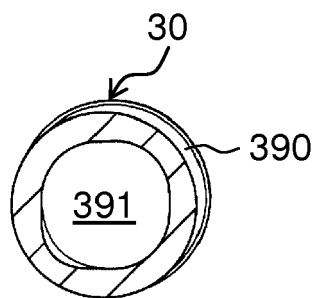


FIG. 21

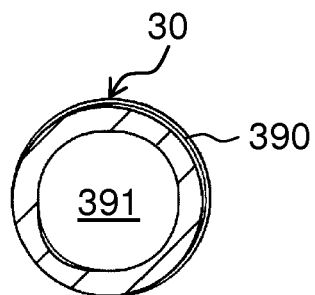


FIG. 22

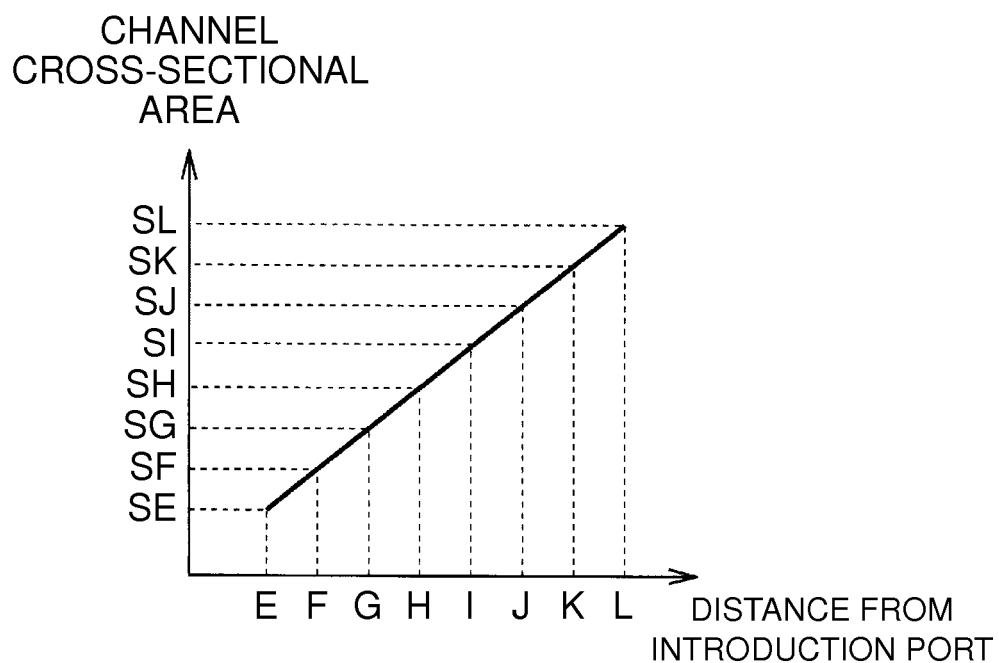


FIG. 23

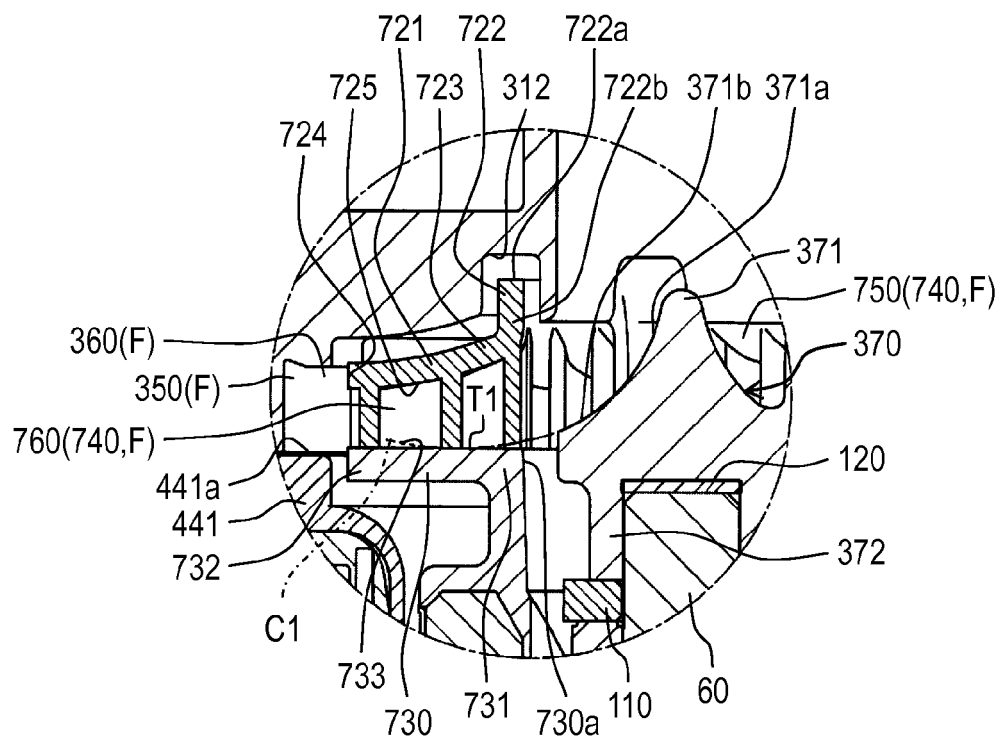


FIG. 24

