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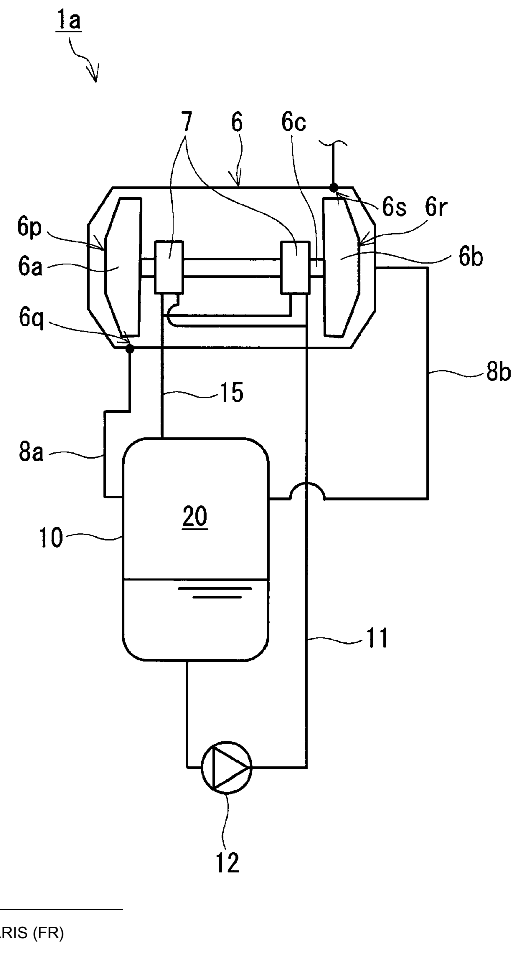
(54) **FLUID MACHINE AND REFRIGERATION CYCLE APPARATUS**

(57) A fluid machine (1a) includes a multi-stage compressor (6), a pressure container (10), a first supply path (11), a pump (12), a first return path (15), and an intermediate pressure space (20). The multi-stage compressor (6) includes a first compressor (6a), a second compressor (6b), and a bearing (7). The pressure container (10) stores a liquid lubricant whose main component is the same kind of substance as a main component of a refrigerant. The first supply path (11) is a flow path for supplying the liquid lubricant to the bearing (7). The pump (12) is disposed on the first supply path (11). The first return path (15) is a flow path for returning the liquid lubricant that has passed through the bearing (7) to the pressure container (10). The intermediate pressure space (20) is filled with a gas refrigerant at an intermediate pressure. The internal space of the pressure container (10) constitutes a part of the intermediate pressure space (20).

FIG. 1



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Description

BACKGROUND

1. Technical Field

[0001] The present disclosure relates to a fluid machine and a refrigeration cycle apparatus.

2. Description of the Related Art

[0002] A technology for supplying lubricating water to a bearing of a compressor in a refrigerator in which water is used as a refrigerant has been known. For example, Japanese Unexamined Patent Application Publication No. 2011-196185 describes a refrigerator 100.

[0003] As illustrated in Fig. 9, the refrigerator 100 includes an evaporator 102, a compressor 104, a condenser 106, a refrigerant-gas lead-out line 109, a cooling-water line 114, a cooling tower 116, a cooling-water pump 118, a lubricating-water pump 111, a lubricating-water supply line 132, and a lubricating-water discharge line 134. A lubricating-water circuit is constituted by the condenser 106, the cooling-water line 114, the cooling tower 116, the cooling-water pump 118, the lubricating-water pump 111, the lubricating-water supply line 132, the compressor 104, and the lubricating-water discharge line 134. The lubricating-water supply line 132 supplies water, which serves as a lubricant, to a bearing or the like of the compressor 104, and connects the bearing or the like of the compressor 104 with a portion of the cooling-water line 114 that is downstream of the cooling tower 116. A part of the cooling water returned from the cooling tower 116 toward the condenser 106 through the cooling-water line 114 is supplied to the compressor 104 through the lubricating-water supply line 132 as lubricating water.

[0004] A technology for supplying a part of liquid refrigerant used in a turbo refrigerator to a bearing of a turbo compressor has also been known. For example, Japanese Unexamined Patent Application Publication No. 10-132395 describes a turbo refrigerator 300.

[0005] As illustrated in Fig. 10, the turbo refrigerator 300 includes a turbo compressor 330, a condenser 302, and an evaporator 305. In the turbo compressor 330, a centrifugal impeller 331 is fixed to an output shaft 333 of an inverter motor 332. The output shaft 333 is supported by a radial bearing 339, a radial bearing 340, a thrust bearing 341, and a thrust bearing 342. A saturated liquid refrigerant stored in a reservoir 343 provided at the bottom of the evaporator 305 is extracted by a liquid refrigerant pump 344. The saturated liquid refrigerant is compressed by the liquid refrigerant pump 344 so as to be supercooled, and is then supplied to the radial bearing 339, the radial bearing 340, the thrust bearing 341, or the thrust bearing 342 to lubricate these bearings. The liquid refrigerant returns to the evaporator 305 due to the weight thereof and a pressure difference after lubricating the radial bearing 339, the radial bearing 340, the thrust bearing 341, or the thrust bearing 342.

SUMMARY

[0006] According to the technologies described in Japanese Unexamined Patent Application Publication Nos. 2011-196185 and 10-132395, the lubricating water or liquid refrigerant supplied to each bearing of the compressor is not always in a desirable state. Accordingly, one non-limiting and exemplary embodiment of the present disclosure provides an effective technology for supplying a liquid lubricant to a bearing of a compressor in a desirable state in the case where the bearing is lubricated by using the liquid lubricant whose main component is the same kind of substance as a main component of a refrigerant.

