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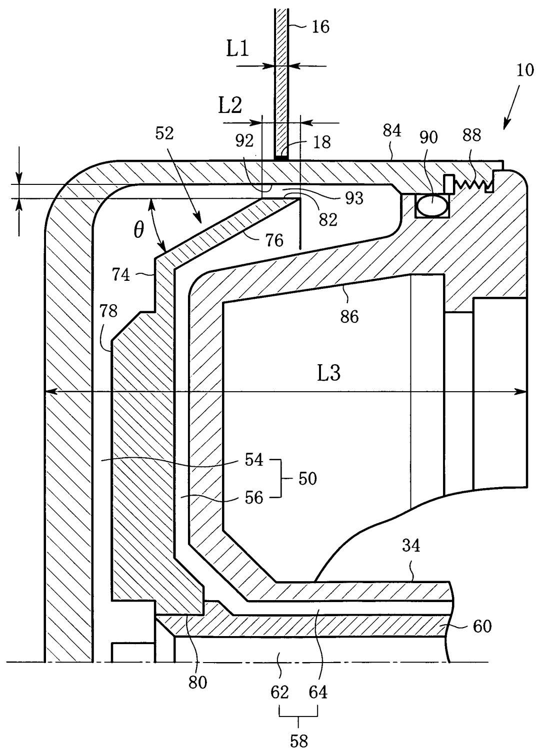
(54) Rotating anode x-ray tube

(57) A rotating anode (10) has an improved separator (52) arranged within a coolant passage (50) which is formed inside the rotating anode. A cylindrical target has an outer periphery whose axial length (L3) is in a range between 20 and 100 millimeters. The separator (52) has a proximal surface (82), a distance (G) between the proximal surface (82) and a must-cooled surface (92) being in a range between 0.1 and 3.0 millimeters. The axial length (L2) of the proximal surface (82) is not greater than five millimeters. Thus, since the axial length (L2) of the proximal surface (82) is set to be small, the load of a rotary driving source would be not so large even with a high-speed rotation of the rotating anode (10). When using an electric motor as the rotary driving source, it is not necessary to exchange the capacity of a motor diver for a larger one.

FIG. 2



EP 1 675 152 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a rotating anode X-ray tube having an improved separator which is disposed within a coolant passage inside a rotating anode.

2. Description of the Related Art

[0002] A rotating anode X-ray tube has a rotating anode within which a coolant passage is formed. Coolant flows through the coolant passage to cool the rotating anode. Fig. 13 is a longitudinal sectional view of the conventional rotating anode X-ray tube, taken along a cutting plane including an axis of rotation. A rotating anode 10 is formed, in its inside, with a coolant passage 12 within which a separator 14 is disposed. The separator 14 remains stationary during rotation of the rotating anode 10. The rotating anode 10 has an outer periphery which consists of a target made of an X-ray generating material. When the outer periphery of the target is irradiated with an electron beam 16, an X-ray emits from an electron beam irradiation region 18. Thinking of an inner surface of the rotating anode 10, i.e., a surface of the coolant passage, the backside of the electron beam irradiation region 18 must be best cooled, the backside being referred to hereinafter as a must-cooled surface 20. On the other hand, thinking of an outer surface of the separator 14, a part facing the must-cooled surface 20 is referred to hereinafter as a proximal surface 22. The distance between the inner surface of the rotating anode 10 and the outer surface of the separator 14 becomes narrowest at a space between the must-cooled surface 20 and the proximal surface 22, the space being referred to hereinafter as a proximal passage. Defining the distance between the inner surface of the rotating anode 10 and the outer surface of the separator 14, i.e., the distance at the proximal passage, as a proximal distance G, it is set to be about 1.5 millimeters. The thus narrowed proximal distance G can provide a high cooling performance for the must-cooled surface 20.

[0003] When using a focus size called as the normal focus, an axial length L1 of the cross section of the electron beam 16, i.e., a length in a direction of an axis of rotation of the rotating anode 10, is about ten millimeters for instance. A circumferential length of the electron beam 16 is about one millimeter for instance, the length being measured in a circumferential direction of the outer periphery of the rotating anode 10, i.e., a length in a direction perpendicular to the drawing sheet of Fig. 13. Then, the sectional size of the electron beam 16 is about ten millimeters times one millimeter, this size being equal to the size of the electron beam irradiation region 18. It is preferable, for good cooling of the must-cooled surface 20 at the backside of the electron beam irradiation region 18, to set the axial length L2 of the proximal surface 22 longer than the length L1. For example, the length L2 is about fifteen millimeters. The rotating anode with such values is used typically with a revolving speed of about 6,000 rpm. The rotating anode having such a separator is disclosed in Japanese patent publication No. 2000-251810 A.

[0004] Incidentally, a small focus size called as the fine focus is sometimes used for the conventional rotating anode shown in Fig. 13. Fig. 14 is a longitudinal sectional view, similar to Fig. 13, of the rotating anode with the fine focus. The electron beam 16 becomes narrower and its section size is about one millimeter times 0.1 millimeter for instance. Namely, the cross section of the electron beam 16 has an axial length L1 of about one millimeter and a circumferential length of about 0.1 millimeter. Then, the axial length of the electron beam irradiation region 18 is equal to L1 too, i.e., one millimeter. In the prior art, the same separator has been used for the fine focus as for the normal focus.

[0005] In Fig. 14, it is necessary to make the energy of the electron beam 16 higher for obtaining a high-intensity X-ray beam with the fine focus. Stating specifically, it is necessary to increase the X-ray generating power which must be supplied to the X-ray tube and depends on the product of the tube voltage and the tube current. When the X-ray generating power is increased, it is necessary to strongly cool the electron beam irradiation region 18. One method of enhancing the cooling performance is to raise the revolving speed of the rotating anode. When the revolving speed is raised, an irradiation time becomes shorter, the irradiation time being defined by a time with which the same region on the outer periphery of the rotating anode is kept on receiving irradiation of the electron beam continually, so that a high-temperature region successfully comes out of the electron beam before the electron beam irradiation region melts at a high temperature. The present invention is concerned with raising the revolving speed to increase an X-ray beam intensity with the fine focus.

[0006] In the conventional rotating anode shown in Fig. 14, when the revolving speed of the rotating anode is raised from 6,000 rpm to 9,000 rpm for instance, the following problem will occur. Since cooling water exists between the rotating anode 10 and the stationary separator 14, a viscous resistance of the cooling water acts as a load on the electric motor which drives the rotating anode 10. The most proximate region between the rotating anode 10 and the separator 14 is a region near the proximal surface 22 of the separator 14. The viscous resistance of the cooling water at this region significantly affects the load of rotation. Since the proximal distance G is set small as 1.5 millimeters and the axial length L2 of the proximal surface 22 is set long as about 15 millimeters, the increase in the revolving speed will lead to the increase in the load of rotation at this region, becoming problem. When the revolving speed is increased, it is necessary to make the input power to the electric motor higher, the electric motor being a rotary driving source. Further, it would be required to replace the capacity of the motor driver with a larger one.

Summary of the Invention

[0007] It is an object of the present invention to provide a rotating anode X-ray tube in which the load on the rotary driving source is not so large even with a high revolving speed.

[0008] A rotating anode X-ray tube according to the present invention comprises a rotating anode, a coolant passage and a separator. The rotating anode includes a cylindrical target which is made of an X-ray generating material and has au outer periphery. The outer periphery has an axial length in a range between 20 and 100 millimeters, preferably between 30 and 100 millimeters. That is, the present invention is applied not to a rotating anode having a very short axial length exclusive to the fine focus but to a rotating anode having a relatively long axial length capable of making the normal focus too. The coolant passage is formed inside the rotating anode so that coolant can flow along a must-cooled surface which is positioned at a backside of an electron beam irradiation region on the outer periphery of the target. The coolant may be typically cooling water, but may be another cooling liquid. The separator is arranged stationary within the coolant passage. The separator has a proximal surface facing the must-cooled surface so that the coolant passage is divided into an inflow passage and an outflow passage. In the inflow passage, the coolant flows toward a proximal passage which is bounded between the must-cooled surface and the proximal surface. In the outflow passage, the coolant flows away from the proximal passage. The proximal surface of the separator is positioned at a distance, from the must-cooled surface, in a range between 0.1 and 3.0 millimeters. If the distance becomes over 3.0 millimeters, the cooling performance would come down. On the other hand, if the distance is under 0.1 millimeter, the stationary separator would be in increased danger of getting contact with the rotating anode. The axial length of the proximal surface is not greater than five millimeters, and is preferably not greater than three millimeters. Considering the electron beam irradiation region of the fine focus, the cooling performance would be good even when the axial length of the proximal surface is five millimeters or under, a length longer than such a value being of no use. Thus, a shorter axial length of the proximal surface leads to not so large load on the rotary driving source even under a high-speed revolution of the rotating anode. In the case of using an electric motor as the rotary driving source, it is not necessary to replace the capacity of the motor driver with a larger one.

[0009] A rotating anode X-ray tube according to the present invention is better suited to generate a high-intensity X-ray beam with the fine focus. The electron beam irradiation region with the fine focus has a size up to three millimeters times 0.3 millimeter, that is, its axial length is not larger than three millimeters. More preferably, the size of the electron beam irradiation region with the fine focus may be one millimeter times 0.1 millimeter or less (i.e., 0.7 millimeter times 0.07 millimeter, for instance), its axial length being not larger than one millimeter.

[0010] The separator may have a disc part and an inclined part connected to an outer periphery of the disc part. The inclined part may have a shape of a frustum of a cone. The inclined part has an outer peripheral surface at its radially outer end, the outer peripheral surface becoming the proximal surface.

[0011] The present invention is also directed to an X-ray generator including a rotating anode X-ray tube as described above. The X-ray generator includes a coolant supply unit for supplying coolant to the coolant passage of the rotating anode X-ray tube, and a high-voltage power supply for supplying a tube voltage and a tube current to the rotating anode X-ray tube.