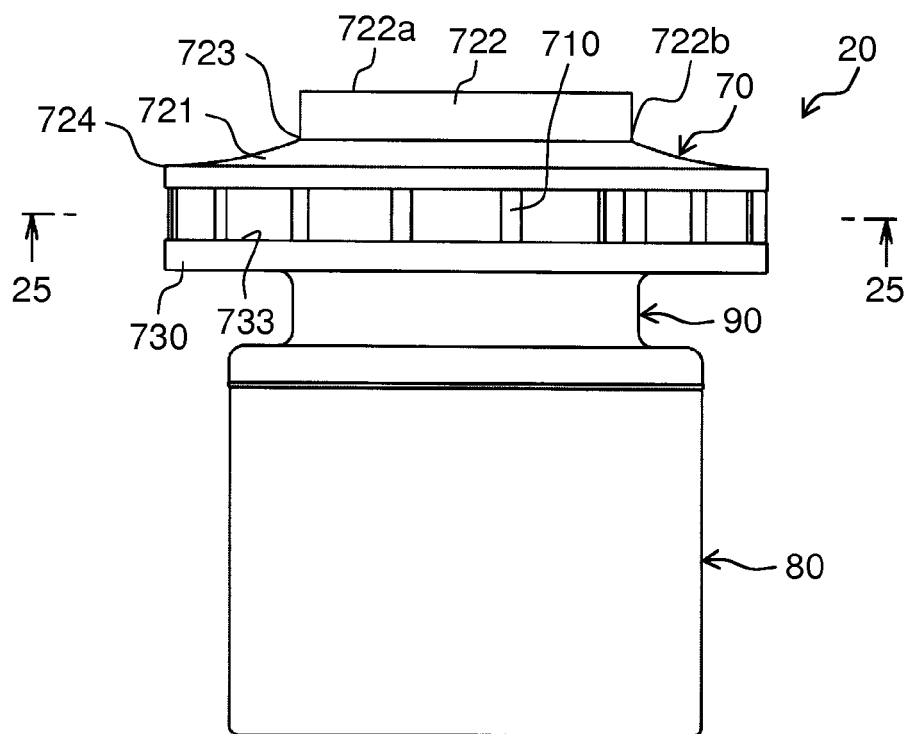


FIG. 25

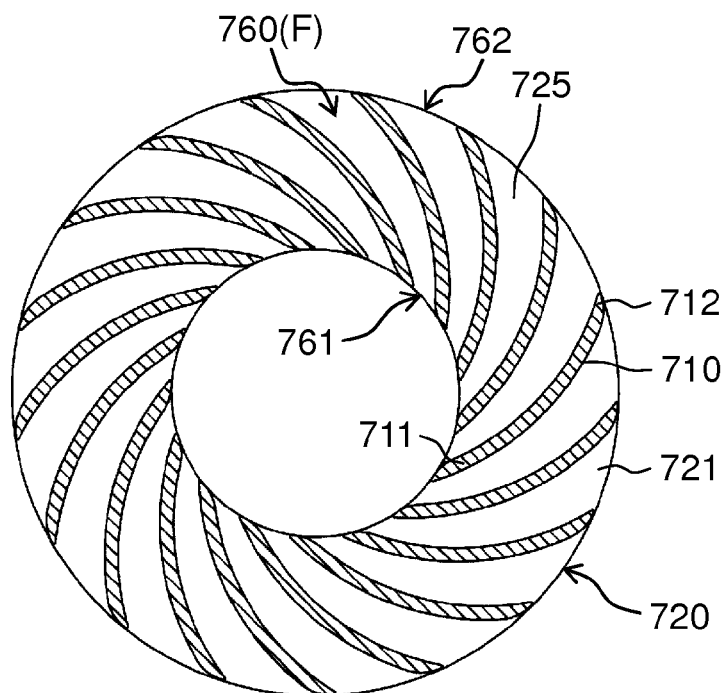


FIG. 26

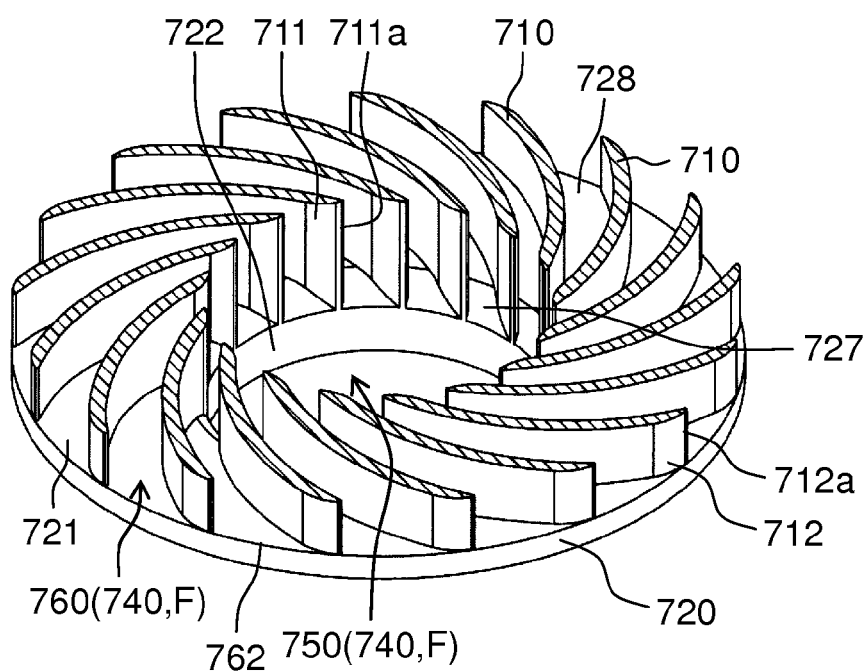