[0007] In one general aspect, the techniques disclosed here feature a fluid machine including a multi-stage compressor that includes a first compressor having a first inlet and a first outlet, a second compressor having a second inlet and a second outlet, and a bearing supporting a shaft for driving at least one of the first compressor and the second compressor, the first compressor sucking a gas refrigerant through the first inlet, compressing the gas refrigerant, and discharging the gas refrigerant through the first outlet, the second compressor sucking the gas refrigerant discharged from the first outlet through the second inlet, compressing the gas refrigerant, and discharging the gas refrigerant through the second outlet; a pressure container that stores a liquid lubricant whose main component is the same kind of substance as a main component of the refrigerant; a first supply path through which the liquid lubricant stored in the pressure container is supplied to the bearing, the first supply path connecting the pressure container with the bearing; a pump that is disposed on the first supply path and pumps the liquid lubricant toward the bearing; a first return path through which the liquid lubricant that has passed through the bearing is returned to the pressure container, the first return path connecting the bearing with the pressure container; and an intermediate pressure space that is maintained at a pressure higher than a pressure of the gas refrigerant at the first inlet and lower than a pressure of the gas refrigerant at the second outlet during operation of the multi-stage compressor. An internal space of the pressure container constitutes a part of the intermediate pressure space.

[0008] According to the above-described fluid machine, the liquid lubricant that is stored in the pressure container and whose main component is the same kind of substance as the main component of the refrigerant can be easily supplied to the bearing of the multi-stage compressor in a desirable state.

[0009] Additional benefits and advantages of the disclosed embodiments will become apparent from the specification and drawings. The benefits and/or advantages may be individually obtained by the various embodiments and features of the specification and drawings, which need not all be provided in order to obtain one or more of such benefits and/or advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Fig. 1 is a diagram illustrating an example of a fluid machine according to the present disclosure;
Fig. 2 is a diagram illustrating a modification of the fluid machine illustrated in Fig. 1;
Fig. 3 is a diagram illustrating another modification of the fluid machine illustrated in Fig. 1;
Fig. 4 is a diagram illustrating another modification of the fluid machine illustrated in Fig. 1;
Fig. 5 is a diagram illustrating another modification of the fluid machine illustrated in Fig. 1;
Fig. 6 is a diagram illustrating another example of a fluid machine according to the present disclosure;
Fig. 7 is a diagram illustrating an example of a refrigeration cycle apparatus according to the present disclosure;
Fig. 8 is a diagram illustrating another example of a refrigeration cycle apparatus according to the present disclosure;
Fig. 9 is a diagram illustrating a refrigerator according to the related art; and
Fig. 10 is a diagram illustrating a turbo refrigerator according to the related art.

DETAILED DESCRIPTION

Underlying Knowledge Forming Basis of the Present Disclosure

[0011] The present inventors have considered using a liquid refrigerant of a refrigeration cycle apparatus as a liquid lubricant for lubricating a bearing of a multi-stage compressor included in the refrigeration cycle apparatus. In this case, for example, a part of the liquid refrigerant from an evaporator or a condenser may be used as the liquid lubricant for lubricating the bearing of the multi-stage compressor. However, the present inventors have newly found that the liquid refrigerant extracted from the evaporator or the condenser is not always in a desirable state as a liquid lubricant. For example, the liquid refrigerant extracted from the evaporator as the liquid lubricant is at the saturation temperature corresponding to a low pressure in the evaporator or a temperature close to the saturation temperature corresponding to the low pressure in the evaporator. In this case, the temperature of the liquid lubricant is low, and condensation of gas refrigerant or dew formation easily occurs at the multi-stage compressor. Also, the liquid refrigerant extracted from the condenser as the liquid lubricant is at the saturation temperature corresponding to a high pressure in the condenser or a temperature close to the saturation temperature corresponding to the high pressure in the condenser. In this case, the temperature of the liquid lubricant is high, and there is a possibility that the bearing cannot be appropriately cooled.

[0012] Accordingly, the present inventors have conducted intensive studies on technologies for supplying a liquid lubricant, whose main component is the same kind of substance as the main component of the refrigerant, to the bearing of the multi-stage compressor in a desirable state. As a result, the present inventors have found that the liquid lubricant can be supplied to the bearing in a desirable state by maintaining a pressure in an internal space of a pressure container, which differs from the evaporator and the condenser and which stores the liquid lubricant, at a predetermined pressure. The present inventors have devised a fluid machine of the present disclosure based on these new findings. In this specification, the term "main component" means the component that is the largest by mass.

[0013] A first aspect of the present disclosure provides a fluid machine including a multi-stage compressor that includes a first compressor having a first inlet and a first outlet, a second compressor having a second inlet and a second outlet, and a bearing supporting a shaft for driving at least one of the first compressor and the second compressor, the first compressor sucking a gas refrigerant through the first inlet, compressing the gas refrigerant, and discharging the gas refrigerant through the first outlet, the second compressor sucking the gas refrigerant discharged from the first outlet through the second inlet, compressing the gas refrigerant, and discharging the gas refrigerant through the second outlet;
a pressure container that stores a liquid lubricant whose main component is the same kind of substance as a main component of the refrigerant;
a first supply path through which the liquid lubricant stored in the pressure container is supplied to the bearing, the first supply path connecting the pressure container with the bearing;
a pump that is disposed on the first supply path and pumps the liquid lubricant toward the bearing;
a first return path through which the liquid lubricant that has passed through the bearing is returned to the pressure container, the first return path connecting the bearing with the pressure container; and
an intermediate pressure space that is maintained at a pressure higher than a pressure of the gas refrigerant at the first inlet and lower than a pressure of the gas refrigerant at the second outlet during operation of the multi-stage compressor, wherein
an internal space of the pressure container constitutes a part of the intermediate pressure space.

[0014] According to the first aspect, the internal space of the pressure container, which stores the liquid lubricant whose main component is the same kind of substance as the main component of the refrigerant, constitutes a part of the intermediate pressure space. Therefore, the temperature of the liquid lubricant stored in the pressure container easily becomes equal to the saturation temperature corresponding to an intermediate pressure or a temperature close to the saturation temperature. Accordingly, the temperature of the liquid lubricant stored in the pressure container can be easily set to a temperature suitable for lubrication of the bearing, and the liquid lubricant can be easily supplied to the bearing of the multi-stage compressor in a desirable state. The intermediate pressure is a pressure higher than the pressure of the gas refrigerant at the first inlet and lower than the pressure of the gas refrigerant at the second outlet during the operation of the multi-stage compressor.