Brief Description of the Drawings

[0012]

Fig. 1 is a sectional view of the principal part of one embodiment of a rotating anode X-ray tube according to the present invention;

Fig. 2 is an enlarged sectional view showing a part of the rotating anode;

Fig. 3 is a front view of a separator;

Fig. 4 is a perspective view of the separator, a part of which is cut away;

Fig. 5 is a sectional view showing a vicinity of a proximal surface of the separator;

Fig. 6 is a sectional view, similar to Fig. 5, of the first modification of the separator;

Fig. 7 is a perspective view, similar to Fig. 4, of the separator shown in Fig. 6;

Fig. 8 is a perspective view, similar to Fig. 4, of the second modification of the separator;

Fig. 9 is a sectional view, similar to Fig. 5, of the third modification of the separator;

Fig. 10 is a perspective view, similar to Fig. 4, of the separator shown in Fig. 9;

Fig. 11 is a graph of the experimental results about a motor load for the rotating anode X-ray tube having the separator shown in Fig. 2 (i.e., the present invention), and for the rotating anode X-ray tube having the separator shown in Fig. 14 (i.e., the prior art);

Fig. 12 is a graph of a water pressure of the cooling water in the case of obtaining the experimental data shown in Fig. 11 for the present invention;

Fig. 13 is a longitudinal sectional view of the conventional rotating anode;

Fig. 14 is a longitudinal sectional view, similar to Fig. 13, with the fine focus; and

Fig. 15 illustrates component parts of an X-ray generator including the rotating anode X-ray tube according to the present invention.

Detailed Description of the Preferred Embodiments

[0013] Embodiments of the present invention will now be described below with reference to the drawings. Fig. 1 is a sectional view of the principal part of one embodiment of a rotating anode X-ray tube according to the present invention, taken along a sectional plane including an axis of rotation of the rotating anode. The rotating anode X-ray tube has a vacuum vessel 24 and a combination of a rotating anode 10 and an electron gun 26 both housed in the vacuum vessel 24. A high voltage is supplied, from a high-voltage power supply, to a circuit between the electron gun 26 and the rotating anode 10, so that an electron beam 16 emits from the electron gun 26. The electron beam 16 irradiates an outer periphery of the cylindrical rotating anode 10 which is a target member, so that an X-ray generates. The rotating anode 10 belongs to an anode assembly 28, which is mounted on the vacuum vessel 24 so that the rotating anode 10 is arranged at a predetermined position inside the vacuum vessel 24. The anode assembly 28 has a casing 30 whose flange 32 can be secured airtightly to the vacuum vessel 24. The rotating anode 10 is fixed to a rotary shaft 34. Between an outer periphery of the rotary shaft 34 and an inner wall of the casing 30 are arranged a magnetic fluid sealing device 36 for rotary vacuum sealing, ball bearings 38 and 40 for rotary support of the rotary shaft 34, an electric brush 42 for passing an electric current from the rotary shaft 34 into the casing 30, and a mechanical seal 44 for rotary sealing of cooling water. A stator 46 of a direct motor is fixed to the inner wall of the casing 30. On the other hand, a rotor 48 of the direct motor is fixed to the outer periphery of the rotary shaft 34. The direct motor drives the rotary shaft 34 so that the rotating anode 10 rotates.

[0014] Fig. 2 is an enlarged sectional view showing a part of the rotating anode 10. Inside the rotating anode 10 is formed the first coolant passage 50 which is divided, by a separator 52, into the first inflow passage 56 and the first outflow passage 54. On the other hand, inside the rotary shaft 34 is formed the second coolant passage 58 which is also divided, by a partition pipe 60, into the outer, second inflow passage 64 and the inner, second outflow passage 62. The separator 52 is fixed to the partition pipe 60 whose root, i.e., the right end in Fig. 1, is fixed to the casing 30. The rotating anode 10 and the rotary shaft 34 can be rotated, while the separator 14 and the partition pipe 60 inside them remain stationary. In Fig. 2, the first inflow passage 56 communicates with the second inflow passage 64, while the first outflow passage 54 communicates with the second outflow passage 62. Referring back to Fig. 1, the casing 30 is formed with a coolant inlet 68 and a coolant outlet 66. An inlet piping nipple 72 is secured to the coolant inlet 68, while an outlet piping nipple 70 is secured to the coolant outlet 66. The cooling water enters into the coolant inlet 68, and then passes through the second inflow passage 64 (see Fig. 2), and further enters into the first inflow passage 56 to cool the inner surface of the rotating anode 10. The returning cooling water passes through the first outflow passage 54 and then the second outflow passage 62 (see Fig. 2), and flows out of the coolant outlet 66.

[0015] Referring to Fig. 2, the separator 52 is comprised of a disc part 74, an inclined part 76 and blades 78. Fig. 3 is a front view of the separator 52, while Fig. 4 is a perspective view of the separator 52, a part of which is cut away. Explaining with reference to Figs. 2 through 4, the disc part 74 has a center which is formed with a through hole 80 through which the cooling water can pass. In the vicinity of the through hole 80, the disc part 74 is fixed to the partition pipe 60. The disc part 74 has an outer periphery which is connected to the inclined part 76, which has a shape of a frustum of a cone, as clearly shown in Fig. 4. In the cross section taken along the axis of rotation of the rotating anode, the inclined part 76 is inclined, as shown in Fig. 2, by an angle θ with respect to the axial direction of the rotating anode. The angle θ is 30 degrees in this embodiment. The inclined part 76 has an outer peripheral surface at its radially outer end, the outer peripheral surface becoming the proximal surface 82. The proximal surface 82 is a cylindrical surface which is two millimeters in axial length L2. Four blades 78 are arranged radially, as shown in Fig. 3, and fixed to the disc part 74.

[0016] Referring to Fig. 2, the rotating anode 10 is comprised of the cup-shaped first member 84 and the second member 86 which is formed integral with the rotary shaft 34. The first member 84 is entirely made of a target member, for example, cupper. The first member 84 is connected with the second member 86 through a threaded part 88. The region of connection between the first member 84 and the second member 86 has an O-ring 90 which seals the cooling water. A combination of the first member 84 and the second member 86 forms the first coolant passage 50. The outer periphery of the first member 84 is irradiated with the fine-focus electron beam 16, whose sectional size is about one millimeter times 0.1 millimeter. That is, the axial length of the electron beam 16 is about one millimeter, while the circumferential length is about 0.1 millimeter. Then, the axial length L1 of the electron beam irradiation region 18 becomes about one millimeter. When such a focus size is used and an X-ray beam is taken out with six degrees in take-off angle in a leftward direction in Fig. 2, a point-focus X-ray source is obtained with a focus size of about 0.1 millimeter times 0.1 millimeter.

[0017] The rotating anode 10 is a hundred millimeters in outer diameter and about 43 millimeters in axial length L3. The rotating anode 10 is capable of acting also as a rotating anode with the normal focus after altering the separator. Therefore, the axial length L3 of the rotating anode is selected to be long, at the same level as that in the usual rotating anode, as compared with that in a special rotating anode exclusive to the fine focus.

[0018] Thinking of the cylindrical part of the first member 84, the inner surface at the backside of the electron beam irradiation region 18 becomes the must-cooled surface 92, which must be cooled by the cooling water especially. The distance between the must-cooled surface 92 and the proximal surface 82 of the separator 52 is about 1.5 millimeters. The passage between the must-cooled surface 92 and the proximal surface 82 will be referred to as a proximal passage 93 hereinafter. The proximal passage 93 divides the first coolant passage 50 into the first inflow passage 56 and the first outflow passage 54. Fig. 5 is a sectional view showing a vicinity of a proximal surface 82 of the separator 52. In the first inflow passage 56, the cooling water 94 flows toward the proximal passage 93. On the other hand, in the first outflow passage 54, the cooling water 94 flows away from the proximal passage 93. The proximal passage 93 provides a narrow way for the cooling water, so that the flow rate becomes higher at this region to cool the must-cooled surface 92 with a sufficient cooling performance. Further, since the axial length of the proximal surface 82 is selected to be short as two millimeters, the rotary load caused by the viscous resistance of the cooling water at the proximal passage 93 is smaller than that in the case of using the conventional separator. Therefore, even if the revolving speed is raised to 9,000 rpm for instance, a required power to the motor would increase not more than in the prior art. The sufficient cooling performance even with such a separator having the short axial length of the proximal surface 82 has been verified by an experiment, in which a high-intensity electron beam with the fine focus irradiates the target to generate an X-ray under the condition of 9,000 rpm in revolving speed, 40 kV in tube voltage and 30 mA in tube current, resulting in no chaps on the target surface.

[0019] Fig. 6 is a sectional view, similar to Fig. 5, of the first modification of the separator, and Fig. 7 is a perspective view, similar to Fig. 4, of the separator shown in Fig. 6. Referring to Fig. 6, a separator 52a of this modification has a disc part 74 whose outer periphery is connected to a cylindrical part 96. The cylindrical part 96 has an axial end which is formed with a protrusion 98 which projects radially outwardly. The outer peripheral surface of the protrusion 98 becomes a proximal surface 82a which is two millimeters in axial length L2. The proximal distance G at a proximal passage 93a is about 1.5 millimeters. The projecting amount of the proximal surface 82a with respect to the cylindrical part 96 is about two millimeters.

[0020] Fig. 8 is a perspective view, similar to Fig. 4, of the second modification of the separator. A separator 52b of this modification would be similar to that in Fig. 6 when viewed in the cross section, but has a special shape in which a proximal surface 82b has triangle concavo-convex surfaces repeating circumferentially. The distance between the top of the peak of the proximal surface 82b and the must-cooled surface is about 1.5 millimeters. A height measured radially from the top of the peak to the bottom of the trough is about two millimeters.

[0021] Fig. 9 is a sectional view, similar to Fig. 5, of the third modification of the separator, and Fig. 10 is a perspective view, similar to Fig. 4, of the separator shown in Fig. 9. A separator 52c of this modification has a disc part 74 whose outer periphery is connected to a cylindrical part 96. The cylindrical part 96 has an axial end which is formed with a protrusion 100, triangle in cross section, which projects radially outwardly. The distance between the top of the triangle protrusion 100 and the must-cooled surface 92 is about 1.5 millimeters. The radial height of the triangle protrusion 100 is about two millimeters. Thinking of the slope of the protrusion 100, a region with a distance, from the must-cooled surface 92, not larger than the predetermined value D (three millimeters for instance) would act as the proximal surface. If the distance from the must-cooled surface 92 becomes larger than the value D, the role of the proximal surface, i.e., sufficient cooling of the must-cooled surface 92, would decrease. The axial length L2 of the protrusion 100, as measured at the point in which the distance from the must-cooled surface 92 is D, is two millimeters.