FIG. 27

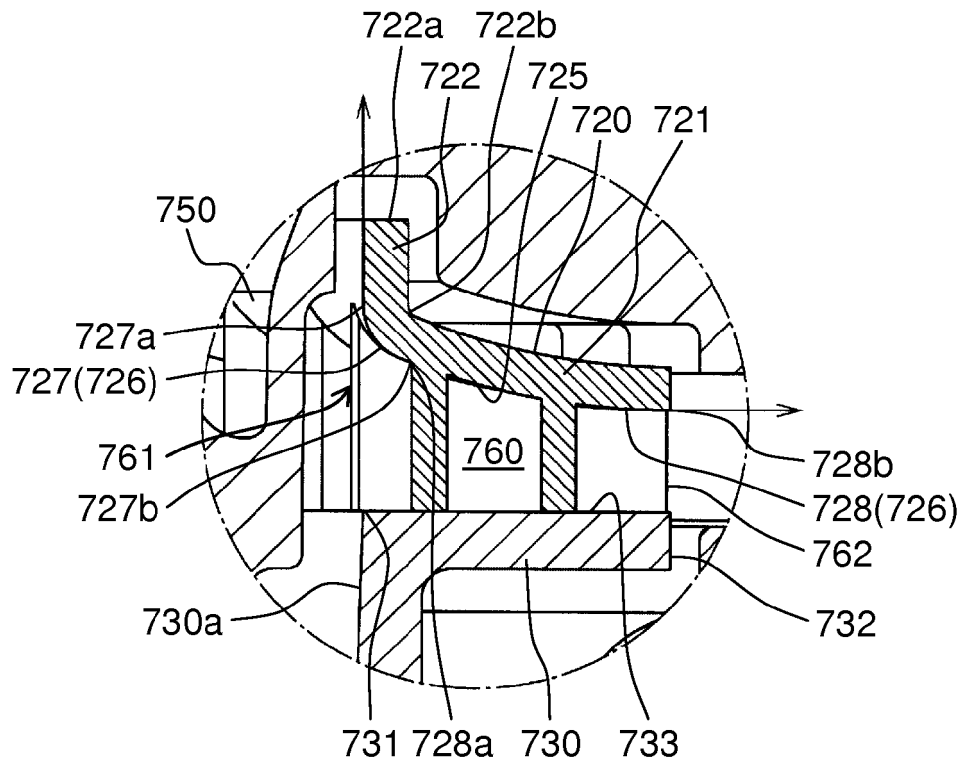


FIG. 28

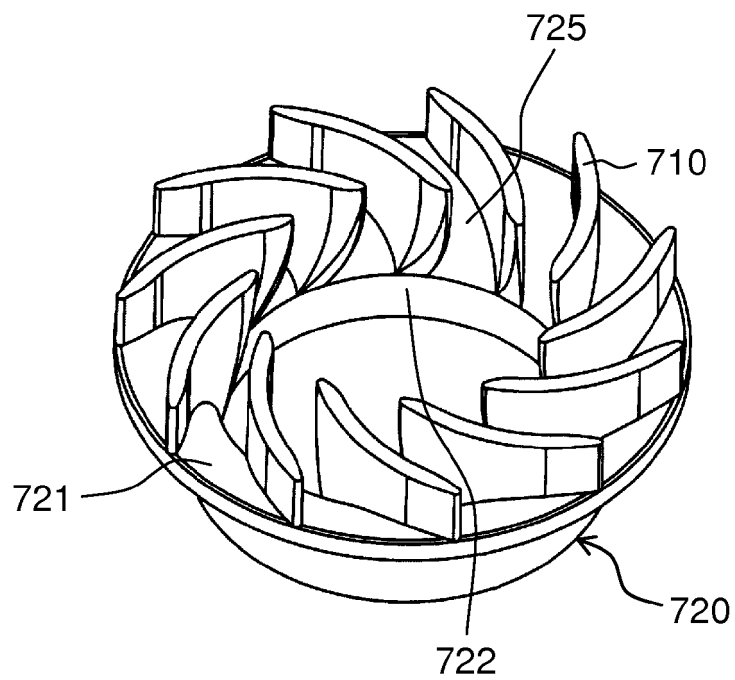