[0015] A second aspect of the present disclosure provides the fluid machine according to the first aspect, wherein the intermediate pressure space is filled with the gas refrigerant that has passed through the first outlet and that has not passed through the second inlet during the operation of the multi-stage compressor. According to the second aspect, the gas refrigerant that has passed through the first outlet and that has not passed through the second inlet can be used to maintain the pressure in the internal space of the pressure container at a desired pressure. In addition, the pressure in the internal space of the pressure container, which stores the liquid lubricant, can be easily maintained at a desirable pressure, and the liquid lubricant can be more reliably supplied to the bearing in a desirable state.

[0016] A third aspect of the present disclosure provides the fluid machine according to the first or second aspect, wherein the intermediate pressure space includes a second supply path through which the gas refrigerant discharged from the first outlet is guided to the internal space of the pressure container, the second supply path connecting the first outlet with the pressure container, and a third supply path through which the gas refrigerant is guided to the second compressor, the third supply path connecting the pressure container with the second inlet. According to the third aspect, the gas refrigerant discharged from the first outlet is guided to the second compressor through the second supply path, the internal space of the pressure container, and the third supply path. Thus, the internal space of the pressure container can be used as a portion of the flow path of the gas refrigerant. In addition, the gas generated as a result of vaporization of the liquid lubricant due to loss at the bearing is guided to the second compressor through the third supply path. Therefore, the pressure in the internal space of the pressure container is maintained at the desired pressure. Furthermore, the temperature of the liquid lubricant can be prevented from being continuously increased.

[0017] A fourth aspect of the present disclosure provides the fluid machine according to the first or second aspect, wherein the intermediate pressure space includes a fourth supply path through which the gas refrigerant is guided to the second compressor, the fourth supply path connecting the first outlet with the second inlet, and a fifth supply path through which gas generated as a result of vaporization of the liquid lubricant is guided to the second compressor, the fifth supply path connecting the pressure container with a merging point on the fourth supply path. According to the fourth aspect, since the internal space of the pressure container communicates with the fourth supply path through the fifth supply path, the pressure in the internal space of the pressure container is maintained at the intermediate pressure, and the internal space of the pressure container constitutes a part of the intermediate pressure space. In addition, since the gas generated as a result of vaporization of the liquid lubricant due to loss at the bearing is guided to the second compressor through the fifth supply path, the pressure in the internal space of the pressure container can be maintained at the desired pressure. Furthermore, the temperature of the liquid lubricant can be prevented from being continuously increased.

[0018] A fifth aspect of the present disclosure provides the fluid machine according to any one of first to fourth aspects, further including a second return path through which a portion of the liquid lubricant in the first supply path is returned to the pressure container, the second return path connecting a branching point located between an outlet of the pump on the first supply path and the bearing with the pressure container so as to bypass the bearing. According to the fifth aspect, the liquid lubricant returned to the pressure container through the second return path can be brought into contact with the gas refrigerant in the pressure container. As a result, the gas refrigerant can be cooled and the temperature of the liquid lubricant stored in the pressure container can be more reliably set to a temperature suitable for lubrication of the bearing.

[0019] A sixth aspect of the present disclosure provides the fluid machine according to the fifth aspect, further including a first filter that is disposed on the first supply path and reduces an amount of impurities contained in the liquid lubricant. According to the sixth aspect, the amount of impurities contained in the liquid lubricant can be reduced by the first filter.

[0020] A seventh aspect of the present disclosure provides the fluid machine according to the sixth aspect, wherein the first filter is disposed between the outlet of the pump and the branching point on the first supply path. According to the seventh aspect, the amount of impurities contained in the liquid lubricant that flows through the second return path and the liquid lubricant supplied to the bearing can be reduced without using a filter other than the first filter. Therefore, the fluid machine can be simplified and the manufacturing cost can be reduced.

[0021] An eighth aspect of the present disclosure provides the fluid machine according to the sixth aspect, wherein the first filter is disposed between the branching point and the bearing on the first supply path. According to the eighth aspect, the amount of impurities contained in the liquid lubricant supplied to the bearing can be reduced.

[0022] A ninth aspect of the present disclosure provides the fluid machine according to the eighth aspect, further including a second filter that is disposed between the outlet of the pump and the branching point on the first supply path and reduces the amount of impurities contained in the liquid lubricant. According to the ninth aspect, the amount of impurities contained in the liquid lubricant that flows through the second return path and the liquid lubricant supplied to the bearing can be reduced by the second filter. In addition, the impurities that have passed through the second filter can be caught by the first filter. As a result, the amount of impurities contained in the liquid lubricant supplied to the bearing can be more reliably reduced. In addition, the first filter is not easily clogged because the impurities caught by the second filter do not reach the first filter.

[0023] A tenth aspect of the present disclosure provides the fluid machine according to the eighth aspect, further including a second filter that is disposed on the second return path and reduces the amount of impurities contained in the liquid lubricant. According to the tenth aspect, the second filter can be replaced without stopping the pump on the first supply path, and the liquid lubricant can be continuously supplied to the bearing.

[0024] An eleventh aspect of the present disclosure provides the fluid machine according to any one of the first to tenth aspects, wherein the refrigerant and the liquid lubricant contain water as the main component. According to the eleventh aspect, since evaporation of water involves a large amount of latent heat, the amount of gas generated as a result of vaporization of the liquid lubricant can be reduced.