[0022] Next, the experimental results will be described regarding the motor load about the rotating anode X-ray tube according to the present invention. Fig. 11 is a graph of the experimental results regarding a motor load about the rotating anode X-ray tube having the separator 52 shown in Fig. 2 (i.e., the present invention), and about the rotating anode X-ray tube having the separator 14 shown in Fig. 14 (i.e., the prior art), noting that both of the separators are used with blades 78 (see Fig. 4) taken off. In the graph, a revolving speed of the rotating anode is in abscissa, while a current passing through the motor coil of the direct motor, which is directly connected to the rotary shaft 34, is in ordinate. In the experiment, the revolving speed is raised up to 9,000 rpm, so that an X-ray intensity of the X-ray beam with the fine focus can be increased. For obtaining 9,000 rpm in revolving speed, 13.1 amperes in motor current was required in the prior art, while 9.3 amperes was required in the present invention. When the motor current is about 9 amperes, the electric power is about 800 watts for the motor used in the experiment. Since there is only the difference in shape of the separator between the prior art and the present invention, it is understood that the light load on the motor arises from the short axial length L2 of the proximal surface 82 (see Fig. 2) of the separator 52 in the present invention.

[0023] Fig. 12 is a graph of a water pressure of the cooling water in the case of obtaining the experimental data shown in Fig. 11 for the present invention. Such an extent of the supply pressure shown in the graph would be used in the real rotating anode X-ray tube.

[0024] Although the rotating anode X-ray tube according to the present invention is assumed to be irradiated with an electron beam with the fine focus, it also may be irradiated with an electron beam with the normal focus, for example, about ten millimeters times one millimeter in focus size, after exchanging the separator for one shown in Fig. 14. Furthermore, the rotating anode X-ray tube may be used in the normal focus even with the separator which remains as shown in Fig. 2, depending on the supply power for X-ray generation. The reason for it is as follows. Since an electron beam energy per unit area is not so large in the normal focus, the proximal surface even shorter than the axial length of the electron beam irradiation region often provides a sufficient cooling performance.

[0025] Fig. 15 illustrates component parts of an X-ray generator including the rotating anode X-ray tube according to the present invention. The X-ray generator includes a rotating anode X-ray tube 102, a high-voltage power supply 104 and a coolant supply unit 106. The high-voltage power supply 104 supplies a tube voltage E to circulate a tube current I between a cathode filament 108 of an electron gun of the rotating anode X-ray tube 102 and the rotating anode 10 electrically connected to ground. A negative high voltage, minus 60 kV for instance, is applied to the cathode filament 108 with respect to the rotating anode 10. An electron beam 16 emits from the cathode filament 108 and irradiates the outer periphery of the rotating anode 10 to generate an X-ray 110.

[0026] The coolant supply unit 106 supplies cooling water 112 to the inlet piping nipple 72 of the rotating anode X-ray tube 102. The cooling water 114 having returned after cooling of the rotating anode 10, with an increased temperature, flows out of the outlet piping nipple 70. The returned cooling water 114 may be drained as it is or may be recycled again after being cooled in the coolant supply unit 106.

10	rotating anode
16	electron beam
18	electron beam irradiation region
20	must-cooled surface
22	proximal surface
50	first coolant passage
52	separator
54	first outflow passage
56	first inflow passage
58	second coolant passage
60	partition pipe
62	second outflow passage
64	second inflow passage
74	disc part
76	inclined part
82	proximal surface
84	first member
86	second member
92	must-cooled surface
93	proximal passage
94	cooling water
102	rotating anode X-ray tube
104	high-voltage power supply
106	coolant supply unit
108	cathode filament
110	X-ray
112	cooling water
L1	axial length of electron beam cross section
L2	axial length of proximal surface
L3	axial length of rotating anode
G	proximal distance between must-cooled surface and proximal surface

Claims

1. A rotating anode X-ray tube comprising:

(a) a rotating anode (10) including a cylindrical target which is made of an X-ray generating material and has au outer periphery;
(b) a coolant passage (50) formed inside the rotating anode (10) so that coolant (94) can flow along a must-cooled surface (92) which is positioned at a backside of an electron beam irradiation region (18) on the outer periphery of the target; and
(c) a separator (52) which is arranged stationary within the coolant passage (50) and has a proximal surface (82) facing the must-cooled surface (92) so that the coolant passage (50) is divided into an inflow passage (56), in which the coolant (94) flows toward a proximal passage (93) bounded between the must-cooled surface (92) and the proximal surface (82), and an outflow passage (54) in which the coolant (94) flows away from the proximal passage (93),

characterized in that:

the outer periphery of the cylindrical target has an axial length (L3) in a range between 20 and 100 millimeters; and
the proximal surface (82) of the separator (52) is positioned at a distance (G), from the must-cooled surface (92), in a range between 0.1 and 3.0 millimeters and has an axial length (L2) not greater than five millimeters.

2. A rotating anode X-ray tube according to claim 1, **characterized in that** the axial length (L2) of the proximal surface (82) is not greater than three millimeters.

3. A rotating anode X-ray tube according to claim 1, **characterized in that** the electron beam irradiation region (18) provided on the outer periphery of the target has an axial length (L1) not greater than three millimeters.

4. A rotating anode X-ray tube according to claim 3, **characterized in that** the axial length (L1) of the electron beam irradiation region (18) is not greater than one millimeter.

5. A rotating anode X-ray tube according to any one of claims 1 to 4, **characterized in that**:

the separator (52) has a disc part (74) and an inclined part (76) connected to an outer periphery of the disc part (74);
the inclined part (76) has a shape of a frustum of a cone; and
the inclined part (76) has an outer peripheral surface at its radially outer end, the outer peripheral surface becoming the proximal surface (82).

6. An X-ray generator comprising:

(a) a rotating anode X-ray tube (102) including:

(a1) a rotating anode (10) including a cylindrical target which is made of an X-ray generating material and has au outer periphery;
(a2) a coolant passage (50) formed inside the rotating anode (10) so that coolant (94) can flow along a must-cooled surface (92) which is positioned at a backside of an electron beam irradiation region (18) on the outer periphery of the target; and
(a3) a separator (52) which is arranged stationary within the coolant passage (50) and has a proximal surface (82) facing the must-cooled surface (92) so that the coolant passage (50) is divided into an inflow passage (56), in which the coolant (94) flows toward a proximal passage (93) bounded between the must-cooled surface (92) and the proximal surface (82), and an outflow passage (54) in which the coolant (94) flows away from the proximal passage (93),

(b) a coolant supply unit (106) for supplying the coolant (94) to the coolant passage (50) of the rotating anode X-ray tube (102); and
(c) a high-voltage power supply (104) for supplying a tube voltage and a tube current to the rotating anode X-ray tube (102),

characterized in that:

the outer periphery of the cylindrical target has an axial length (L3) in a range between 20 and 100 millimeters; and
the proximal surface (82) of the separator (52) is positioned at a distance (G), from the must-cooled surface (92), in a range between 0.1 and 3.0 millimeters and has an axial length (L2) not greater than five millimeters.

7. An X-ray generator according to claim 6, **characterized in that** the axial length (L2) of the proximal surface (82) is not greater than three millimeters.

8. An X-ray generator according to claim 6, **characterized in that** the electron beam irradiation region (18) provided on the outer periphery of the target has an axial length (L1) not greater than three millimeters.

9. An X-ray generator according to claim 8, **characterized in that** the axial length (L1) of the electron beam irradiation region (18) is not greater than one millimeter.

10. An X-ray generator according to any one of claims 6 to 9, **characterized in that**:

the separator (52) has a disc part (74) and an inclined part (76) connected to an outer periphery of the disc part (74) ;
the inclined part (76) has a shape of a frustum of a cone; and
the inclined part (76) has an outer peripheral surface at its radially outer end, the outer peripheral surface becoming the proximal surface (82).