FIG. 29

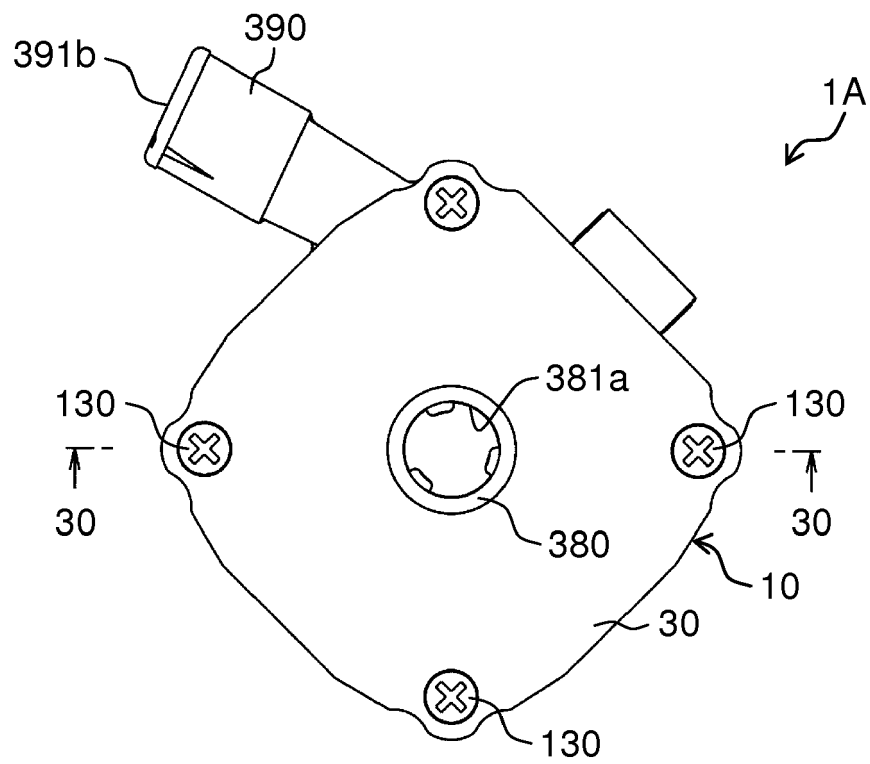


FIG. 30

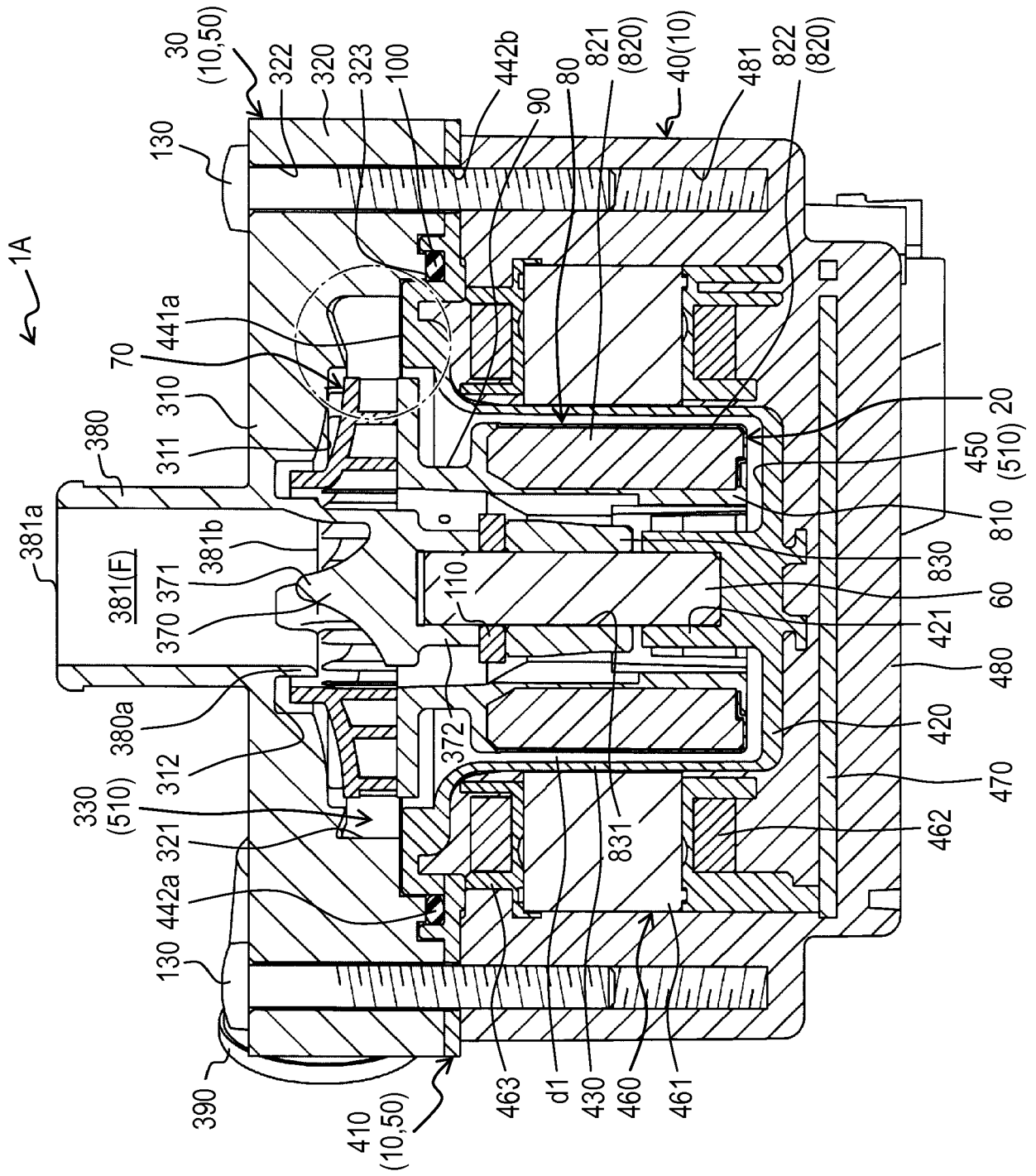


