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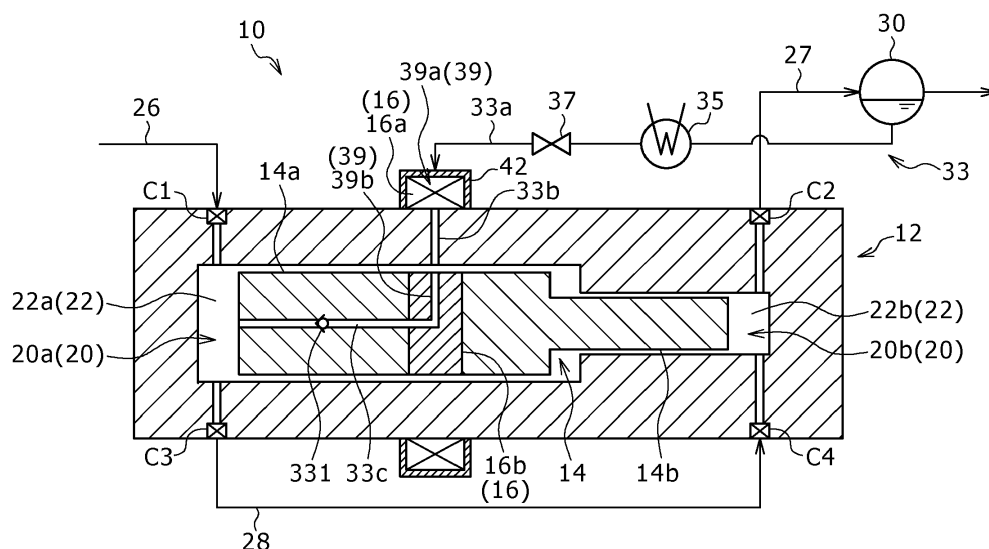
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(54) **RECIPROCATING COMPRESSION APPARATUS**

(57) To simplify a configuration for returning to un-compressed gas a lubricant separated from gas discharged from a compression chamber, while effectively using the lubricant, a reciprocating compression apparatus includes: a cylinder; a piston disposed in the cylinder to form a compression chamber therein; a drive section for generating drive force for reciprocating the piston in the cylinder; a separator for separating a lubricant from gas discharged from the compression chamber; and a

return line for returning the lubricant separated in the separator to a return destination where gas containing the lubrication is present and a pressure is lower than that in the separator. The return line includes a lubrication cooling unit for cooling the lubricant flowing through the return line and a drive section cooling section for cooling the drive section with the lubricant which has been cooled in the lubricant cooling unit 35.

FIG. 1



Description

BACKGROUND OF THE INVENTION

(FIELD OF THE INVENTION)

[0001] The present invention relates to a reciprocating compression apparatus.

(DESCRIPTION OF THE RELATED ART)

[0002] Hitherto, as disclosed in JP 2004-116330 A, a reciprocating compressor for compressing a working gas in a compression chamber by reciprocating a plunger in a cylinder is known. This reciprocating compressor is provided with a lubricating oil flow passage which supplies a lubricating oil for lubricating and sealing the outer periphery of the plunger.

[0003] Moreover, as disclosed in below, using a linear motor for reciprocating a piston is also known. A fluid machine disclosed in JP 2010-513779 A is provided with a cooling medium circuit for cooling the linear motor.

(SUMMARY OF THE INVENTION)

(TECHNICAL PROBLEM)

[0004] JP 2004-116330 A discloses supplying the lubricating oil to the outer periphery of the plunger through a lubricating oil flow passage. However, JP 2004-116330 A discloses, as a configuration for supplying a lubricant, no other configurations than the lubricating oil flow passage. On the other hand, JP 2010-513779 A discloses the cooling medium circuit for cooling the linear motor for reciprocating the piston. However, JP 2010-513779 A merely indicates that, as a cooling medium, the same cooling medium as a cooling medium for cooling a discharged gas can be used.

[0005] The present invention has been made in view of the above related art, and an object of the present invention is to simplify a configuration for returning to an uncompressed gas a lubricant separated from a gas discharged from a compression chamber, while effectively using the lubricant.

(SOLUTION TO PROBLEM)

[0006] To achieve the above object, the present invention provides a reciprocating compression apparatus including: a cylinder; a piston disposed in the cylinder in such a manner as to form a compression chamber therein; a drive section which generates a drive force for reciprocating the piston in the cylinder; a separator for separating a lubricant from a gas discharged from the compression chamber; and a return line for returning the lubricant separated in the separator to a return destination in which a gas is present and a pressure is lower than that in the separator, in which the return line is provided

with a drive section cooling section for cooling the drive section with the lubricant.

[0007] In the present invention, the lubricant is separated in the separator from the gas which has been discharged from the compression chamber. The lubricant which has been separated in the separator is returned through the return line to the return destination. In the return line, the lubricant cools the drive section. Then, the lubricant which has cooled the drive section is returned to the return destination in which a gas is present and a pressure is lower than that in the separator. Consequently, a pressure-feed means for returning the lubricant is unnecessary so that a configuration for returning the lubricant to the uncompressed gas can be simplified. Moreover, the lubricant is not only merely returned to the gas, but effectively used for cooling the cooling parts. Consequently, a configuration for cooling the drive section which drives the piston can be simplified. Accordingly, newly adding a cooling circuit or the like is unnecessary, and thus simplifying a configuration of the reciprocating compression apparatus can be performed. Note that the return destination is not limited to a portion in which a pressure is constantly lower than that in the separator, but may be a portion in which a pressure is temporarily lower than that in the separator.

[0008] The return line may include a piston internal passage formed in the piston and communicating with the compression chamber. In this case, the lubricant which has cooled the drive section may be returned through the piston internal passage into the compression chamber as the return destination.

[0009] In this embodiment, the lubricant which has cooled the drive section flows through the piston internal passage formed in the piston and is returned into the compression chamber. Thus, the lubricant can be directly returned into the compression chamber in a constant manner without being influenced by a position of the piston. A pressure in the compression chamber is lower than a pressure on a discharge side during a process excluding a gas discharge process so that a differential pressure between the pressure in the separator and the pressure in the compression chamber allows the lubricant to flow through the return line. Consequently, a pressure-feed means for the lubricant is unnecessary.

[0010] The return line may include, in the cylinder, an outflow part provided at a position constantly between piston rings during reciprocation of the piston. In this case, the lubricant may be returned to a space between the piston rings as the return destination.

[0011] In this embodiment, the lubricant is supplied to the space between the piston rings. Consequently, the gas in the compression chamber can be prevented from leaking into a gap between the cylinder and the piston. A pressure in the space between the piston rings is approximately equal to or lower than a time average value of the pressure in the compression chamber, and consequently a pressure-feed means for the lubricant is unnecessary.