FIG. 1

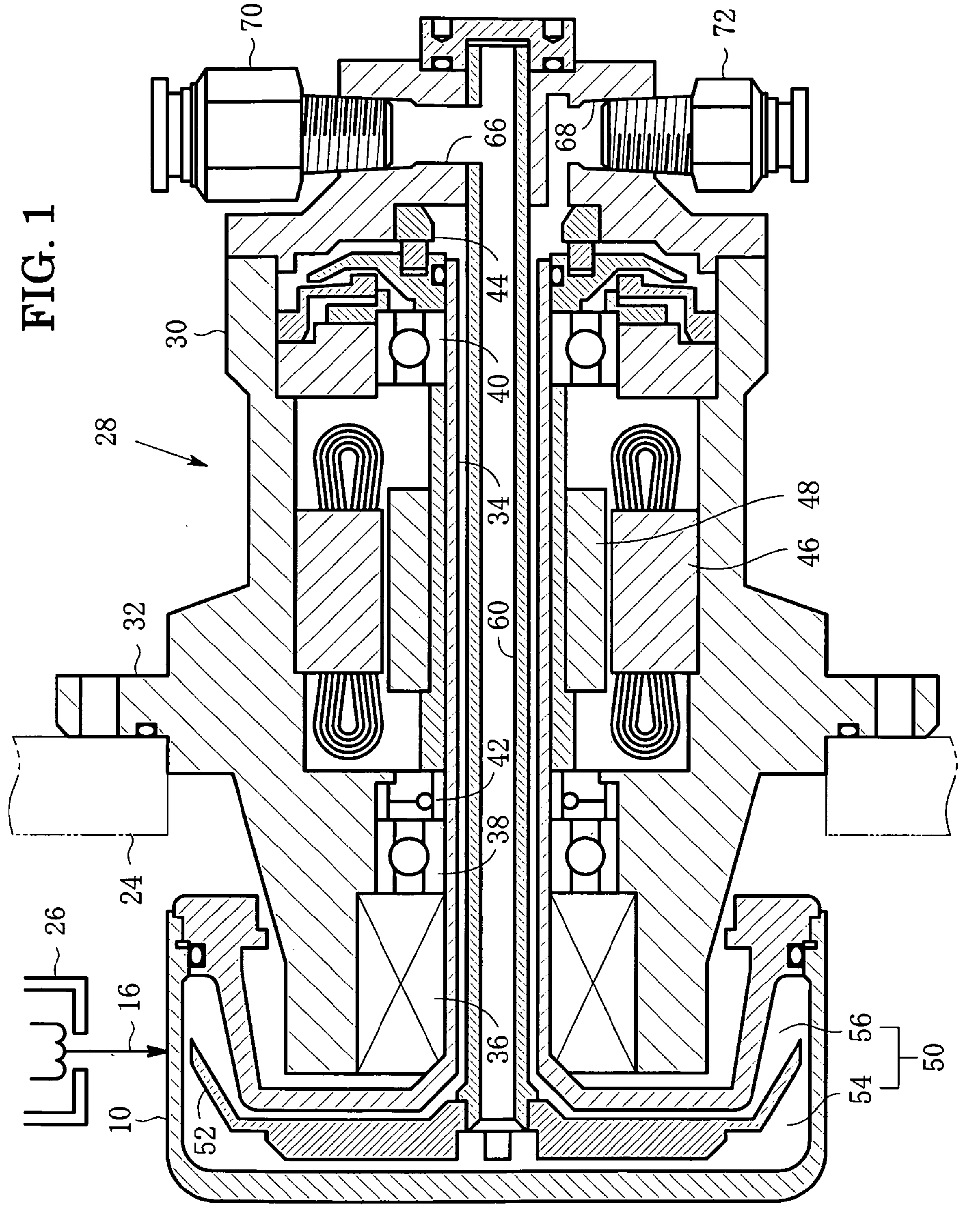


FIG. 2

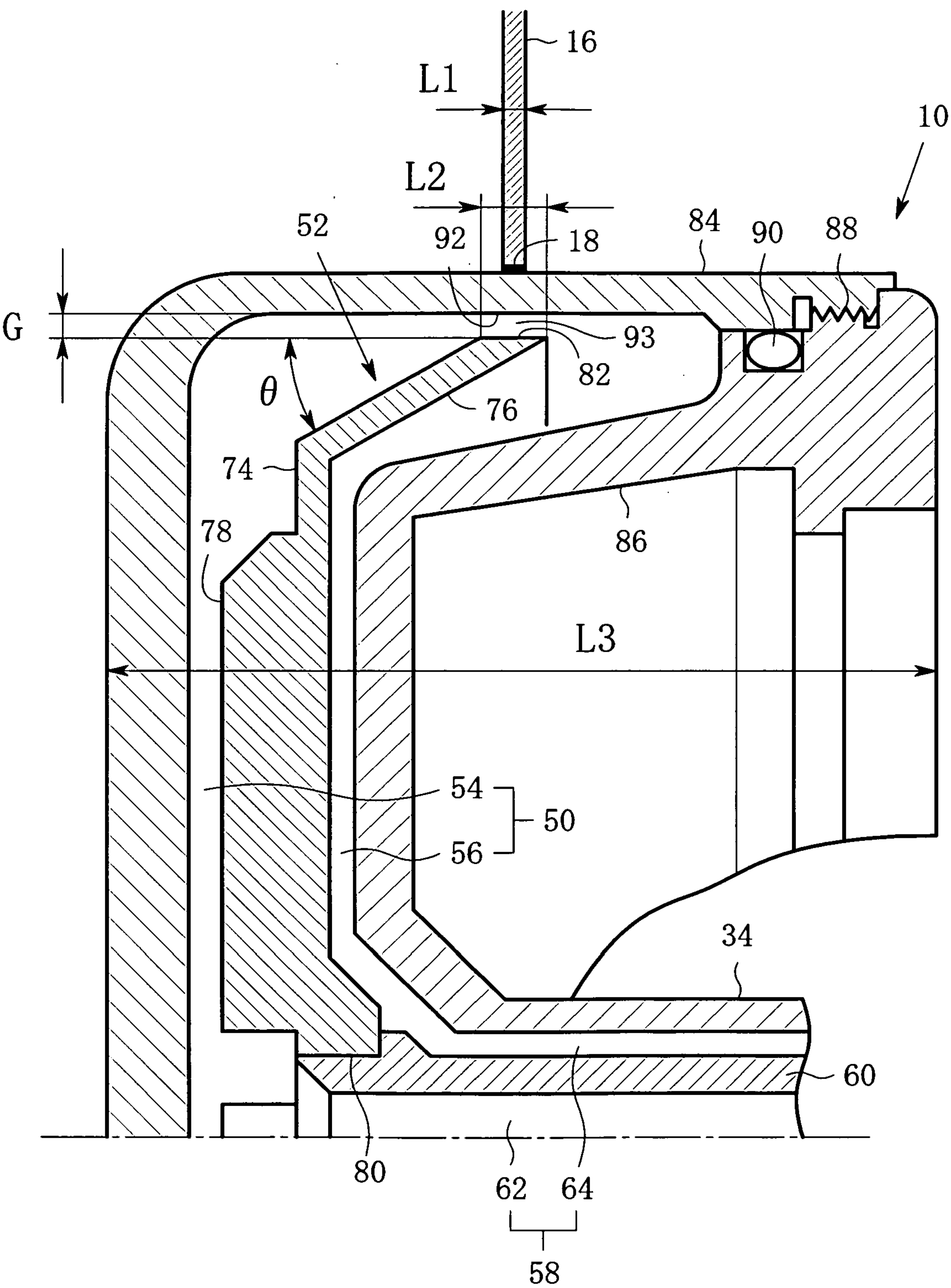

16
L1
10
L2
52
92
18
84
90
88
G
93
82
θ
76
74
78
86
L3
54
50
56
34
60
80
62
64
58

FIG. 3

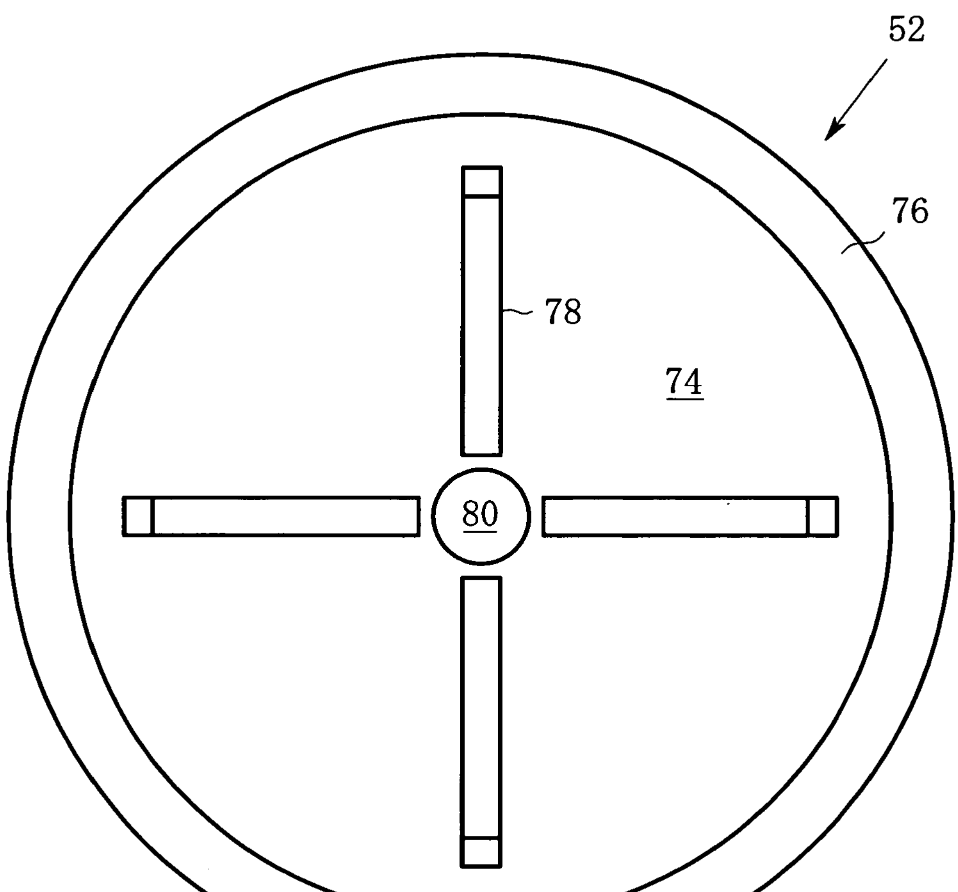