FIG. 31

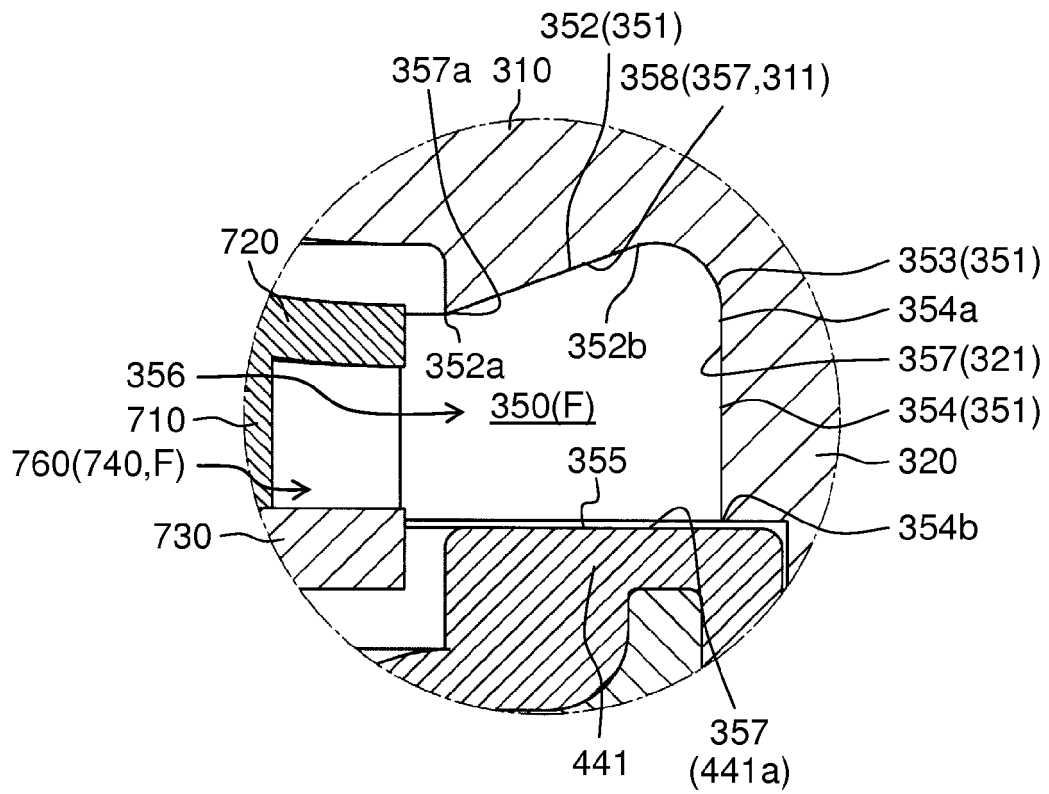


FIG. 32

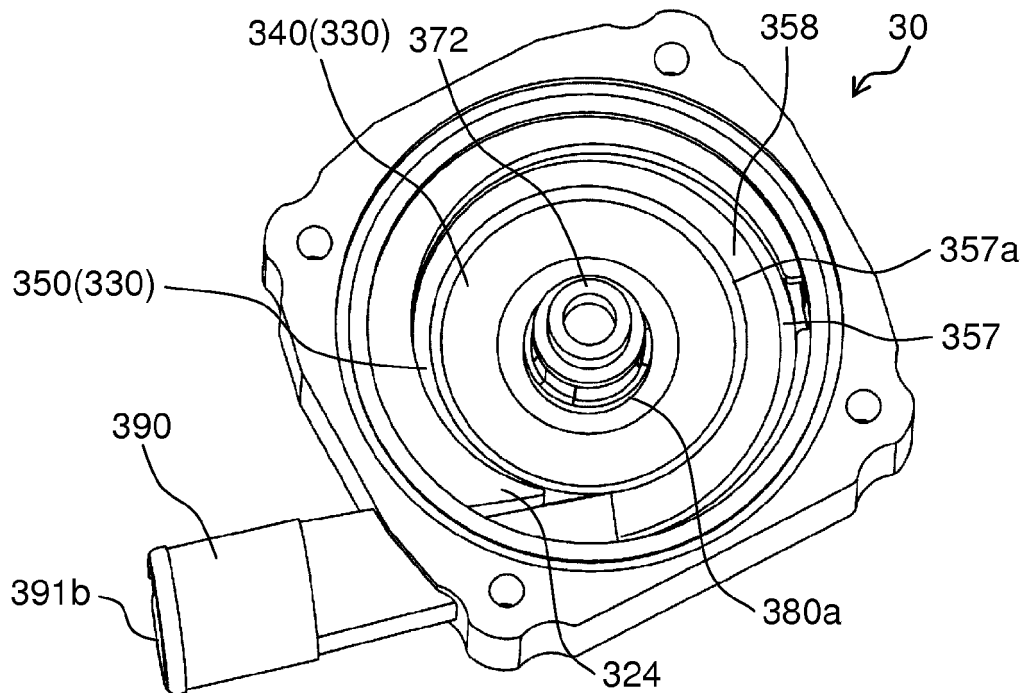