[0012] The return line may be connected to a suction line connected to the cylinder. In this case, the lubricant may be returned into the suction line as the return destination. In this embodiment, the lubricant is returned to the suction line in which a pressure is lower than that in the compression chamber. Thus, a differential pressure between the pressure in the separator and the pressure in the suction line allows the lubricant to effectively return to the gas.

[0013] The return line may be, in the cylinder, connected to a portion at least temporarily communicating with the compression chamber. In this case, the lubricant may be returned into the compression chamber as the return destination.

[0014] In this embodiment, if the portion to which the return portion is connected temporarily communicates with the compression chamber, the lubricant flows into the compression chamber only when the return line communicates with the compression chamber. If the portion to which the return portion is connected constantly communicates with the compression chamber, the lubricant flows into the compression chamber without such a restriction.

[0015] The drive section cooling section may be configured such that the lubricant flowing through the return line is supplied to the drive section. In this embodiment, the lubricant can effectively cool the drive section.

(EFFECTS OF THE INVENTION)

[0016] As described above, according to the present invention, a configuration for returning to an uncompressed gas the lubricant separated from a gas discharged from the compression chamber can be simplified, while effectively using the lubricant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017]

FIG. 1 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus according to a first embodiment of the present invention.

FIG. 2 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus according to a second embodiment of the present invention.

FIG. 3 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus according to a third embodiment of the present invention.

FIG. 4 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus according to a fourth embodiment of the present invention.

FIG. 5 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus

according to a fifth embodiment of the present invention.

FIG. 6 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus according to a modification of the second embodiment of the present invention.

FIG. 7 is a diagram schematically illustrating a configuration of a reciprocating compression apparatus according to another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0018] Hereinafter, preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

(FIRST EMBODIMENT)

[0019] As illustrated in FIG. 1, a reciprocating compression apparatus 10 according to a first embodiment includes a cylinder 12, a piston 14 disposed in the cylinder 12, and a drive section 16 which generates a drive force for reciprocating the piston 14. In this reciprocating compression apparatus 10, a hydrogen gas, for example, is a gas to be compressed.

[0020] An inner space 20 of the cylinder 12 in which the piston 14 is housed is formed in a shape long in one direction. This inner space 20 has a shape in which a part having a large width, which is a length in a direction orthogonal to a longitudinal direction (hereinafter referred to as first space part 20a), and a part having a small width (hereinafter referred to as second space part 20b) are connected to each other. Note that the inner space 20 is not limited to a shape in which space parts having lengths different from each other are connected to each other. The inner space 20 may be formed to have the same width over the entire longitudinal direction.

[0021] In the cylinder 12, a portion forming the first space part 20a and a portion forming the second space part 20b may be integrally formed, and may be separately formed and then connected to each other.

[0022] The piston 14 includes a first portion 14a having a width corresponding to the width of the first space part 20a and a second portion 14b having a width corresponding to the width of the second space part 20b. An end part of the first portion 14a in the longitudinal direction is connected to an end part of the second portion 14b in the longitudinal direction, and the first portion 14a and the second portion 14b are integrally formed. The first portion 14a is housed in the first space part 20a. The second portion 14b is disposed mainly in the second space part 20b, while a portion on the first portion 14a side enters the first space part 20a from the second space part 20b.

[0023] In the first space part 20a, a portion between the cylinder 12 and a tip part of the first portion 14a, which is an end part on the side opposite to the second portion

14b, is a first compression chamber 22a. In the second space part 20b, a portion between the cylinder 12 and a tip part of the second portion 14b, which is an end part on the side opposite to the first portion 14a, is a second compression chamber 22b. In other words, in the compression apparatus 10 according to the first embodiment, a compression chamber 22 including the first compression chamber 22a and the second compression chamber 22b is formed.

[0024] The drive section 16 is configured to include a linear motor. Specifically, the drive section 16 includes a coil 16a, which is an electromagnet, as a stator fixed on an outer surface of the cylinder 12 and a magnet 16b fixed on the piston 14 as a mover. The magnet 16b is disposed on the first portion 14a in the piston 14. A repelling force and an attractive force between the coil 16a and the magnet 16b cause the piston 14 to reciprocate.

[0025] A suction line 26 through which a gas to be drawn into the first compression chamber 22a flows, a discharge line 27 through which the gas which has been discharged from the second compression chamber 22b flows, and a connection line 28 through which the first compression chamber 22a and the second compression chamber 22b communicate with each other are connected to the cylinder 12.

[0026] A connection line through which the suction line 26 and the compression chamber 22 (first compression chamber 22a) communicate with each other is provided with a check valve C1 which allows only a flow from the suction line 26 to the compression chamber 22. A connection line through which the compression chamber 22 (second compression chamber 22b) and the discharge line 27 communicate with each other is provided with a check valve C2 which allows only a flow from the compression chamber 22 to the discharge line 27. A connection line through which the connection line 28 and the first compression chamber 22a communicate with each other is provided with a check valve C3 which allows only a flow from the first compression chamber 22a to the connection line 28. A connection line through which the connection line 28 and the second compression chamber 22b communicate with each other is provided with a check valve C4 which allows only a flow from the connection line 28 to the second compression chamber 22b. Consequently, the gas flows through the connection line 28 from the first compression chamber 22a toward the second compression chamber 22b. In other words, the reciprocating compression apparatus 10 is configured as the two-stage compression type compression apparatus 10 in which the gas which has been compressed in the first compression chamber 22a is further compressed in the second compression chamber 22b.

[0027] The discharge line 27 is provided with a separator 30. The gas discharged from the reciprocating compression apparatus 10 contains an ionic liquid as a lubricant. The separator 30 separates the ionic liquid from the gas which has been discharged from the compression chamber 22 (second compression chamber 22b).

[0028] The separator 30 is connected to a return line 33. The return line 33 returns the ionic liquid separated in the separator 30 to a return destination in which a pressure is lower than that in the separator 30. In this embodiment, the return destination is set to be the first compression chamber 22a.

[0029] The return line 33 includes a cylinder external passage 33a which connects the separator 30 to the cylinder 12, a cylinder internal passage 33b which penetrates a peripheral wall of the cylinder 12, and a piston internal passage 33c provided in the piston 14. The piston internal passage 33c is provided with a check valve 331.

[0030] The cylinder external passage 33a is provided with a lubricant cooling unit 35 for cooling the ionic liquid flowing through the return line 33. The lubricant cooling unit 35 is configured to include a heat exchanger which cools the ionic liquid with a cooling medium, such as cooling water. Moreover, the cylinder external passage 33a is provided with a pressure reducing valve 37. The pressure reducing valve 37 may be also omitted.