FIG. 4

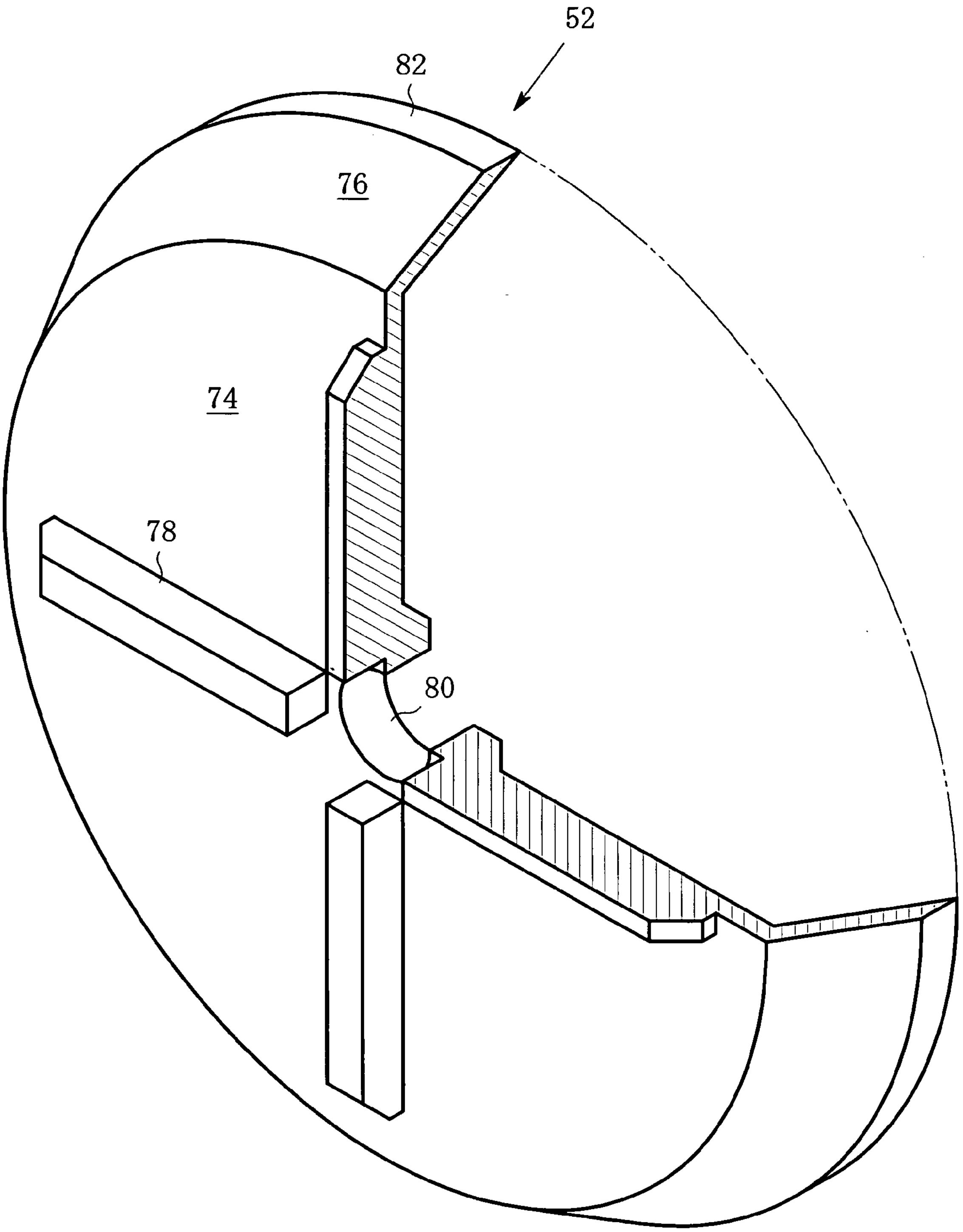


FIG. 5

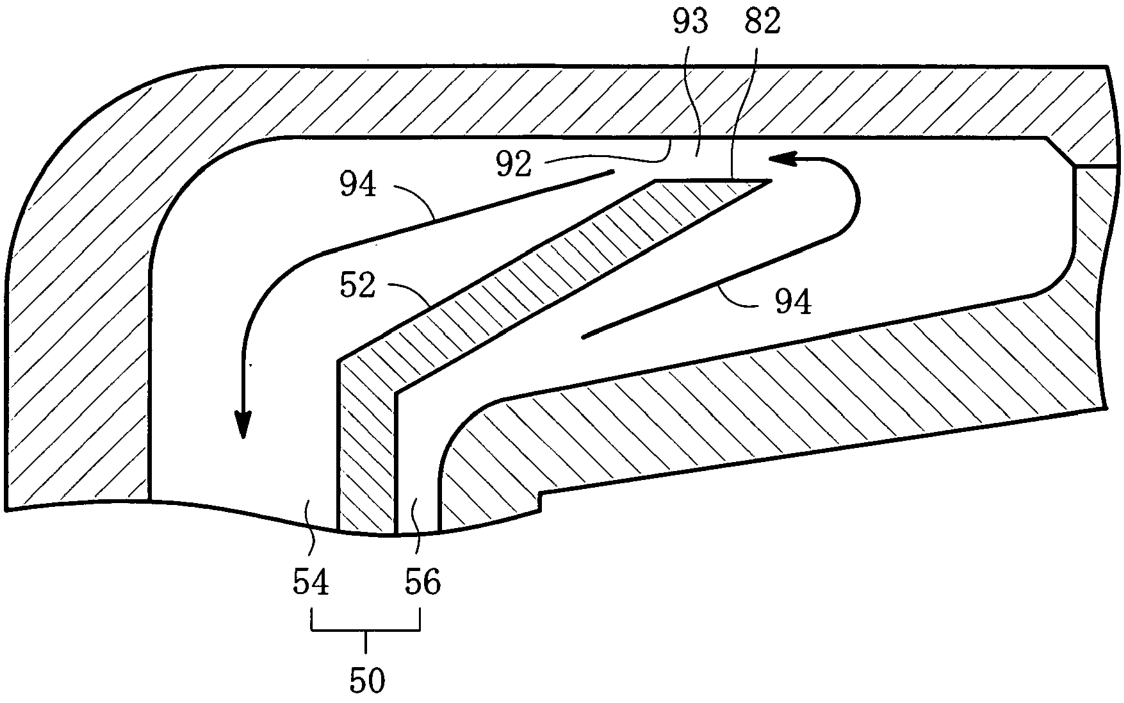


FIG. 6

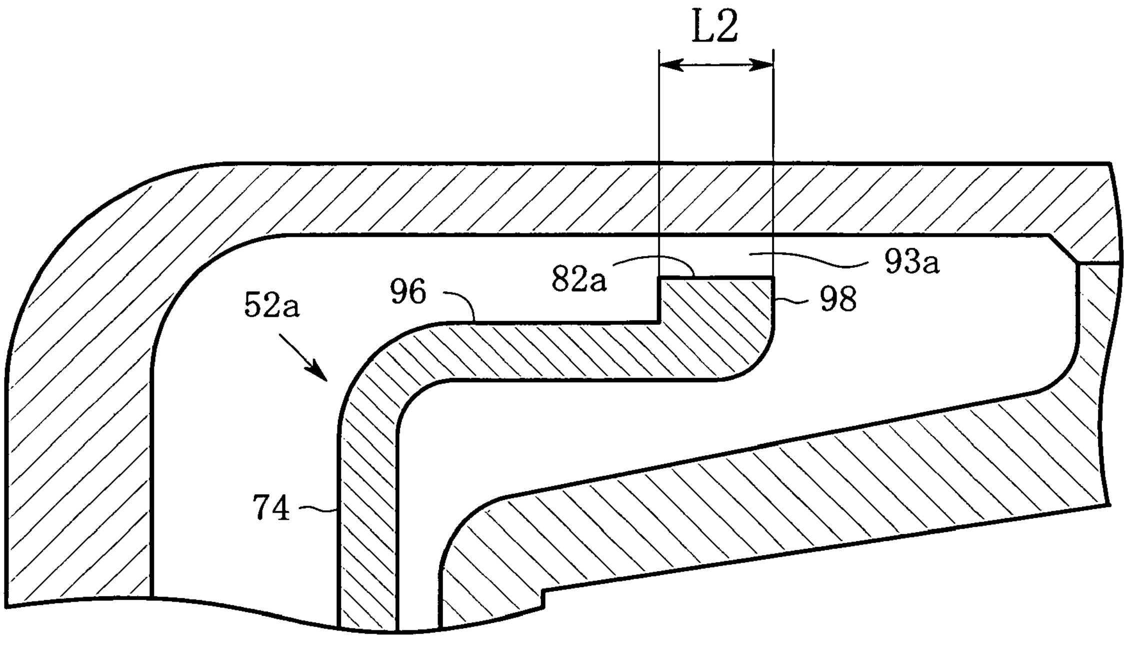


FIG. 7

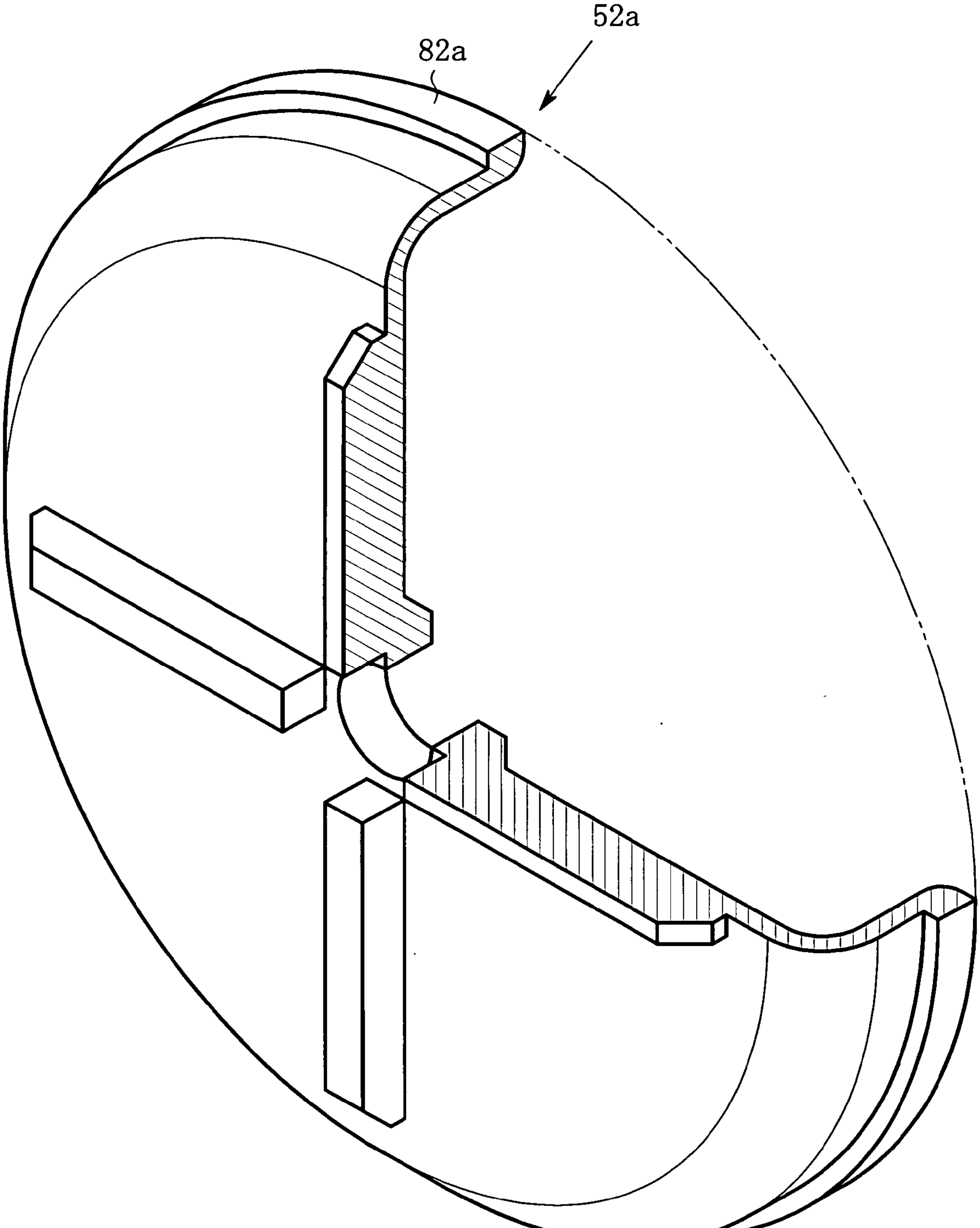


FIG. 8