[0025] A twelfth aspect of the present disclosure provides a refrigeration cycle apparatus including

the fluid machine according to any one of the first to eleventh aspects;

an evaporator that generates the gas refrigerant by evaporating liquid refrigerant;

a first vapor path through which the gas refrigerant is guided to the first compressor, the first vapor path connecting the evaporator with the first inlet;

a condenser that condenses the gas refrigerant discharged from the second outlet; and

a second vapor path through which the gas refrigerant discharged from the second outlet is guided to the condenser, the second vapor path connecting the second outlet with the condenser.

[0026] According to the twelfth aspect, since the fluid machine according to any one of the first to eleventh aspects is included, the bearing of the multi-stage compressor can be appropriately lubricated, and the refrigeration cycle apparatus has a high reliability.

[0027] Embodiments of the present disclosure will now be described with reference to the drawings. The embodiments described below are merely illustrations, and do not limit the present disclosure.

First Embodiment

[0028] As illustrated in Fig. 1, a fluid machine 1a includes a multi-stage compressor 6, a pressure container 10, a first supply path 11, a pump 12, a first return path 15, and an intermediate pressure space 20. The multi-stage compressor 6 includes a first compressor 6a, a second compressor 6b, and bearings 7. The fluid machine 1a typically constitutes a part of a refrigeration cycle apparatus. The first compressor 6a includes a first inlet 6p and a first outlet 6q. The first compressor 6a sucks a gas refrigerant through the first inlet 6p, compresses the gas refrigerant, and discharges the gas refrigerant through the first outlet 6q. The second compressor 6b includes a second inlet 6r and a second outlet 6s. The second compressor 6b sucks the gas refrigerant discharged from the first outlet 6q through the second inlet 6r, compresses the gas refrigerant, and discharges the gas refrigerant through the second outlet 6s. The bearings 7 support a shaft 6c that drives at least of the first compressor 6a and the second compressor 6b. The pressure container 10 stores a liquid lubricant whose main component is the same kind of substance as the main component of the refrigerant. The first supply path 11 connects the pressure container 10 with the bearings 7 and serves as a flow path for supplying the liquid lubricant stored in the pressure container 10 to the bearings 7. The pump 12 is disposed on the first supply path 11 and pumps the liquid lubricant toward the bearings 7. The first return path 15 connects the bearings 7 with the pressure container 10, and serves as a flow path for returning the liquid lubricant that has passed through the bearings 7 to the pressure container 10. The pressure in the intermediate pressure space 20 is maintained at a pressure (intermediate pressure) higher than the pressure of the gas refrigerant at the first inlet 6p and lower than the pressure of the gas refrigerant at the second outlet 6s during operation of the multi-stage compressor 6. The internal space of the pressure container 10 constitutes a part of the intermediate pressure space 20.

[0029] The pressure in the internal space of the pressure container 10 is maintained at a desired pressure by the gas refrigerant having the intermediate pressure, so that the temperature of the liquid lubricant can be easily maintained at the saturation temperature corresponding to the intermediate pressure or a temperature close to the saturation temperature. Therefore, the liquid lubricant has a temperature suitable for lubrication of the bearings 7. Accordingly, the liquid lubricant can be easily supplied to the bearings 7 of the multi-stage compressor 6 in a desirable state. As a result, condensation of the gas refrigerant and dew formation due to excessive cooling of the bearings 7 of the multi-stage compressor 6 can be prevented, and unstable vibration, such as whirl vibration, which occurs due to insufficient cooling of the bearings 7, can also be reduced.

[0030] There is no particular limitation regarding the intermediate pressure space 20 as long as the intermediate pressure space 20 is filled with the gas refrigerant at the intermediate pressure. For example, the intermediate pressure space 20 is filled with the gas refrigerant that has passed through the first outlet 6q and that has not passed the second inlet 6r during the operation of the multi-stage compressor 6. In this case, the gas refrigerant that has passed through the first outlet 6q and that has not passed through the second inlet 6r may be used to maintain the pressure in the internal space of the pressure container 10 at the desired pressure. In addition, the pressure in the internal space of the pressure container 10, which stores the liquid lubricant, can be more easily maintained at a desirable pressure, and the liquid lubricant can be more reliably supplied to the bearings 7 in a desirable state.

[0031] The intermediate pressure space 20 may include a flow path along which the refrigerant flows between the first outlet 6q and the second inlet 6r in the multi-stage compressor 6. The intermediate pressure space 20 may also include a space in which the gas refrigerant that has passed through the first outlet 6q stays instead of flowing toward the second inlet 6r during the operation of the multi-stage compressor 6. In some cases, the intermediate pressure space 20 may include a space in which the gas refrigerant stays after the pressure thereof is reduced to the intermediate pressure.

[0032] As illustrated in Fig. 1, the intermediate pressure space 20 of the fluid machine 1a includes, for example, a second supply path 8a and a third supply path 8b. The second supply path 8a connects the first outlet 6q with the pressure container 10, and serves as a flow path for guiding the gas refrigerant discharged from the first outlet 6q to the internal space of the pressure container 10. The third supply path 8b connects the pressure container 10 with the second inlet 6r, and serves as a flow path for guiding the gas refrigerant to the second compressor 6b. In this case, the gas refrigerant discharged from the first outlet 6q is guided to the second compressor 6b through the second supply path 8a, the internal space of the pressure container 10, and the third supply path 8b. Thus, the internal space of the pressure container 10 can be used as a portion of the flow path of the gas refrigerant. The liquid lubricant supplied to the bearings 7 is returned to the pressure container 10 through the first return path 15 in such a state that the enthalpy thereof is increased due to loss at the bearings 7. Owing to the increase in enthalpy of the liquid lubricant, gas is generated as a result of vaporization of the liquid lubricant. The gas is guided to the second compressor 6b through the third supply path 8b. Therefore, the pressure in the internal space of the pressure container 10 can be easily maintained at the desired pressure. In addition, even when no radiator is provided on the first return path 15, the temperature of the liquid lubricant stored in the pressure container 10 can be prevented from being continuously increased due to loss at the bearings 7.