FIG. 33

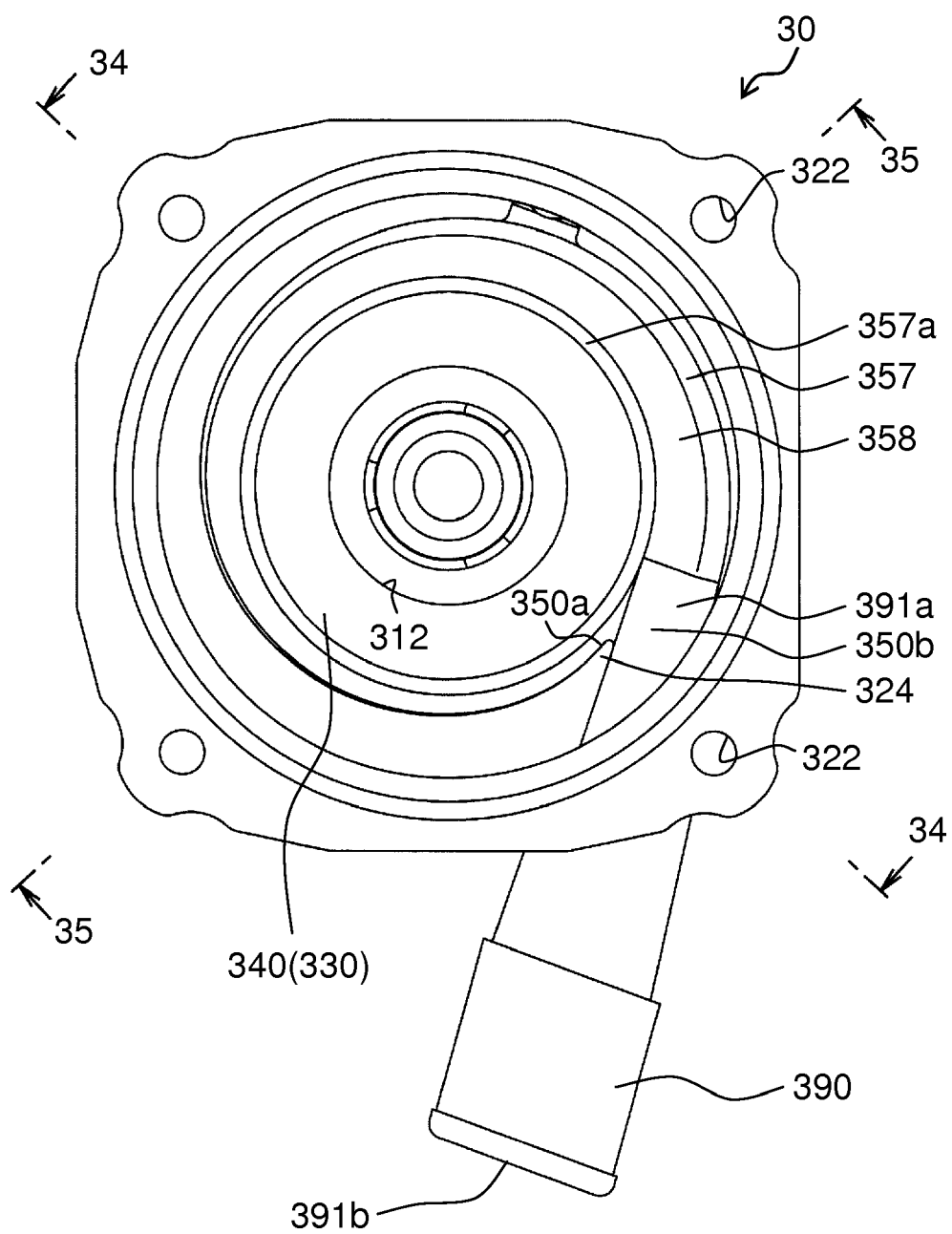


FIG. 34

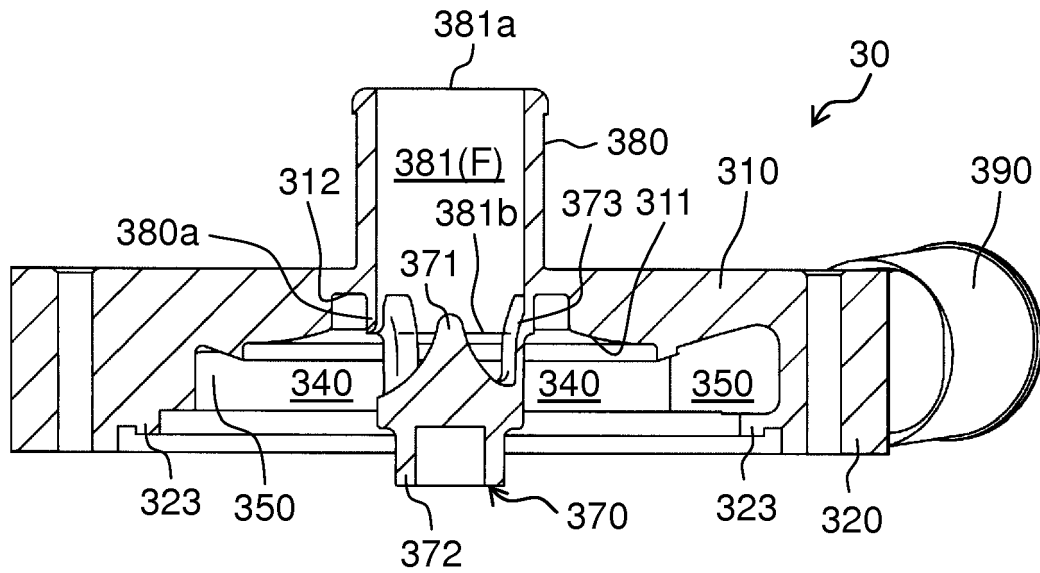