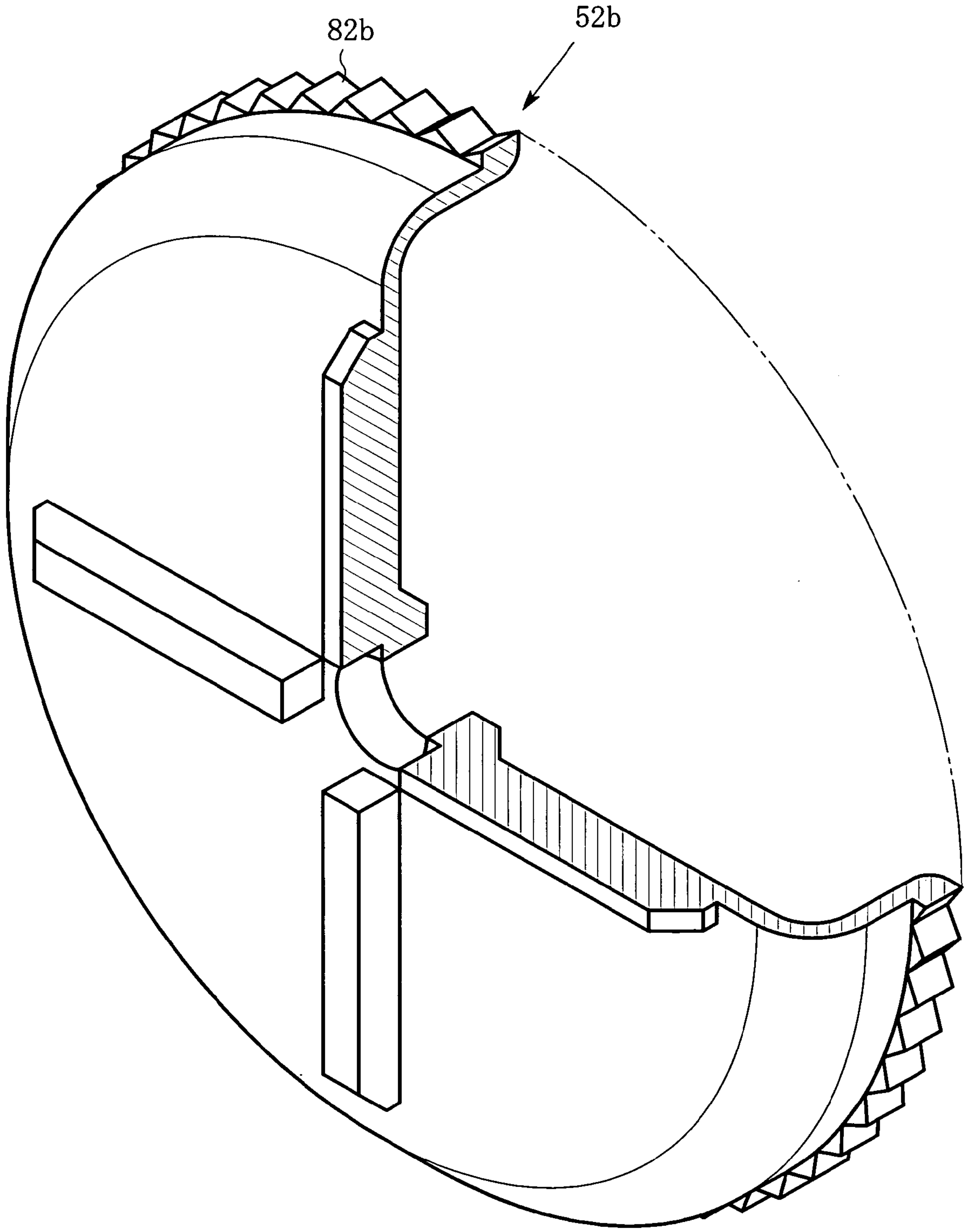


FIG. 9

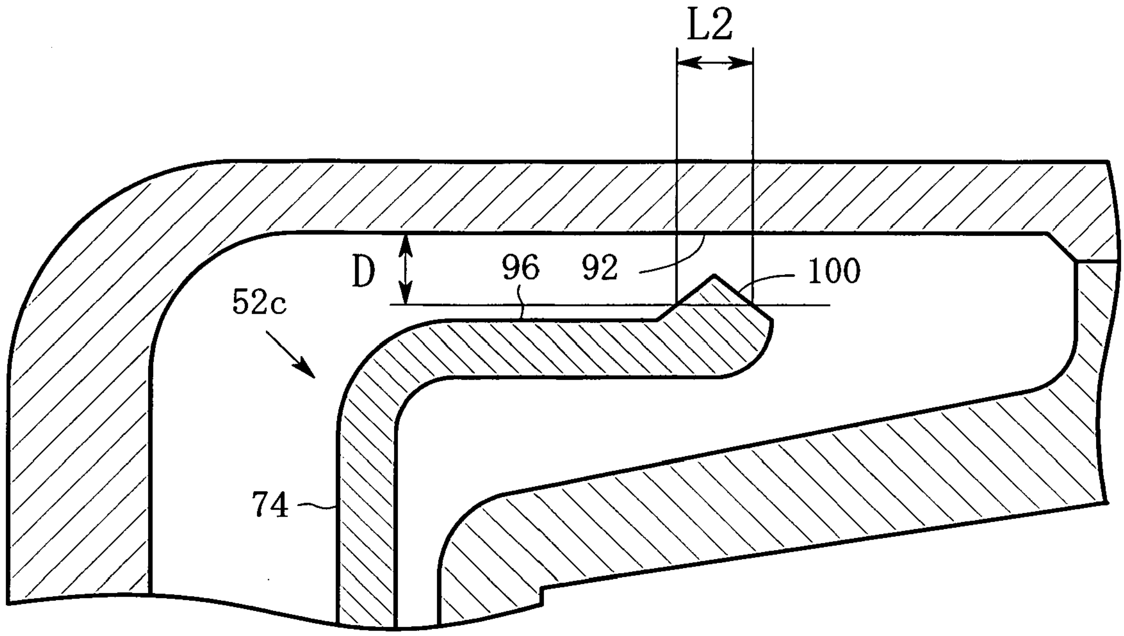


FIG. 10

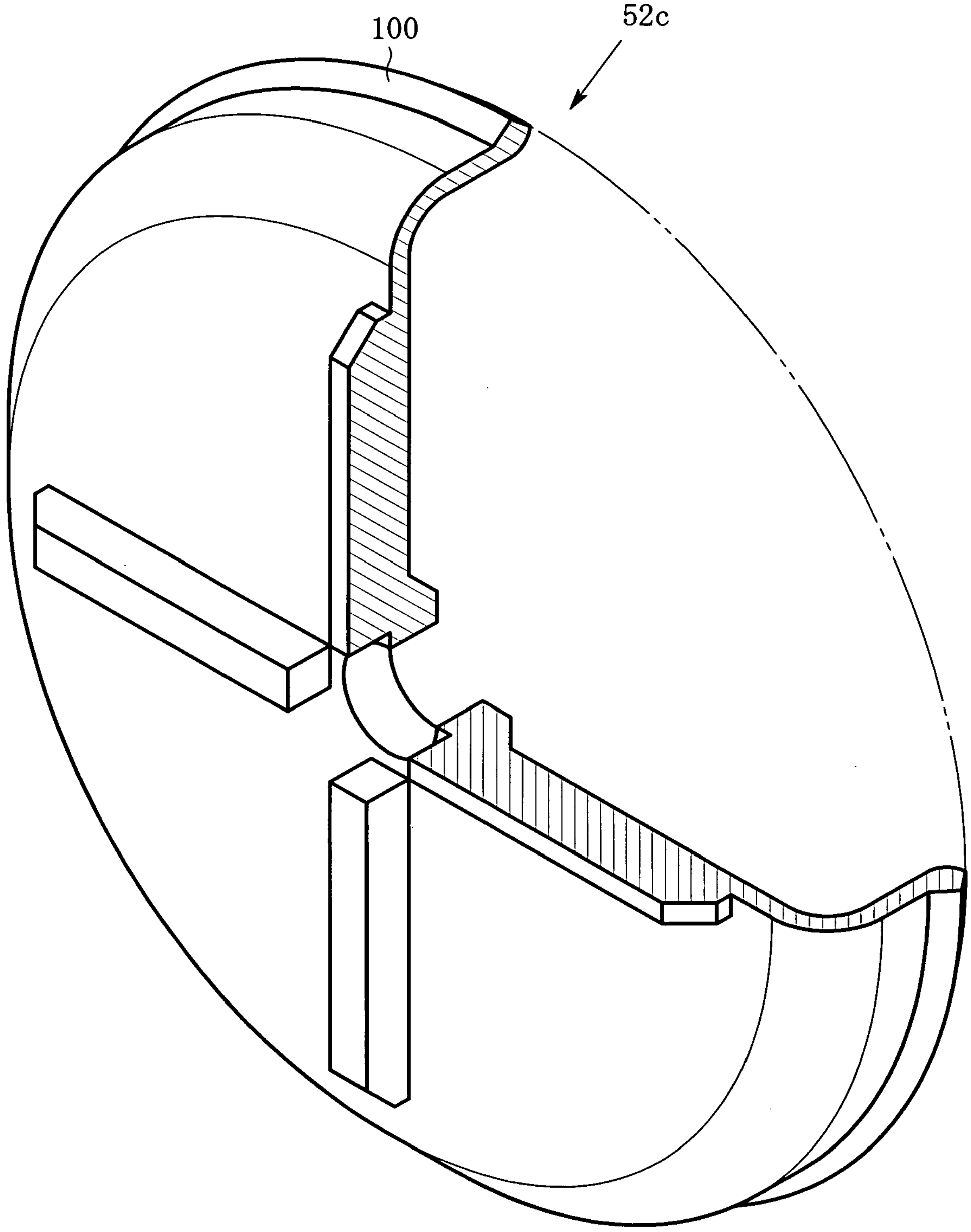


FIG. 11

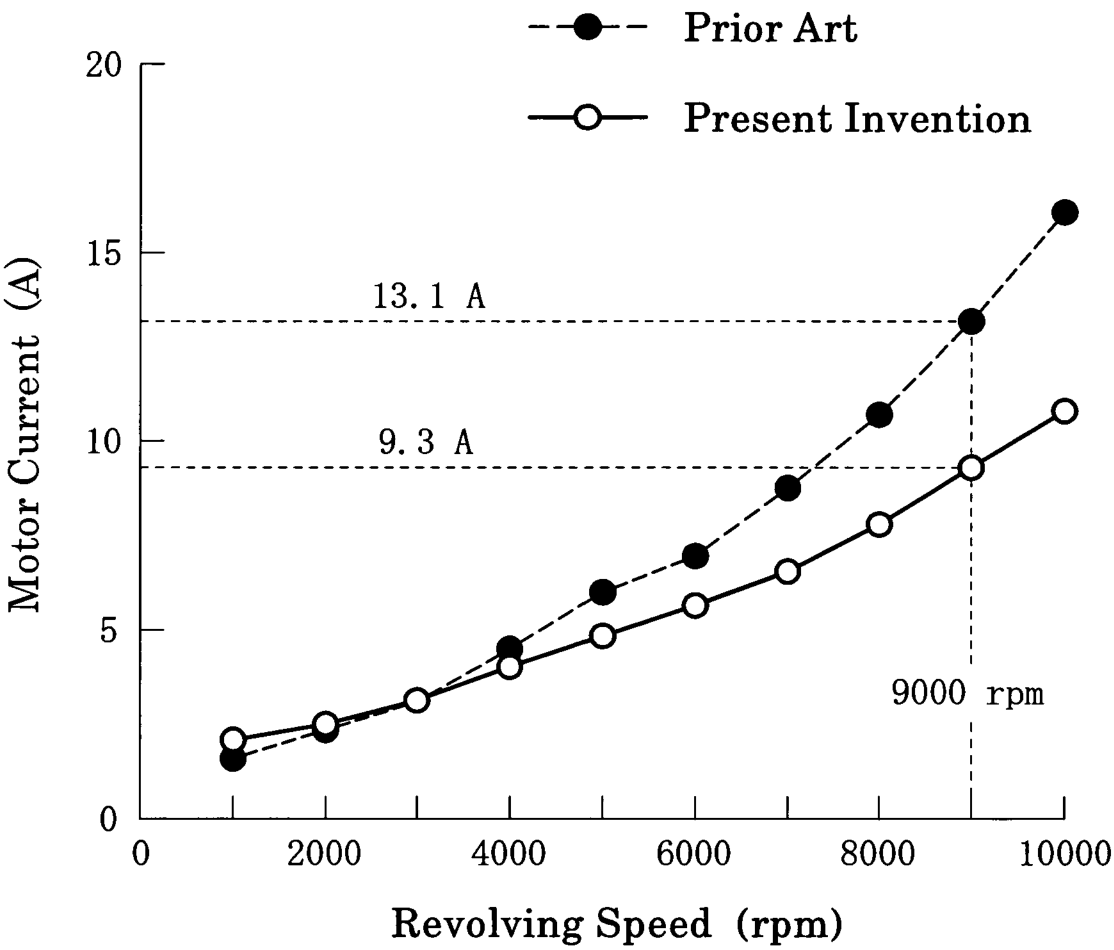

Prior Art
Present Invention
20
15
10
5
0
Motor Current (A)