[0033] The gas refrigerant discharged from the first outlet 6q is guided to the internal space of the pressure container 10 through the second supply path 8a. In this case, for example, the gas refrigerant can be cooled in the internal space of the pressure container 10 by heat exchange with the liquid lubricant. Thus, the cooled gas refrigerant can be guided to the second compressor 6b through the third supply path 8b. In this way, the liquid lubricant stored in the pressure container 10 can be used for intercooling of the gas refrigerant in the multi-stage compressor 6. As a result, the coefficient of performance (COP) of the refrigeration cycle apparatus including the fluid machine 1a can be increased. Thus, the pressure container 10 may be used as an intercooler.

[0034] Each of the first compressor 6a and the second compressor 6b may be, for example, a dynamic compressor (turbo compressor) or a positive displacement compressor. The dynamic compressor is a compressor that compresses the refrigerant by applying momentum to the refrigerant, and the positive displacement compressor is a compressor that compresses the refrigerant by changing the volume thereof, such as a screw compressor. The multi-stage compressor 6 includes, for example, a casing, and the first compressor 6a and the second compressor 6b are disposed in the casing. The first compressor 6a and the second compressor 6b may be disposed in a single casing or in different casings.

[0035] When the first compressor 6a and the second compressor 6b are driven by the shaft 6c, movable components of the first compressor 6a and the second compressor 6b perform a rotational movement, a linear movement, or a reciprocal movement. The movable components of the first compressor 6a and the second compressor 6b include, for example, impellers of turbo compressors or rotors of screw compressors. The shaft 6c is made of, for example, a metal or an alloy. The multi-stage compressor 6 includes, for example, a single shaft 6c. In this case, the components of the first compressor 6a and the second compressor 6b, such as impellers of turbo compressors or rotors of screw compressors, are attached to the single shaft 6c, and the shaft 6c drives the first compressor 6a and the second compressor 6b. The shaft 6c is connected to, for example, an electric motor (not shown), and is driven when the electric motor is operated. The multi-stage compressor 6 may instead include a plurality of shafts 6c. In this case, for example, the movable component of the first compressor 6a is attached to one of the shafts 6c, and the movement component of the second compressor 6b is attached to another one of the shafts 6c.

[0036] The bearings 7 are, for example, plain bearings or ball bearings, and are lubricated by the liquid lubricant. The bearings 7 support the shaft 6c in at least one of the radial direction and the thrust direction.

[0037] The pressure container 10 is a pressure-resistant container made of a metal material, such as steel, and the internal space of the pressure container 10 is sealed from the space outside the pressure container 10 by welding or by a sealing member. Accordingly, leakage of the liquid lubricant from the internal space of the pressure container 10 and entrance of external gas into the internal space of the pressure container 10 are prevented.

[0038] The pump 12 may be, for example, a positive displacement pump or a dynamic pump. The positive displacement pump increases the pressure of the liquid refrigerant by changing the volume thereof, and the dynamic pump increases the pressure of the liquid refrigerant by applying momentum to the refrigerant. The pump 12 may be provided with a mechanism for changing the rotational speed of the pump 12. The mechanism may be, for example, a motor driven by an inverter. The discharge pressure of the pump 12 is not particularly limited, and may be, for example, 100 to 1000 kPa. The pump 12 may be wired or wirelessly connected to a controller so as to be capable of receiving a control signal from the controller. In this case, the pump 12 is operated in response to the control signal from the controller.

[0039] At least a portion of each of the first supply path 11, the first return path 15, the second supply path 8a, and the third supply path 8b is constituted by, for example, a pipe made of a metal material, such as steel. In this case, the inside of the pipe is sealed from the space outside the pipe by welding or by a sealing member. Accordingly, leakage of the liquid lubricant that flows through the first supply path 11 and the first return path 15 and entrance of external gas into the first supply path 11 and the first return path 15 can be prevented. In addition, leakage of the refrigerant that flows through the second supply path 8a and the third supply path 8b and entrance of external gas into the second supply path 8a and the third supply path 8b can be prevented.

[0040] There is no particular limitation regarding the refrigerant. For example, the refrigerant has a relatively low saturation vapor pressure of 50 kPaA or less at normal temperature (low-pressure refrigerant). The main component of such a refrigerant is, for example, a hydrofluoroolefin (HFO) based material, such as R-1233zd or R-1234ze, or water.

[0041] Preferably, the refrigerant and the liquid lubricant contain water as the main component. Since evaporation of water involves a large amount of latent heat, even when the liquid lubricant is vaporized due to loss at the bearings 7 or contact with the gas refrigerant, the amount of gas generated as a result of vaporization of the liquid lubricant is small. Therefore, the amount of gas refrigerant guided to the second compressor 6b through the third supply path 8b is reduced, and work to be performed by the second compressor 6b can be reduced accordingly. In addition, the gas refrigerant guided to the internal space of the pressure container 10 through the second supply path 8a can be cooled so that the temperature of the gas refrigerant sucked into the second compressor 6b is reduced to the saturation temperature corresponding to the intermediate pressure or a temperature close to the saturation temperature.

Modifications

[0042] The fluid machine 1a may be modified in various respects. The fluid machine 1a may further include a filter disposed on the first supply path 11 to reduce the amount of impurities contained in the liquid lubricant. The filter is constituted by, for example, a sintered metal filter or a metal mesh. The fluid machine 1a may be modified as in fluid machines 1b, 1c, 1d, and 1e illustrated in Figs. 2 to 5.

[0043] The fluid machines 1b, 1c, 1d, and 1e have a structure similar to that of the fluid machine 1a except for differences specifically described. Components of the fluid machines 1b, 1c, 1d, and 1e that are the same as or correspond to those of the fluid machine 1a are denoted by the same reference numerals, and detailed description thereof is omitted.