[0031] The cylinder internal passage 33b is a passage through which the exterior and interior of the cylinder 12 communicate with each other, in which an outer end part (inflow end part) is connected to one end part (outflow end part) of the cylinder external passage 33a. An inner end part (outflow end part) of the cylinder internal passage 33b opens to the inner space 20. Specifically, the ionic liquid is fed through the cylinder internal passage 33b from the exterior of the cylinder 12 to the interior of the cylinder 12.

[0032] The piston internal passage 33c communicates with the cylinder internal passage 33b through a gap between an inner wall surface of the cylinder 12 and an outer peripheral surface of the piston 14. The piston internal passage 33c is formed to penetrate the piston 14, in which one end part opens to a peripheral surface of the first portion 14a and the other end part opens to a tip surface of the first portion 14a. This tip surface faces the first compression chamber 22a so that the other end part (outflow end part) of the piston internal passage 33c opens to the first compression chamber 22a. The piston internal passage 33c is configured, such that the one end part opens to the peripheral surface and the other end part opens to the tip surface, so as to be bent therebetween. Consequently, the ionic liquid which has passed through the cylinder internal passage 33b radially flows in from the peripheral surface of the piston 14, and then the direction of a flow of the ionic liquid changes to a longitudinal direction of the piston 14.

[0033] The return line 33 is provided with a drive section cooling section 39 for cooling the drive section 16 with the ionic liquid which has been cooled in the lubricant cooling unit 35. The drive section cooling section 39 includes a stator cooling part 39a for cooling the coil 16a and a mover cooling part 39b for cooling the magnet 16b.

[0034] The stator cooling part 39a is configured to include a portion passing through the coil 16a in the cylinder external passage 33a. In the stator cooling part 39a, the

ionic liquid flowing through the cylinder external passage 33a is directly supplied to the coil 16a. The coil 16a is covered by a case 42 such that the high-pressure ionic liquid passes through the coil 16a without leaking to the exterior. Note that the stator cooling part 39a may include a passage radially penetrating the coil 16a and a passage circumferentially penetrating the same. When this configuration is employed, the coil 16a is cooled by the ionic liquid flowing through the passages.

[0035] The mover cooling part 39b is configured to include a hole formed in the magnet 16b in the piston internal passage 33c. In the mover cooling part 39b, the ionic liquid which has flown through the cylinder internal passage 33b is directly supplied to the magnet 16b and then flows into the hole. Note that the mover cooling part 39b may include a passage radially penetrating the magnet 16b and a passage circumferentially penetrating the same. In this configuration, the magnet 16b is cooled by the ionic liquid flowing through the passages.

[0036] In the reciprocating compression apparatus 10 according to the first embodiment, when the drive force generated by the drive section 16 causes the piston 14 to work in a direction to expand the first compression chamber 22a, the check valve C1 opens and the gas is drawn from the suction line 26 into the first compression chamber 22a. Subsequently, when the piston 14 works in a direction to compress the first compression chamber 22a, the gas in the first compression chamber 22a is compressed, then pressurized to equal to or higher than a predetermined pressure, thereby causing the check valve C3 to open, and discharged from the first compression chamber 22a to the connection line 28. This gas contains the ionic liquid.

[0037] The gas in the connection line 28 is drawn into the second compression chamber 22b by a work of the piston 14 for expanding the second compression chamber 22b. The gas in the second compression chamber 22b is further compressed by a work of the piston 14 for compressing the second compression chamber 22b, then pressurized to equal to or higher than a predetermined pressure, thereby causing the check valve C2 to open, and discharged from the second compression chamber 22b to the discharge line 27. The gas discharged to the discharge line 27 flows into the separator 30. In the separator 30, the ionic liquid is separated from the gas. The gas from which the ionic liquid has been separated is supplied to a supply destination.

[0038] A differential pressure between a pressure in the separator 30 and a pressure in the first compression chamber 22a allows the ionic liquid which has been separated in the separator 30 to flow through the return line 33. The ionic liquid flowing through the return line 33 is, in the cylinder external passage 33a, cooled by the cooling medium in the lubricant cooling unit 35, and then cools the coil 16a in the stator cooling part 39a. At this time, the ionic liquid is directly supplied to the coil 16a to cool the coil 16a. The ionic liquid which has cooled the coil 16a passes through the cylinder internal passage 33b

and flows into the piston internal passage 33c. At this time, a part of the ionic liquid flows into the gap between the outer peripheral surface of the piston 14 and the inner wall surface of the cylinder 12. Meanwhile, the other part of the ionic liquid is directly supplied to the magnet 16b and then enters the hole formed in the magnet 16b. Thereby, the magnet 16b is cooled by the ionic liquid, and this ionic liquid is fed into the first compression chamber 22a. The check valve 331 is provided in the cylinder internal passage 33b so that, even when the pressure in the first compression chamber 22a is higher than that in the return line 33, flows of the ionic liquid and the gas from the first compression chamber 22a to the separator 30 can be prevented.

[0039] As described above, in the first embodiment, the ionic liquid is separated in the separator 30 from the gas which has been discharged from the second compression chamber 22b. The ionic liquid which has been separated in the separator 30 is returned through the return line 33 to the return destination. In the return line 33, the ionic liquid is cooled in the lubricant cooling unit 35, and this cooled ionic liquid cools the drive section 16. Then, the ionic liquid which has cooled the drive section 16 is returned to the return destination in which a gas containing the ionic liquid is present and a pressure is lower than that in the separator 30. Consequently, a pressure-feed means for returning the ionic liquid is unnecessary so that a configuration for returning the ionic liquid to the uncompressed gas can be simplified. Moreover, the ionic liquid is not only merely returned to the gas, but effectively used for cooling the cooling parts. Consequently, a configuration for cooling the drive section 16 which drives the piston 14 can be simplified. Accordingly, newly adding a cooling circuit or the like is unnecessary, and thus simplifying a configuration as the reciprocating compression apparatus 10 can be performed.

[0040] Moreover, in the first embodiment, the ionic liquid which has cooled the drive section 16 flows through the piston internal passage 33c formed in the piston 14 and is returned into the first compression chamber 22a. Thus, the ionic liquid can be directly returned into the first compression chamber 22a in a constant manner without being influenced by a position of the piston 14. The pressure in the first compression chamber 22a is lower than a pressure on a discharge side so that the differential pressure between the pressure in the separator 30 and the pressure in the first compression chamber 22a allows the ionic liquid to flow through the return line 33. Consequently, a pressure-feed means for the ionic liquid is unnecessary.

[0041] Moreover, in the first embodiment, the ionic liquid is directly supplied, or sprayed, to the coil 16a and the magnet 16b, and the ionic liquid can thereby effectively cool the drive section 16.

(SECOND EMBODIMENT)

[0042] FIG. 2 illustrates a second embodiment of the

present invention. Note that the same reference numerals are given to the same elements as in the first embodiment and the detailed description thereof will be omitted herein.