13. 1 A
9. 3 A
9000 rpm
0
2000
4000
6000
8000
10000
Revolving Speed (rpm)

FIG. 12

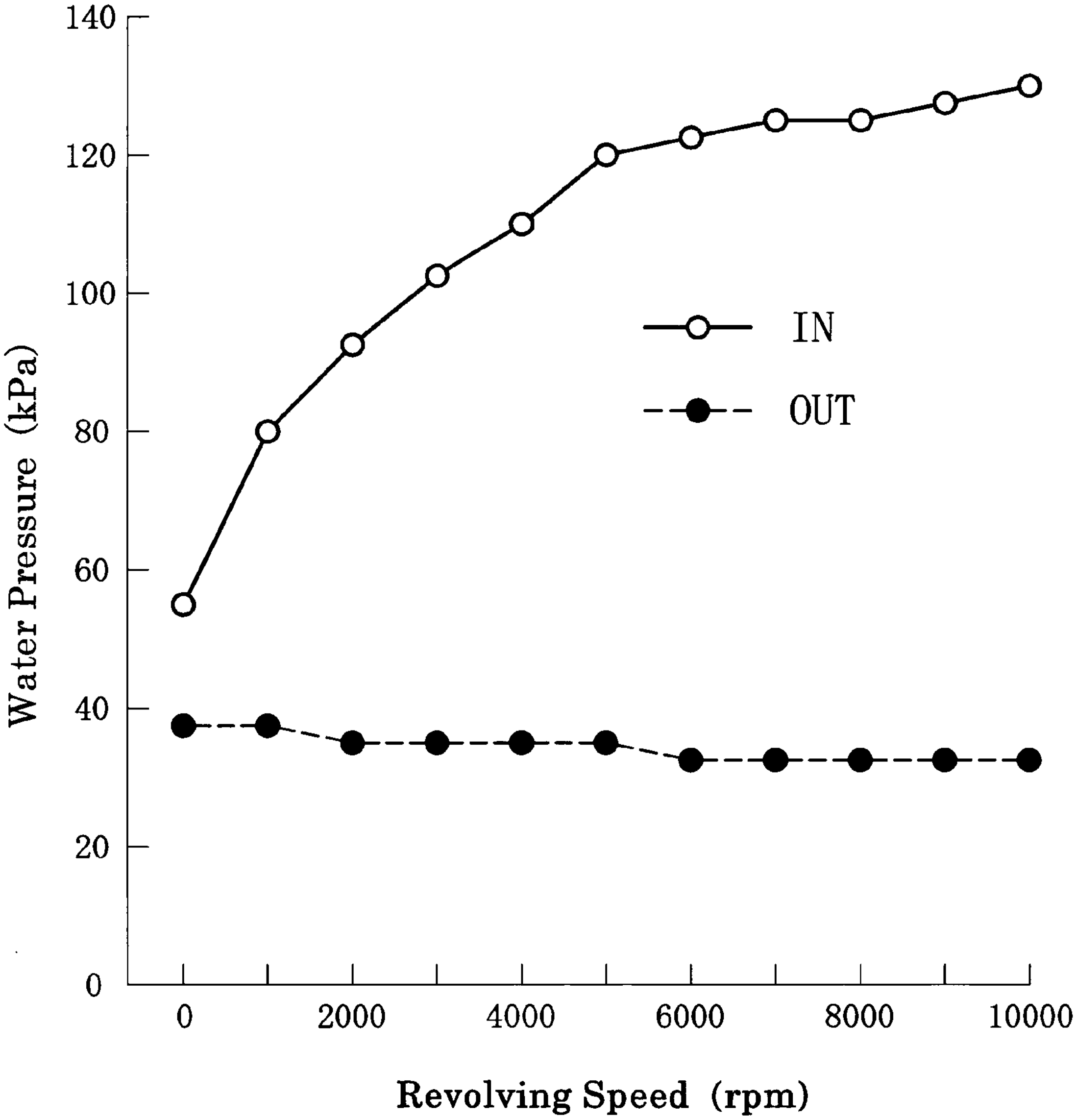

140
120
100
80
60
40
20
0
Water Pressure (kPa)
IN
OUT
0
2000
4000
6000
8000
10000
Revolving Speed (rpm)