[0044] As illustrated in Figs. 2 to 5, each of the fluid machines 1b, 1c, 1d, and 1e additionally includes a second return path 16. The second return path 16 connects a branching point B located between the outlet of the pump 12 on the first supply path 11 and the bearings 7 with the pressure container 10 so as to bypass the bearings 7, and serves as a flow path for returning a portion of the liquid lubricant in the first supply path 11 to the pressure container 10. Therefore, a portion of the liquid lubricant that flows through the first supply path 11 is returned to the internal space of the pressure container 10 through the second return path 16 without passing through the bearings 7. Accordingly, the liquid lubricant can be brought into contact with the gas refrigerant. The outlet of the second return path 16 is typically connected with the intermediate pressure space 20 in the internal space of the pressure container 10.

[0045] At least a portion of the second return path 16 is constituted by, for example, a pipe made of a metal material, such as steel. In this case, the inside of the pipe is sealed from the space outside the pipe by welding or by a sealing member. Accordingly, leakage of the liquid lubricant that flows through the second return path 16 and entrance of external gas into the second return path 16 can be prevented.

[0046] Each of the fluid machines 1b, 1c, 1d, and 1e further includes, for example, a first filter 18a. The first filter 18a is disposed on the first supply path 11, and serves as a filter for reducing the amount of impurities contained in the liquid lubricant. The amount of impurities contained in the liquid lubricant to be supplied to the bearings 7 can be reduced by the first filter 18a.

[0047] The first filter 18a is constituted by, for example, a sintered metal filter or a metal mesh, and is capable of catching impurities of 7 μm or greater.

[0048] As illustrated in Fig. 2, in the fluid machine 1b, the first filter 18a is disposed between the outlet of the pump 12 and the branching point B on the first supply path 11. According to the fluid machine 1b, the amount of impurities contained in the liquid lubricant that flows through the second return path 16 and the liquid lubricant supplied to the bearings 7 can be reduced without using a filter other than the first filter 18a. Therefore, the fluid machine 1b can be simplified and the manufacturing cost of the fluid machine 1b can be easily reduced. In this case, the outlet of the second return path 16 may be defined by a nozzle. Thus, the liquid lubricant that flows out of the outlet of the second return path 16 can be refined. In addition, the first filter 18a reduces the risk that the impurities will clog the nozzle that defines the outlet of the second return path 16.

[0049] As illustrated in Figs. 3 to 5, in the fluid machines 1c, 1d, and 1e, the first filter 18a is disposed between the branching point B and the bearings 7 on the first supply path 11. Also in this case, the amount of impurities contained in the liquid lubricant supplied to the bearings 7 can be reduced.

[0050] In the fluid machine 1c, the first filter 18a is the only filter disposed on the first supply path 11 to reduce the amount of impurities contained in the liquid lubricant. In this case, the outlet of the second return path 16 is preferably not defined by a nozzle. This is because there is a possibility that the impurities will pass through the second return path 16.

[0051] As illustrated in Fig. 4, the fluid machine 1d further includes a second filter 18b. The second filter 18b is disposed between the outlet of the pump 12 and the branching point B on the first supply path 11, and serves as a filter for reducing the amount of impurities contained in the liquid lubricant. In this case, the amount of impurities contained in the liquid lubricant that flows through the second return path 16 and the liquid lubricant supplied to the bearings 7 can be reduced by the second filter 18b. In addition, the impurities that have passed through the second filter 18b can be caught by the first filter 18a. As a result, the amount of impurities contained in the liquid lubricant supplied to the bearings 7 can be more reliably reduced. According to the fluid machine 1d, the first filter 18a is not easily clogged because the impurities caught by the second filter 18b do not reach the first filter 18a.

[0052] As illustrated in Fig. 5, the fluid machine 1e further includes a second filter 18b. The second filter 18b is disposed on the second return path 16, and serves as a filter for reducing the amount of impurities contained in the liquid lubricant. In this case, the second filter 18b can be replaced without stopping the pump 12, and the liquid lubricant can be continuously supplied to the bearings 7.

[0053] In the fluid machine 1d and the fluid machine 1e, the second filter 18b is constituted by, for example, a sintered metal filter or a metal mesh, and is capable of catching impurities that are larger in size than the impurities catchable by the first filter 18a. For example, the second filter 18b is capable of catching impurities of 40 μm or greater.

[0054] In the fluid machine 1d and the fluid machine 1e, the outlet of the second return path 16 is defined by, for example, a nozzle. In this case, the liquid lubricant that flows out of the outlet of the second return path 16 can be refined. In addition, the second filter 18b reduces the risk that the impurities will clog the nozzle that defines the outlet of the second return path 16.

Second Embodiment

[0055] A fluid machine 1f according to a second embodiment will now be described. The fluid machine 1f has a structure similar to that of the fluid machine 1a except for differences specifically described. Components of the fluid machine 1f that are the same as or correspond to those of the fluid machine 1a are denoted by the same reference numerals, and detailed description thereof is omitted. The description of the first embodiment including the description regarding the modifications applies also to the second embodiment unless there is a technical contradiction.

[0056] As illustrated in Fig. 6, in the fluid machine 1f, the intermediate pressure space 20 includes a fourth supply path 8c and a fifth supply path 9. The fourth supply path 8c connects the first outlet 6q with the second inlet 6r, and serves as a flow path for guiding the gas refrigerant to the second compressor 6b. The fifth supply path 9 connects the pressure container 10 with a merging point J on the fourth supply path 8c, and serves as a flow path for guiding gas generated as a result of vaporization of the liquid lubricant to the second compressor 6b.

[0057] According to the fluid machine 1f, since the internal space of the pressure container 10 communicates with the fourth supply path 8c through the fifth supply path 9, the pressure in the internal space of the pressure container 10 is maintained at the intermediate pressure, and the internal space of the pressure container 10 constitutes a part of the intermediate pressure space 20. In addition, since the gas generated as a result of vaporization of the liquid lubricant due to loss at the bearings 7 is guided to the second compressor 6b through the fifth supply path 9, the pressure in the internal space of the pressure container 10 can be easily maintained at the desired pressure. Furthermore, even when no radiator is provided on the first return path 15, the temperature of the liquid lubricant stored in the pressure container 10 can be prevented from being continuously increased due to loss at the bearings 7. As a result, the liquid lubricant can be supplied to the bearings 7 in a desirable state.