[0043] In the first embodiment, the return destination of the return line 33 is the first compression chamber 22a, whereas, in the second embodiment, a return destination of the return line 33 is a space between piston rings 45 arranged in the piston 14.

[0044] The inner space 20 of the cylinder 12 includes the first space part 20a on the first compression chamber 22a side and the second space part 20b on the second compression chamber 22b side. In the first embodiment, the first space part 20a and the second space part 20b have widths different from each other, whereas, in the second embodiment, the first space part 20a and the second space part 20b are configured to have the same width. Note that, also in the second embodiment, similarly to the first embodiment, the first space part 20a and the second space part 20b may have widths different from each other.

[0045] The piston 14 includes the first portion 14a which forms the first compression chamber 22a and the second portion 14b which forms the second compression chamber 22b. In the second embodiment, the first portion 14a and the second portion 14b are configured to have the same width. Note that, also in the second embodiment, when, similarly to the first embodiment, the first space part 20a and the second space part 20b have widths different from each other, the first portion 14a and the second portion 14b may have widths different from each other.

[0046] On the peripheral surface of the piston 14, a plurality of recess parts 14c are formed in such a manner as to be longitudinally spaced from each other on each of the first portion 14a and the second portion 14b. The piston rings 45 are correspondingly fitted into these recess parts 14c.

[0047] The return line 33 includes the cylinder external passage (first cylinder external passage) 33a, a cylinder passage 33e, the piston internal passage 33c, a second cylinder external passage 33f, and an outflow part 33g. Through the first cylinder external passage 33a, the separator 30 and the cylinder passage 33e communicate with each other. The cylinder passage 33e radially penetrates the piston 14 in such a manner as to penetrate at least two portions facing each other in the peripheral wall of the cylinder 12. Consequently, the cylinder passage 33e includes a feeding portion 33h through which the ionic liquid is fed from the exterior of the cylinder 12 to the interior of the cylinder 12 and a lead-out portion 33i through which the ionic liquid is led out of the interior of the cylinder 12 to the exterior of the cylinder 12. Through the second cylinder external passage 33f, the cylinder passage 33e and the outflow part 33g communicate with each other. The outflow part 33g penetrates the peripheral wall of the cylinder 12 in such a manner as to constantly penetrate between the piston rings 45

during reciprocation of the piston 14. A slight gap formed between the outer peripheral surface of the piston 14 and the inner wall surface of the cylinder 12 allows the ionic liquid which has flown out from the outflow part 33g to be fed to a space between the piston rings 45 within this gap.

[0048] Consequently, in the second embodiment, the ionic liquid is supplied to the space between the piston rings 45 so that the gas in the compression chamber can be prevented from leaking into the gap between the cylinder 12 and the piston 14. A pressure in the space between the piston rings 45 is approximately equal to or lower than the pressure in the first compression chamber 22a, and consequently a pressure-feed means for the ionic liquid is unnecessary.

[0049] The other configurations, workings, and effects will not be described but are similar to those according to the above first embodiment.

(THIRD EMBODIMENT)

[0050] FIG. 3 illustrates a third embodiment of the present invention. Note that the same reference numerals are given to the same elements as in the second embodiment and the detailed description thereof will be omitted herein.

[0051] In the second embodiment, the ionic liquid is returned to the space between the piston rings 45. On the other hand, in the third embodiment, the ionic liquid is returned to the suction line 26. Specifically, the return line 33 includes the first cylinder external passage 33a, the cylinder passage 33e, the piston internal passage 33c, and the second cylinder external passage 33f. Differently from the second embodiment, the cylinder passage 33e and the suction line 26 communicate with each other through the second cylinder external passage 33f. A pressure in the suction line 26 is constantly lower than the pressure in the separator 30. Consequently, the pressure reducing valve 37 is omitted.

[0052] In the third embodiment, the ionic liquid is returned to the suction line 26 in which the pressure is lower than that in the compression chamber 22. Thus, a differential pressure between the pressure in the separator 30 and the pressure in the suction line 26 allows the ionic liquid to effectively return to the gas.

[0053] The other configurations, workings, and effects will not be described but are similar to those according to the above second embodiment.

(FOURTH EMBODIMENT)

[0054] FIG. 4 illustrates a fourth embodiment of the present invention. Note that the same reference numerals are given to the same elements as in the second embodiment and the detailed description thereof will be omitted herein.

[0055] In the first to third embodiments, the drive section 16 of the piston 14 is configured to include the linear

motor which generates the drive force for linearly moving the piston 14. On the other hand, in the fourth embodiment, the drive section 16 of the piston 14 is configured to include a motor which generates a rotational drive force. The reciprocating compression apparatus 10 is provided with a drive force conversion section 48 for converting the rotational drive force generated by the drive section 16 into a drive force for reciprocating the piston 14. This drive force conversion section 48 may be configured to include a hypocycloid mechanism or a crank mechanism. This reciprocating compression apparatus 10 is provided with the only one compression chamber 22 of a single-stage compression type.

[0056] The return line 33 includes the first cylinder external passage 33a, the cylinder passage 33e, and the second cylinder external passage 33f. Through the first cylinder external passage 33a, the separator 30 and the cylinder passage 33e communicate with each other. The cylinder passage 33e includes the feeding portion 33h through which the ionic liquid is fed from the exterior of the cylinder 12 to the interior of the cylinder 12 and the lead-out portion 33i through which the ionic liquid is lead out of the interior of the cylinder 12 to the exterior of the cylinder 12. The feeding portion 33h and the lead-out portion 33i open to a housing part 20c, in which the drive section 16 is housed, in the inner space 20 of the cylinder 12. The feeding portion 33h is configured to directly supply the ionic liquid to the drive section 16. The lead-out portion 33i leads out the ionic liquid collecting on a bottom part in the housing part 20c. The cylinder passage 33e and the suction line 26 communicate with each other through the second cylinder external passage 33f. Note that, in the fourth embodiment, the drive section 16 is not disposed within the piston 14, and accordingly the piston internal passage 33c is not provided.

[0057] In the fourth embodiment, the ionic liquid is returned to the suction line 26 in which the pressure is lower than that in the compression chamber 22. Thus, a differential pressure between the pressure in the separator 30 and the pressure in the suction line 26 allows the ionic liquid to effectively return to the gas.

[0058] Note that the fourth embodiment includes a configuration in which the second cylinder external passage 33f of the return line 33 communicates with the suction line 26, which is not limitative. The return line 33 may be configured to include the cylinder internal passage (unillustrated) and directly communicate with the compression chamber 22. In this case, the return destination is the compression chamber 22. A pressure in the compression chamber 22 is not constantly lower than the pressure in the separator 30 but temporarily (that is, during a process excluding a discharge process and including at least an expansion process) lower than the pressure in the separator 30. Consequently, providing a pressure-feed means is unnecessary. In this manner, when the ionic liquid which has been discharged from the compression chamber 22 flows into the return line 33 without passing through a space in which a pressure is higher

than that in the compression chamber 22, the ionic liquid is returned to the compression chamber 22 during a process excluding a discharge process.