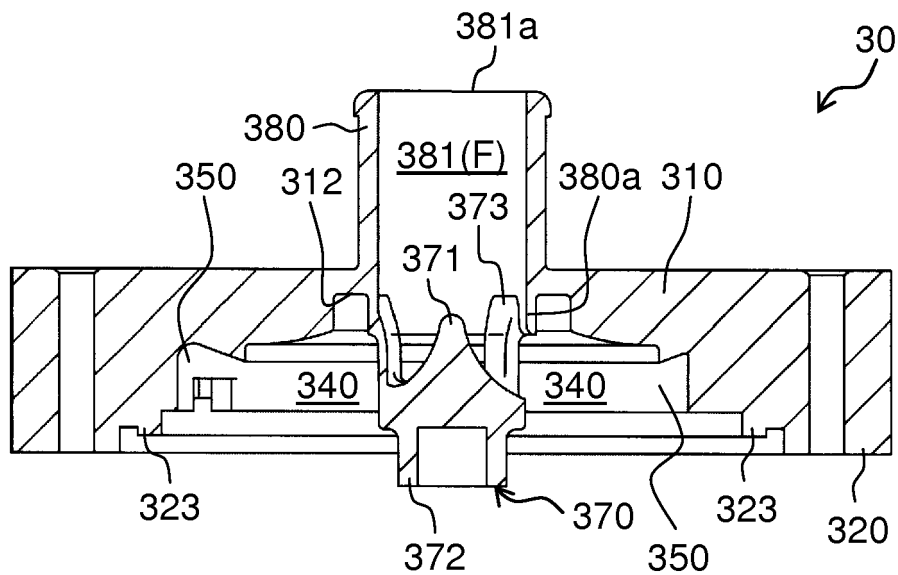


FIG. 35



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2014194190 A [0002]