[0058] At least a portion of each of the fourth supply path 8c and the fifth supply path 9 is constituted by, for example, a pipe made of a metal material, such as steel. In this case, the inside of the pipe is sealed from the space outside the pipe by welding or by a sealing member. Accordingly, leakage of the gas generated as a result of vaporization of the liquid lubricant and the gas refrigerant that flow through the fourth supply path 8c and the fifth supply path 9 and entrance of external gas into the fourth supply path 8c and the fifth supply path 9 can be prevented. In the case where the first compressor 6a and the second compressor 6b are disposed in a single casing, the pipe that constitutes the fourth supply path 8c is typically disposed outside the casing. However, in some cases, the pipe that constitutes the fourth supply path 8c may be disposed in the casing. Alternatively, the space in the casing may constitute the entirety of the fourth supply path 8c. In this case, the fifth supply path 9 is constituted by a pipe that opens into the space inside the casing that defines the fourth supply path 8c.

Refrigeration Cycle Apparatus

[0059] As illustrated in Fig. 7, a refrigeration cycle apparatus 50a includes the fluid machine 1a, an evaporator 2, a first vapor path 5a, a condenser 3, and a second vapor path 5b. The evaporator 2 generates gas refrigerant by evaporating liquid refrigerant. The first vapor path 5a connects the evaporator 2 with the first inlet 6p, and serves as a flow path for guiding the gas refrigerant to the first compressor 6a. The condenser 3 condenses the gas refrigerant discharged from the second outlet 6s. The second vapor path 5b connects the second outlet 6s with the condenser 3, and serves as a flow path for guiding the gas refrigerant discharged from the second outlet 6s to the condenser 3.

[0060] The evaporator 2 absorbs heat from a heat source provided outside the refrigeration cycle apparatus 50a to evaporate the liquid refrigerant. The evaporator 2 is, for example, an indirect heat exchanger, such as a shell-and tube heat exchanger or a plate heat exchanger, or a direct heat exchanger, such as a spray heat exchanger or a direct heat exchanger having a filler. As illustrated in Fig. 7, the evaporator 2 includes, for example, a tank 23, a liquid refrigerant flow path 25, and a pump 27. The tank 23 is a container that stores the liquid refrigerant. The tank 23 is made of a metal material, such as steel, and the internal space of the tank 23 is sealed from the space outside the tank 23 by welding or by a sealing member. Accordingly, leakage of the liquid refrigerant from the internal space of the tank 23 and entrance of external gas into the internal space of the tank 23 can be prevented. The liquid refrigerant flow path 25 is a flow path having an inlet and an outlet connected to the internal space of the tank 23 and extending from the inlet to the outlet in the space outside the tank 23. The pump 27 is disposed on the liquid refrigerant flow path 25, and discharges the liquid refrigerant toward the internal space of the tank 23. Thus, when the pump 27 is operated, a portion of the liquid refrigerant stored in the tank 23 is extracted and returned to the inside of the tank 23 through the liquid refrigerant flow path 25. In some cases, the liquid refrigerant flow path 25 and the pump 27 of the evaporator 2 may be omitted.

[0061] At least a portion of each of the first vapor path 5a and the second vapor path 5b is constituted by, for example, a pipe made of a metal material, such as steel. The inside of the pipe is sealed from the space outside the pipe by welding or by a sealing member. Accordingly, leakage of the gas refrigerant that flows through the first vapor path 5a and the second vapor path 5b and entrance of external gas into the first vapor path 5a and the second vapor path 5b can be prevented.

[0062] The condenser 3 dissipates heat of the gas refrigerant to the outside of the refrigeration cycle apparatus 50a to condense the gas refrigerant. The condenser 3 is, for example, an indirect heat exchanger, such as a shell-and tube heat exchanger or a plate heat exchanger, or a direct heat exchanger, such as a spray heat exchanger or a direct heat exchanger having a filler. The condenser 3 stores, for example, the liquid refrigerant.

[0063] The refrigerant used in the refrigeration cycle apparatus 50a is, for example, a low-pressure refrigerant. An example of an operation of the refrigeration cycle apparatus 50a in the case where the main component of the refrigerant is water will be described. The temperature of the liquid refrigerant stored in the tank 23 of the evaporator 2 is a saturation temperature corresponding to a low pressure in the evaporator 2 or a temperature close to the saturation temperature corresponding to the low pressure in the evaporator 2, and is 5°C, for example. Since the temperature of the liquid refrigerant stored in the evaporator 2 is low, when the liquid refrigerant stored in the evaporator 2 is used as the liquid lubricant for the bearings 7, condensation of the gas refrigerant or dew formation easily occurs at the multi-stage compressor 6. The temperature of the liquid refrigerant stored in the condenser 3 is a saturation temperature corresponding to a high pressure in the condenser 3 or a temperature close to the saturation temperature corresponding to the high pressure in the condenser 3, and is 35°C, for example. Since the temperature of the liquid refrigerant stored in the condenser 3 is high, when the liquid refrigerant stored in the condenser 3 is used as the liquid lubricant, there is a risk that the bearings 7 cannot be appropriately cooled.

[0064] While the refrigeration cycle apparatus 50a is in operation, the pump 12 is operated so that the liquid lubricant stored in the pressure container 10 is supplied to the bearings 7. Since the internal space of the pressure container 10 constitutes a part of the intermediate pressure space 20, the pressure in the internal space of the pressure container 10 is maintained at the intermediate pressure while the refrigeration cycle apparatus 50a is in operation. The temperature of the liquid lubricant stored in the pressure container 10 is the saturation temperature corresponding to the intermediate pressure or a temperature close to the saturation temperature, and is 20 °C, for example. The liquid lubricant stored in the pressure container 10 has a temperature suitable for lubrication of the bearings 7, and the bearings 7 are appropriately cooled in the refrigeration cycle apparatus 50a.