[0059] The return destination is not limited to the compression chamber 22 but may be, as in the second embodiment, the space between the piston rings 45 arranged in the piston 14.

[0060] The other configurations, workings, and effects will not be described but are similar to those according to the above second embodiment.

(FIFTH EMBODIMENT)

[0061] FIG. 5 illustrates a fifth embodiment of the present invention. Note that the same reference numerals are given to the same elements as in the first embodiment and the detailed description thereof will be omitted herein.

[0062] In the fourth embodiment, the piston 14 is composed of the solid piston 14. On the other hand, in the fifth embodiment, the piston 14 is configured to include a liquid portion. Specifically, in this embodiment, the piston 14 includes a reception part 14d for receiving a drive force directly from the drive section 16, a working part 14e disposed to be spaced from the reception part 14d, and a liquid portion 14f composed of a working liquid sandwiched between the reception part 14d and the working part 14e. As the working liquid, oil, ionic liquid, or the like is used. A liquid layer 14g made of the ionic liquid is arranged on the working part 14e. In other words, the compression apparatus 10 is configured as an ionic compressor.

[0063] Similarly to the first embodiment, the drive section 16 may be configured to include a linear motor. Alternatively, similarly to the fourth embodiment, the drive section 16 may be configured to include a motor which generates a rotational drive force. In this case, the drive force conversion section 48 is provided. Still alternatively, in place of the reception part 14d, a pump other than a piston type pump (e.g. rotation type pump) may be provided.

[0064] The separator 30 and the suction line 26 communicate with each other through the return line 33. The return line 33 is provided with the drive section cooling section 39. The drive section cooling section 39 is configured such that the ionic liquid is directly supplied to the drive section 16.

[0065] Note that the fifth embodiment includes a configuration in which the return line 33 communicates with the suction line 26, which is not limitative. The return line 33 may be configured to include the cylinder internal passage opening to the compression chamber 22 and directly communicate with the compression chamber 22. In this case, the return destination is the compression chamber 22. The pressure in the compression chamber 22 is lower than the pressure in the separator 30 during a process excluding a discharge process, and consequently a differential pressure between the pressure in

the separator 30 and the pressure in the compression chamber 22 allows the ionic liquid to flow.

[0066] The other configurations, workings, and effects will not be described but are similar to those according to the above first embodiment.

[0067] Although particular embodiments of the present invention have been described above, the embodiments disclosed herein are to be considered in all respects as illustrative and not restrictive. The scope of the present invention is defined by the terms of claims, rather than the description of the embodiments as set forth above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

[0068] In the first embodiment, a cooling unit for cooling the gas and ionic liquid which are about to flow into the separator 30 may be provided. In this case, the lubricant cooling unit 35 may be omitted. This also applies to the other embodiments.

[0069] In the first embodiment, a valve other than the pressure reducing valve 37 which can regulate a pressure or flow rate of the ionic liquid in the return line 33 may be used. If the ionic liquid does not excessively flow into the return line 33, the pressure reducing valve 37 may be omitted. This also applies to the second embodiment.

[0070] In the second embodiment, a configuration in which the ionic liquid is returned between the piston rings 45 arranged on a side near the first compression chamber 22a rather than the second compression chamber 22b is illustrated, which is, however, not limitative. As illustrated in FIG. 6, the return line 33 may be provided with another second cylinder external passage 33m through which the cylinder passage 33e and an outflow part 33n connected to the piston rings 45 arranged on a side near the second compression chamber 22b rather than the first compression chamber 22a communicate with each other. The second cylinder external passage 33m is provided with a check valve 332. The ionic liquid which has flown out from the outflow part 33n is fed to the space between the piston rings 45.

[0071] As illustrated in FIG. 7, the gas of the same pressure may be fed through one flow passage to the first and second compression chambers 22a, 22b on respective sides of the piston 14. The gas pressurized in the first compression chamber 22a and the gas pressurized in the second compression chamber 22b are discharged at respective pressures similar to each other, and flow into the separator 30. In FIG. 7, the ionic liquid which has passed from the separator 30 through the piston internal passage 33c is fed to the spaces between the piston rings 45 near the respective first and second compression chambers 22a, 22b through the two second cylinder external passages 33f, 33m and the two outflow parts 33g, 33n. In this embodiment, the suction line 26 is branched halfway, and the gas flowing through the suction line 26 is split and drawn into the first compression chamber 22a and the second compression chamber 22b. The connection line 28 is omitted, and the discharge line

27 is branched halfway and connected to the first compression chamber 22a and the second compression chamber 22b. The gas compressed in the first compression chamber 22a and the gas compressed in the second compression chamber 22b each flow through the discharge line 27 and fed to the separator 30.

[0072] To simplify a configuration for returning to uncompressed gas a lubricant separated from gas discharged from a compression chamber, while effectively using the lubricant, a reciprocating compression apparatus includes: a cylinder; a piston disposed in the cylinder to form a compression chamber therein; a drive section for generating drive force for reciprocating the piston in the cylinder; a separator for separating a lubricant from gas discharged from the compression chamber; and a return line for returning the lubricant separated in the separator to a return destination where gas containing the lubrication is present and a pressure is lower than that in the separator. The return line includes a lubrication cooling unit for cooling the lubricant flowing through the return line and a drive section cooling section for cooling the drive section with the lubricant which has been cooled in the lubricant cooling unit 35.

Claims

1. A reciprocating compression apparatus comprising:

a cylinder;
a piston disposed in the cylinder in such a manner as to form a compression chamber therein;
a drive section which generates a drive force for reciprocating the piston in the cylinder;
a separator for separating a lubricant from a gas discharged from the compression chamber; and
a return line for returning the lubricant separated in the separator to a return destination in which a gas is present and a pressure is lower than that in the separator,
wherein the return line is provided with a drive section cooling section for cooling the drive section with the lubricant.

2. The reciprocating compression apparatus according to claim 1,
wherein the return line includes a piston internal passage formed in the piston and communicating with the compression chamber, and
the lubricant which has cooled the drive section is returned through the piston internal passage into the compression chamber as the return destination.

3. The reciprocating compression apparatus according to claim 1,
wherein the return line includes, in the cylinder, an outflow part provided at a position constantly between piston rings during reciprocation of the piston,

and
the lubricant is returned to a space between the piston rings as the return destination.