FIG. 13

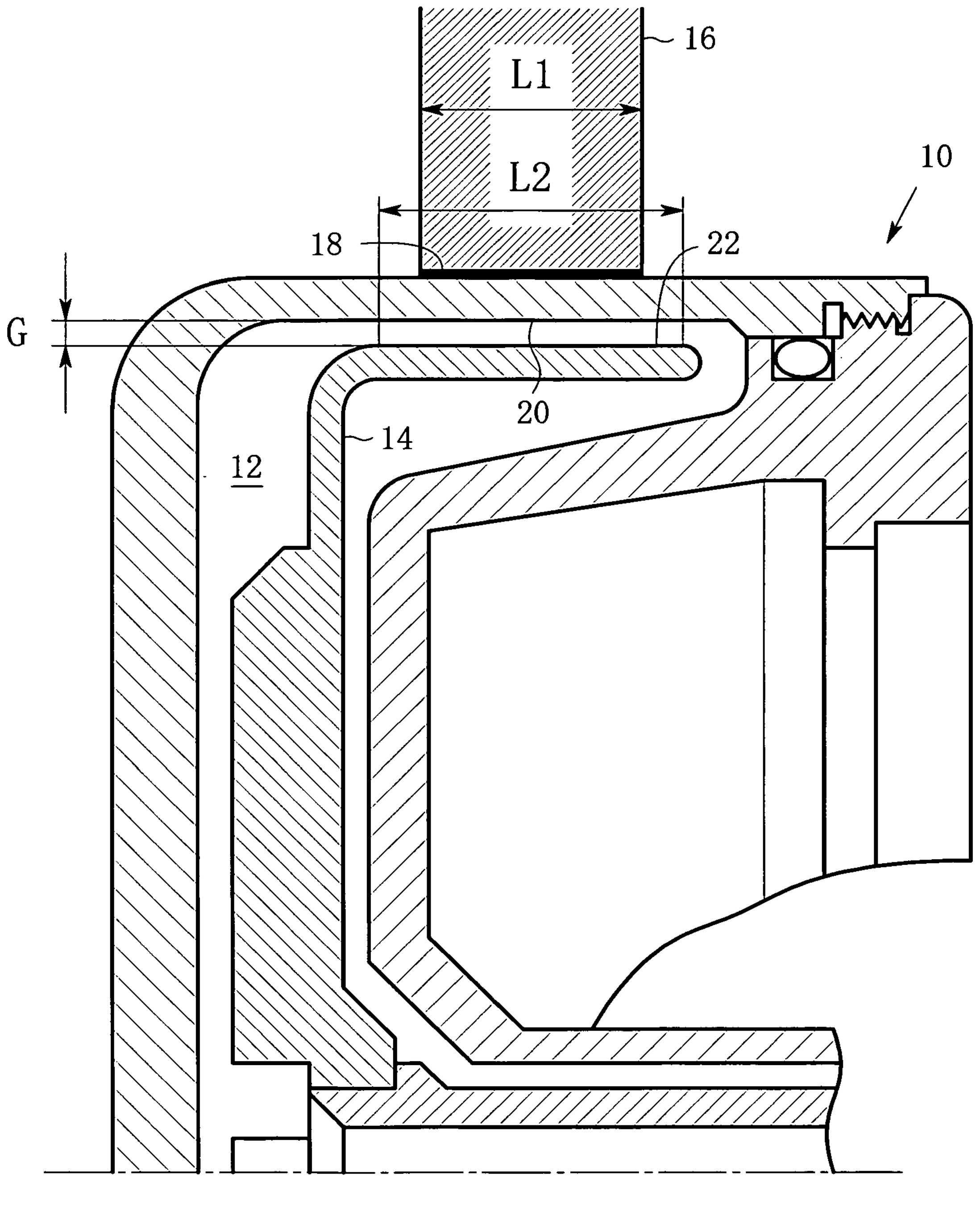


FIG. 14

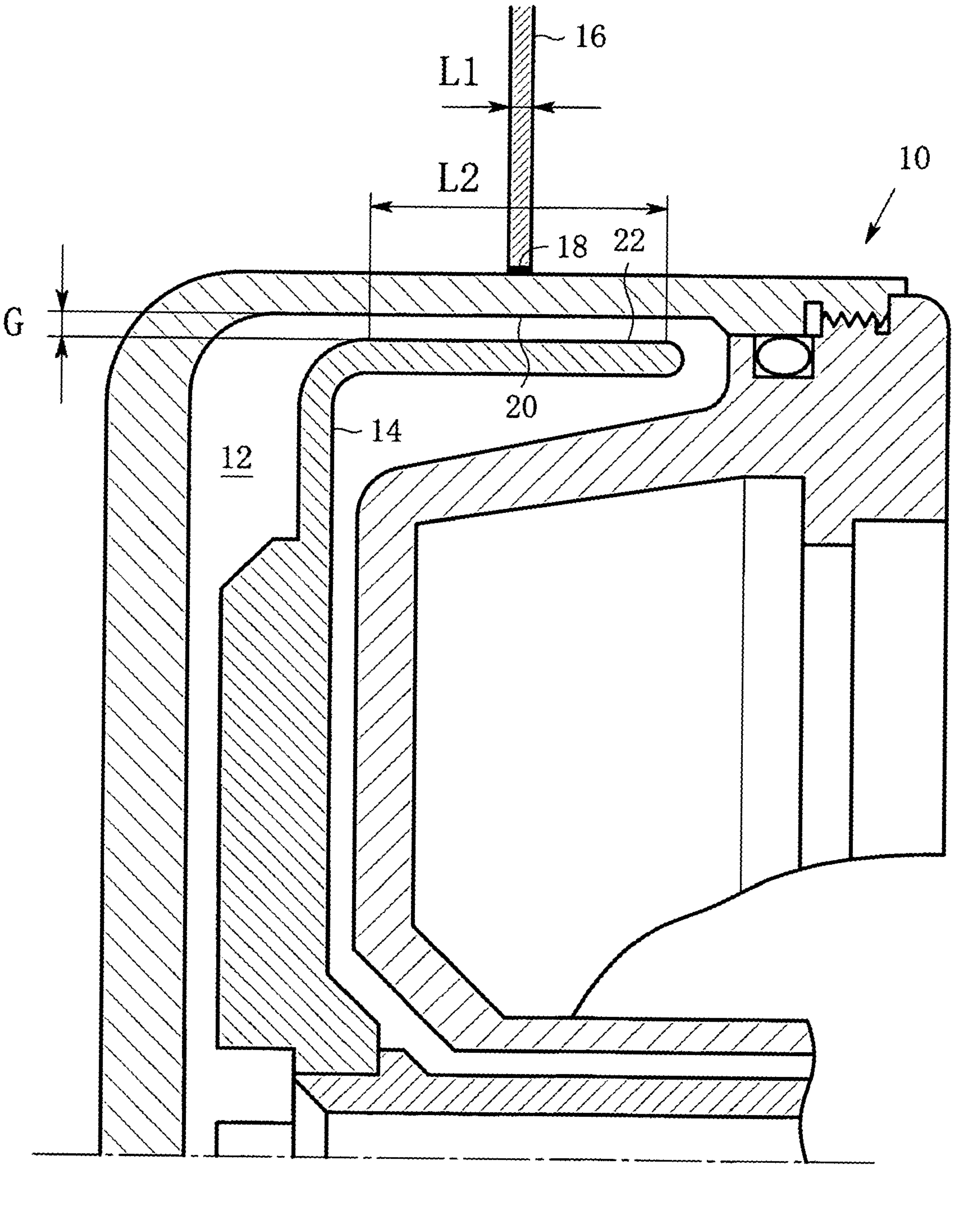
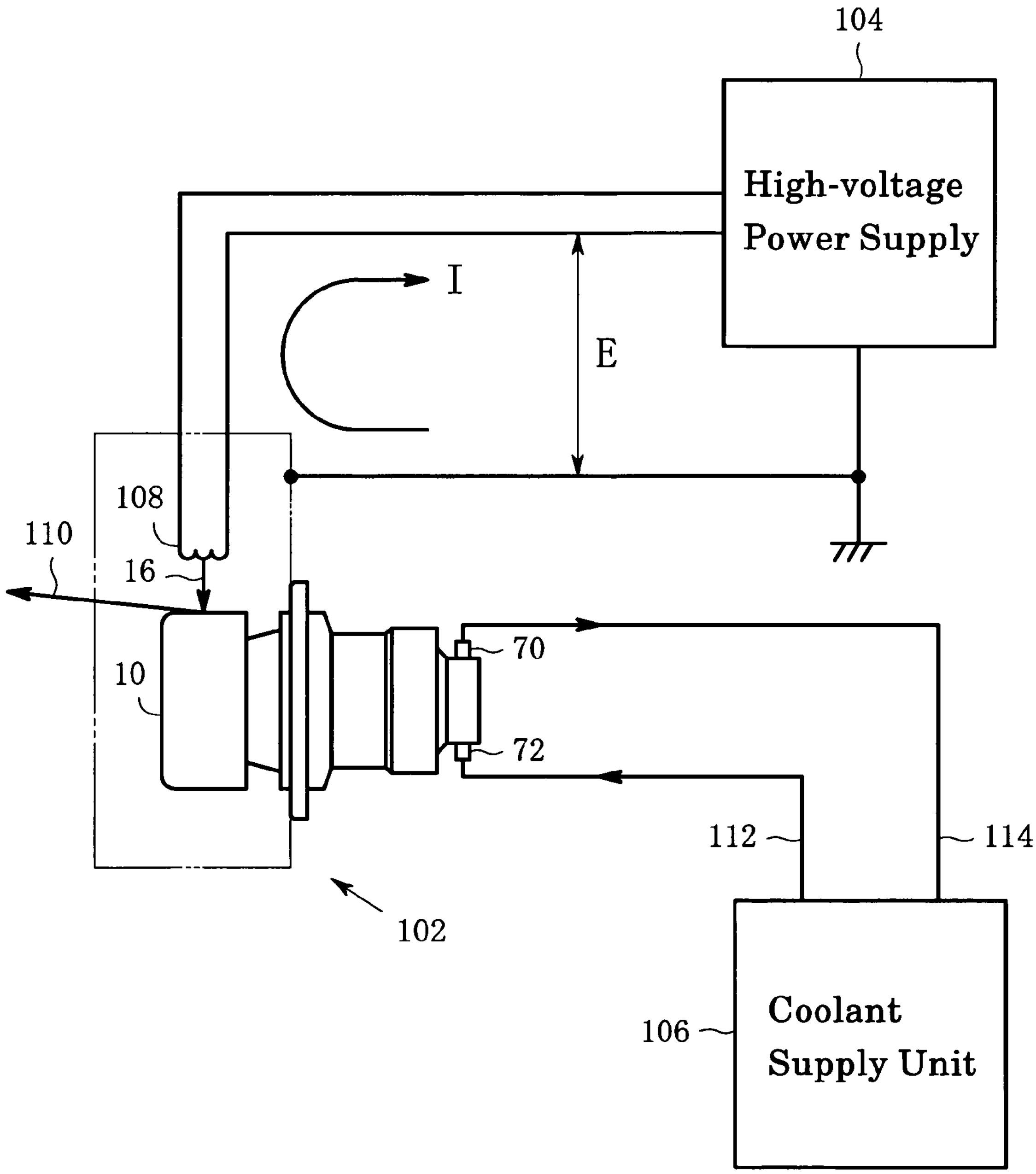


FIG. 15


104
High-voltage
Power Supply
I
E
108
110
16
10
70
72
112
114
102
106
Coolant
Supply Unit