4. The reciprocating compression apparatus according to claim 1,
wherein the return line is connected to a suction line connected to the cylinder, and
the lubricant is returned into the suction line as the return destination. 5
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5. The reciprocating compression apparatus according to claim 1,
wherein the return line is, in the cylinder, connected to a portion at least temporarily communicating with the compression chamber, and
the lubricant is returned into the compression chamber as the return destination. 15
6. The reciprocating compression apparatus according to any one of claims 1-5,
wherein the drive section cooling section is configured such that the lubricant flowing through the return line is supplied to the drive section. 20
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FIG. 1

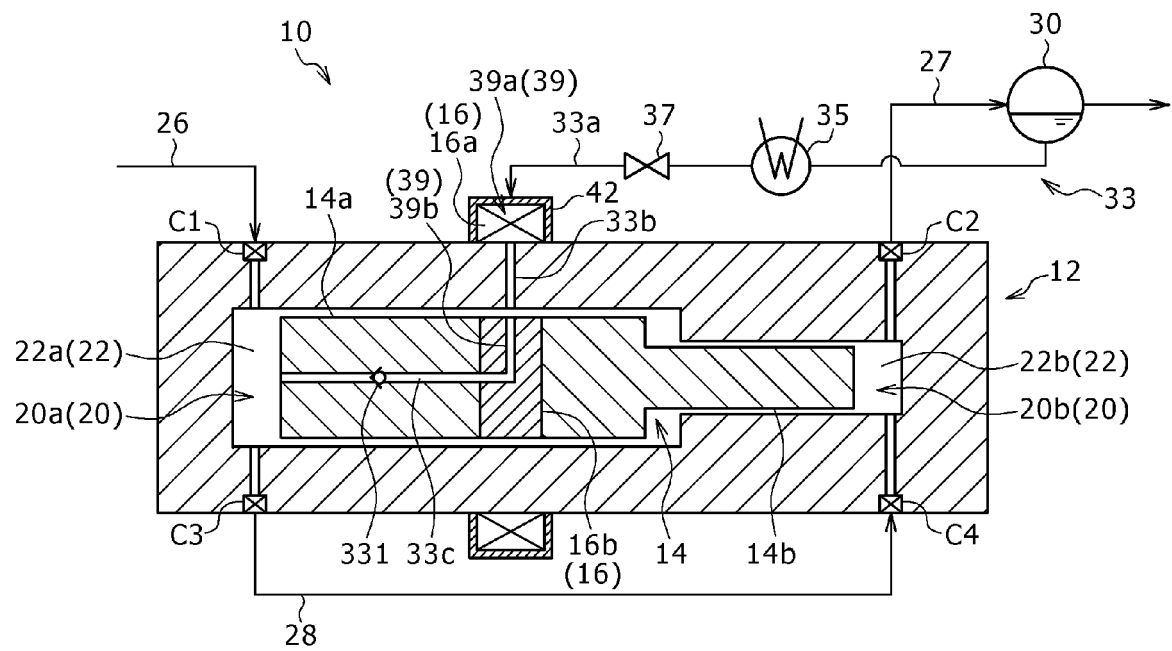


FIG. 2

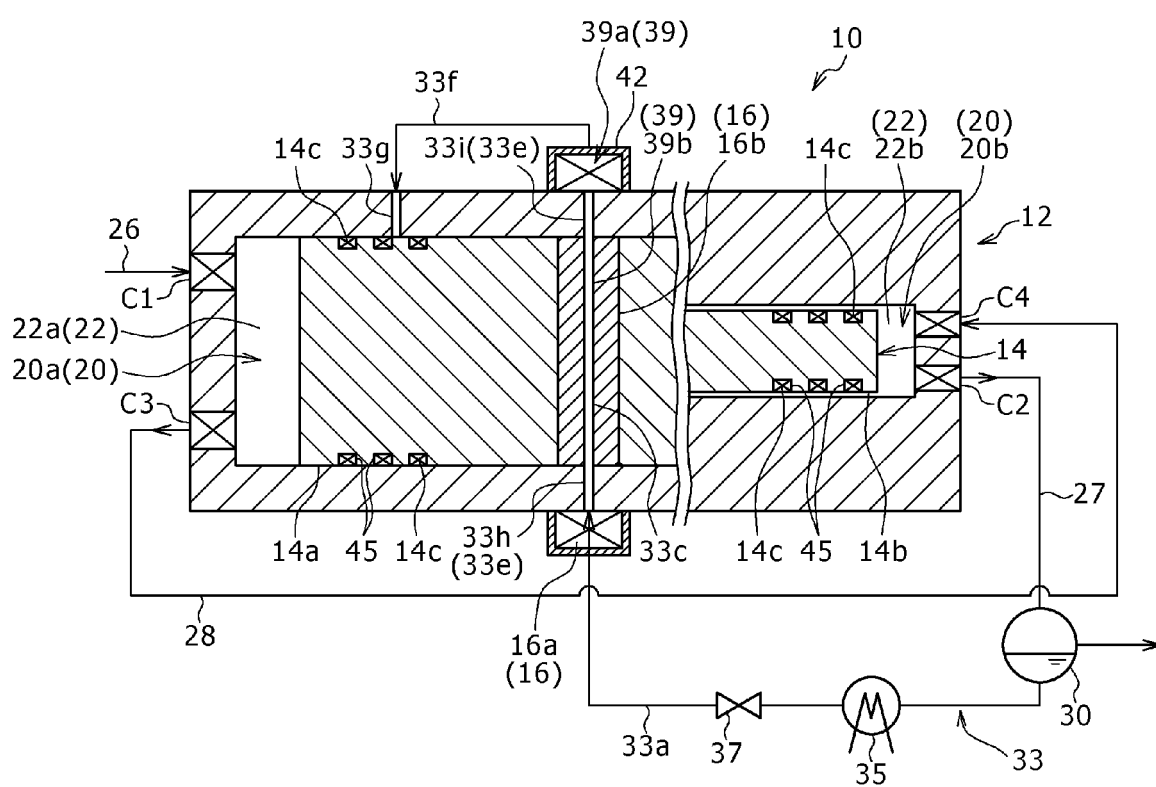


FIG. 3

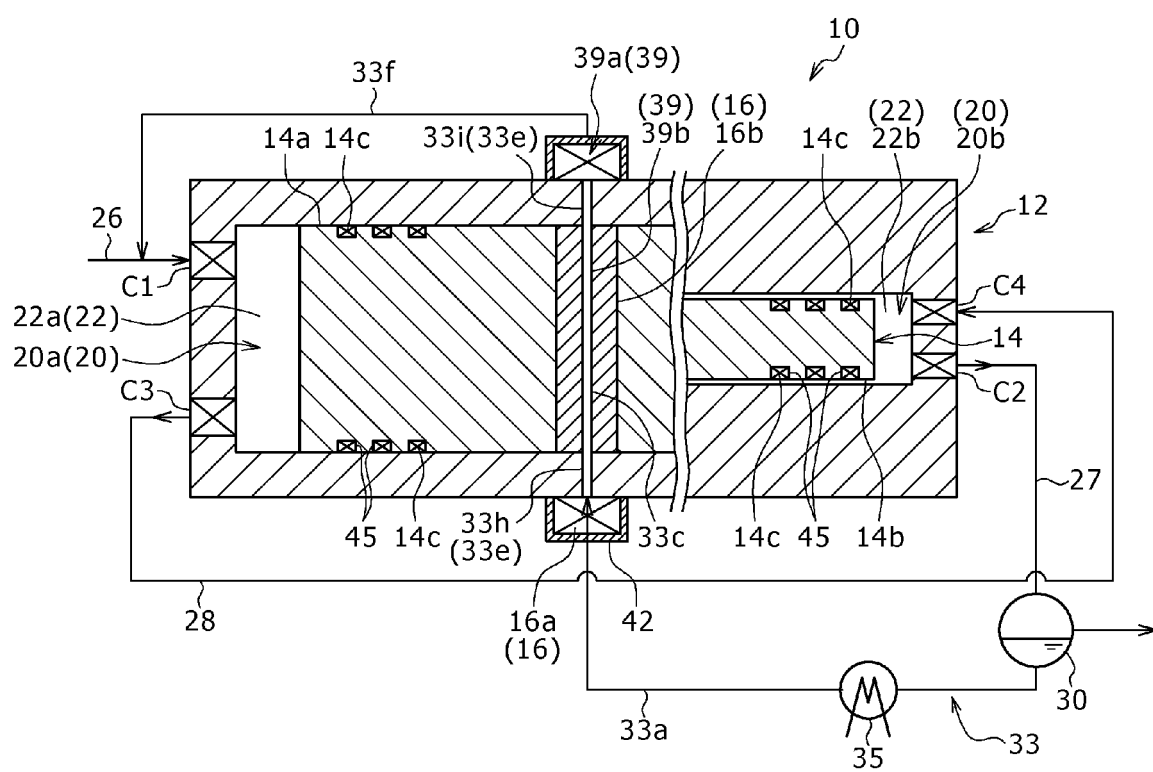


FIG. 4

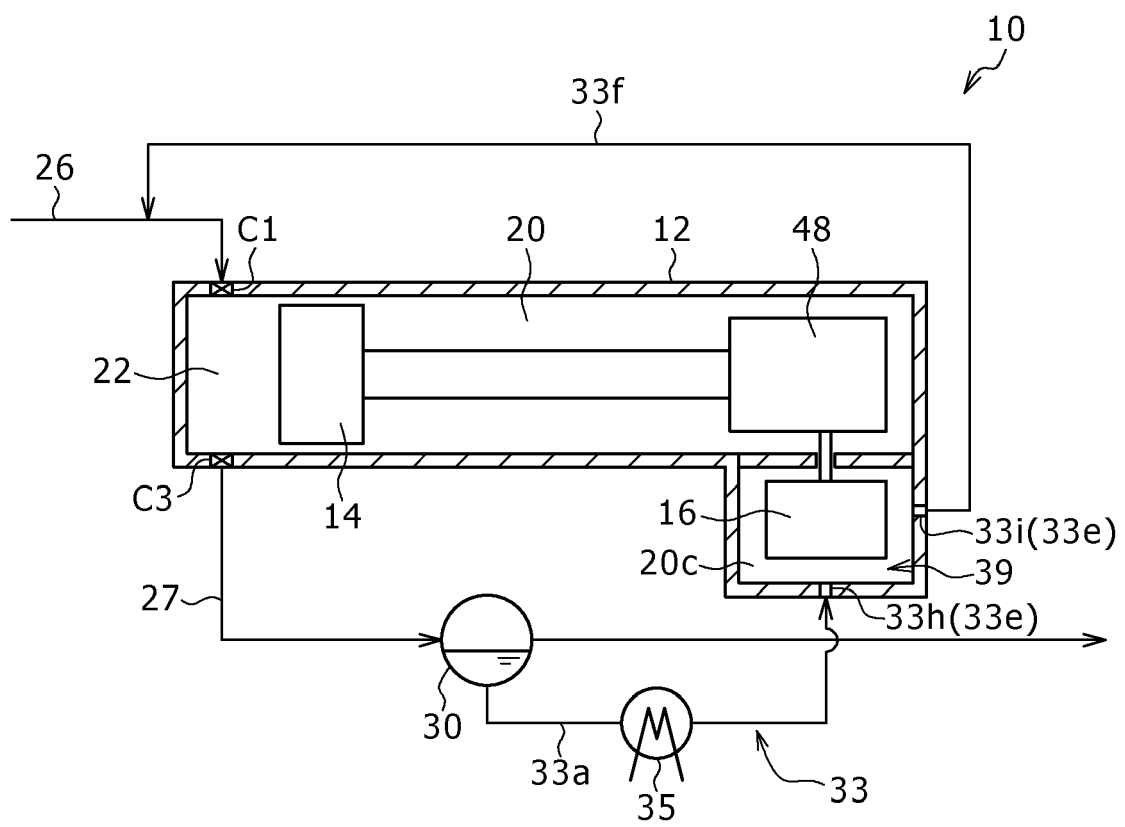


FIG. 5

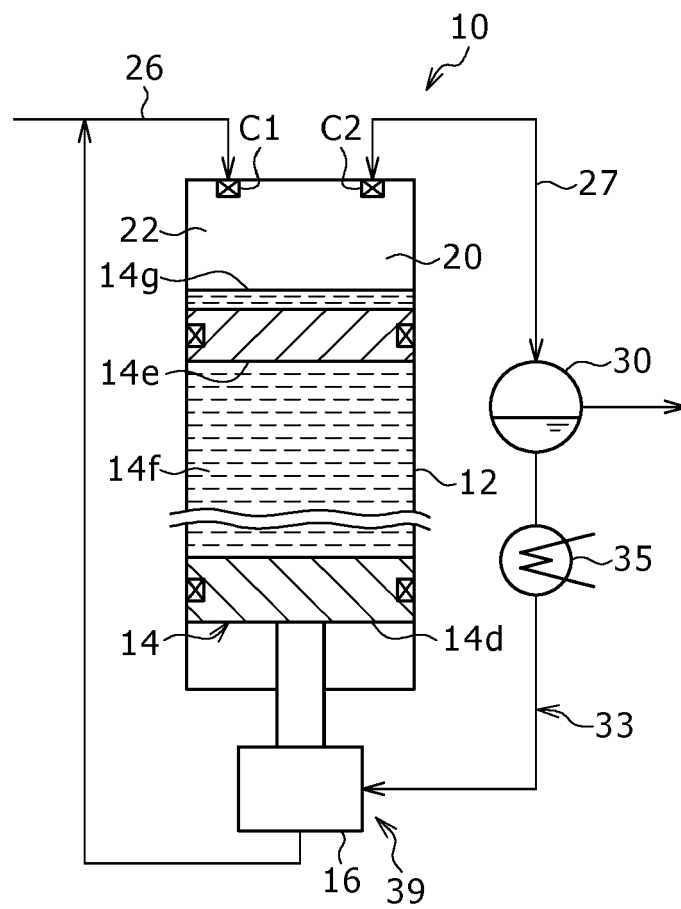


FIG. 6

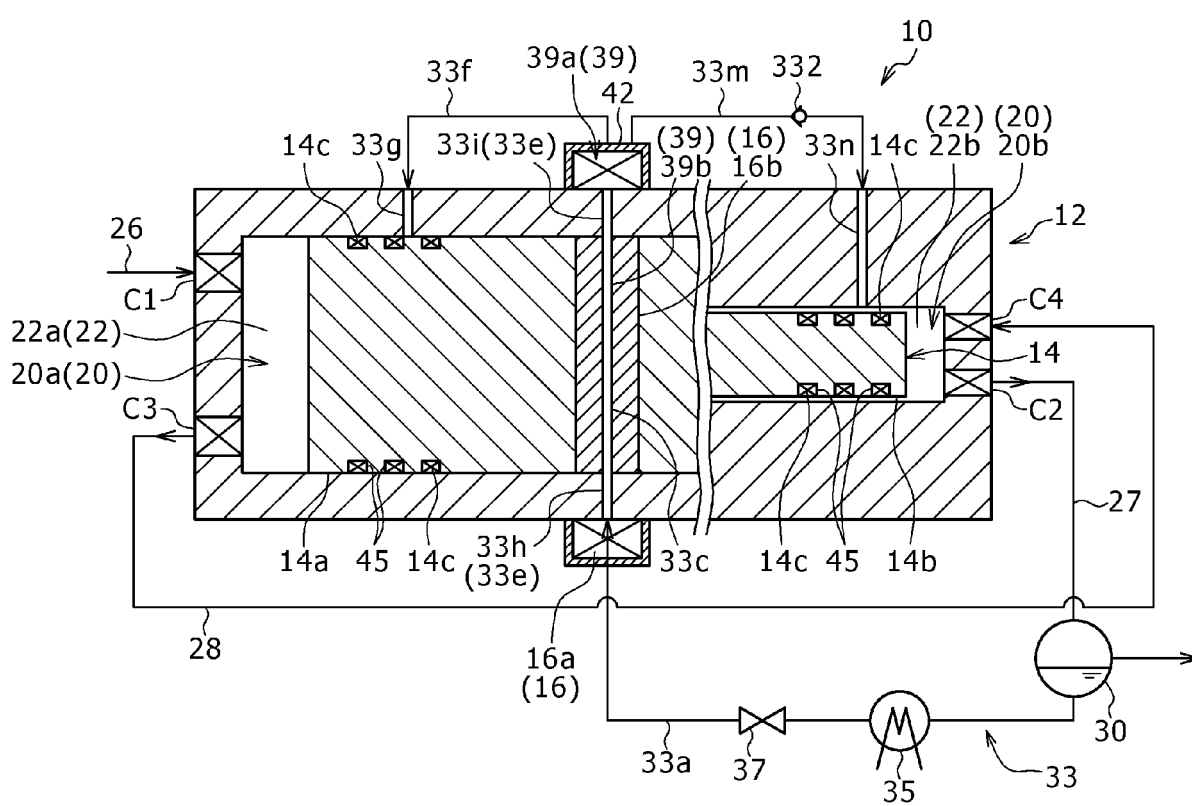
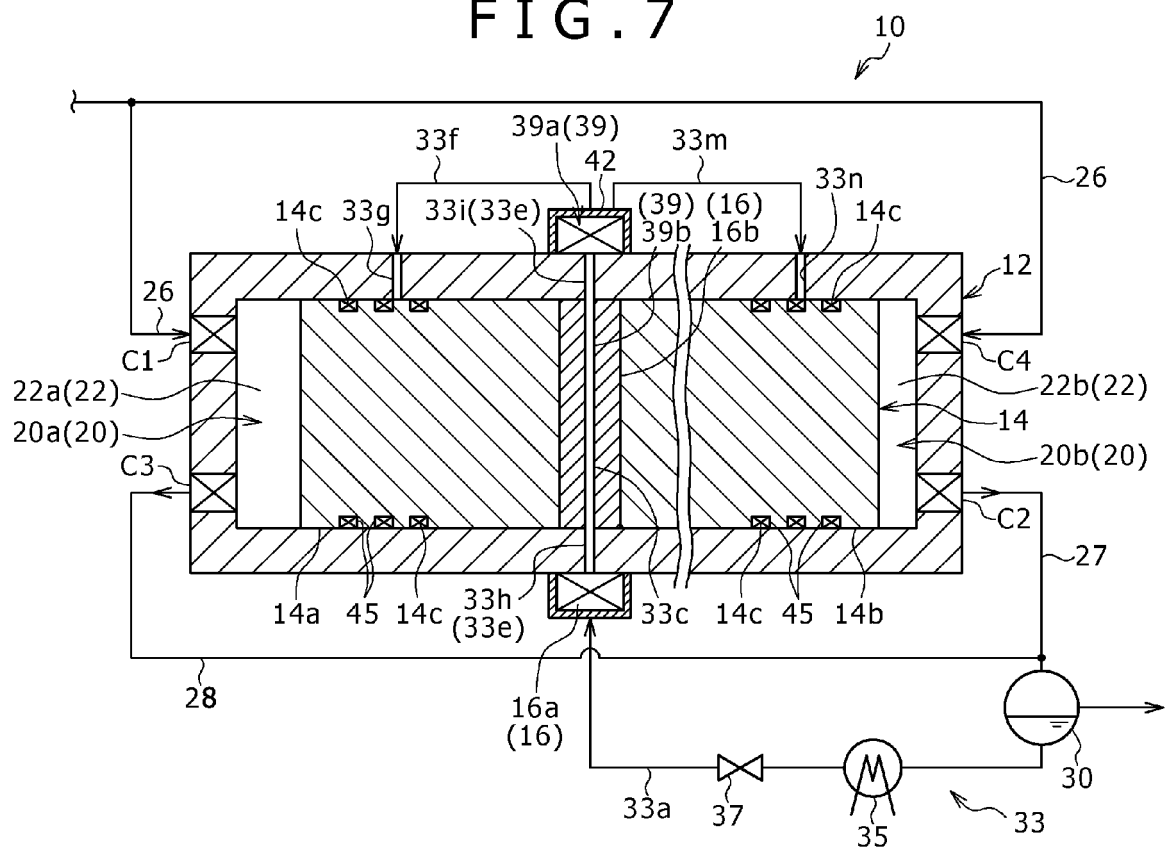


FIG. 7



REFERENCES CITED IN THE DESCRIPTION

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