Modification

[0065] The refrigeration cycle apparatus 50a may be modified in various respects. For example, the refrigeration cycle apparatus 50a may include the fluid machine 1b, 1c, 1d, or 1e instead of the fluid machine 1a. In addition, the refrigeration cycle apparatus 50a may be modified as in a refrigeration cycle apparatus 50b illustrated in Fig. 8. The refrigeration cycle apparatus 50b has a structure similar to that of the refrigeration cycle apparatus 50a except that the fluid machine 1f is provided instead of the fluid machine 1a. The refrigeration cycle apparatus 50a may be modified so as to include a flow path that connects a merging point between the pressure container 10 and the inlet of the pump 12 on the first supply path 11 with the tank 23. The refrigeration cycle apparatus 50a may also be modified so as to include a flow path that connects a merging point between the pressure container 10 and the inlet of the pump 12 on the first supply path 11 with a branching point on the liquid refrigerant flow path 25. In this case, the liquid refrigerant stored in the tank 23 may be supplied to the bearings 7 depending on the operation conditions of the multi-stage compressor 6.

[0066] The fluid machine according to the present disclosure may be applied to, for example, a large air conditioner or a turbo chiller.

Claims

1. A fluid machine (1a-1f) comprising:

a multi-stage compressor (6) that includes a first compressor (6a) having a first inlet (6p) and a first outlet (6q), a second compressor (6b) having a second inlet (6r) and a second outlet (6s), and a bearing (7) supporting a shaft (6c) for driving at least one of the first compressor (6a) and the second compressor (6b), the first compressor (6a) sucking a gas refrigerant through the first inlet (6p), compressing the gas refrigerant, and discharging the gas refrigerant through the first outlet (6q), the second compressor (6b) sucking the gas refrigerant discharged from the first outlet (6q) through the second inlet (6r), compressing the gas refrigerant, and discharging the gas refrigerant through the second outlet (6s);

a pressure container (10) that stores a liquid lubricant whose main component is the same kind of substance as a main component of the refrigerant;

a first supply path (11) through which the liquid lubricant stored in the pressure container (10) is supplied to the bearing (7), the first supply path (11) connecting the pressure container (10) with the bearing (7);

a pump (12) that is disposed on the first supply path (11) and pumps the liquid lubricant toward the bearing (7);

a first return path (15) through which the liquid lubricant that has passed through the bearing (7) is returned to the pressure container (10), the first return path (15) connecting the bearing (7) with the pressure container (10); and

an intermediate pressure space (20) that is maintained at a pressure higher than a pressure of the gas refrigerant at the first inlet (6p) and lower than a pressure of the gas refrigerant at the second outlet (6s) during operation of the multi-stage compressor (6), wherein

an internal space of the pressure container (10) constitutes a part of the intermediate pressure space (20).

2. The fluid machine (1a-1f) according to Claim 1, wherein the intermediate pressure space (20) is filled with the gas refrigerant that has passed through the first outlet (6q) and that has not passed through the second inlet (6r) during the operation of the multi-stage compressor (6).

3. The fluid machine (1a-1e) according to Claim 1 or 2, wherein the intermediate pressure space (20) includes a second supply path (8a) through which the gas refrigerant discharged from the first outlet (6q) is guided to the internal space of the pressure container (10), the second supply path (8a) connecting the first outlet (6q) with the pressure container (10), and a third supply path (8b) through which the gas refrigerant is guided to the second compressor (6b), the third supply path (8b) connecting the pressure container (10) with the second inlet (6r).

4. The fluid machine (1f) according to Claim 1 or 2, wherein the intermediate pressure space (20) includes a fourth supply path (8c) through which the gas refrigerant is guided to the second compressor (6b), the fourth supply path (8c) connecting the first outlet (6q) with the second inlet (6fr), and a fifth supply path (9) through which gas generated as a result of vaporization of the liquid lubricant is guided to the second compressor (6b), the fifth supply path (9) connecting the pressure container (10) with a merging point (J) on the fourth supply path (8c).

5. The fluid machine (1b-1e) according to any one of Claims 1 to 4, further comprising a second return path (16) through which a portion of the liquid lubricant in the first supply path (11) is returned to the pressure container (10), the second return path (16) connecting a branching point (B) located between an outlet of the pump (12) on the first supply path (11) and the bearing (7) with the pressure container (10) so as to bypass the bearing (7).

6. The fluid machine (1b-1e) according to Claim 5, further comprising a first filter (18a) that is disposed on the first supply path (11) and reduces an amount of impurities contained in the liquid lubricant.

7. The fluid machine (1b) according to Claim 6, wherein the first filter (18a) is disposed between the outlet of the pump (12) and the branching point (B) on the first supply path (11).

8. The fluid machine (1c) according to Claim 6, wherein the first filter (18a) is disposed between the branching point (B) and the bearing (7) on the first supply path (11).

9. The fluid machine (1d) according to Claim 8, further comprising a second filter (18b) that is disposed between the outlet of the pump (12) and the branching point (B) on the first supply path (11) and reduces the amount of impurities contained in the liquid lubricant.

10. The fluid machine (1e) according to Claim 8, further comprising a second filter (18b) that is disposed on the second return path (16) and reduces the amount of impurities contained in the liquid lubricant.

11. The fluid machine (1a-1f) according to any one of Claims 1 to 10,
wherein the refrigerant and the liquid lubricant contain water as the main component.

12. A refrigeration cycle apparatus (50a, 50b) comprising:

the fluid machine (1a-1f) according to any one of Claims 1 to 11;
an evaporator (2) that generates the gas refrigerant by evaporating liquid refrigerant;
a first vapor path (5a) through which the gas refrigerant is guided to the first compressor (6a), the first vapor path (5a), connecting the evaporator (2) with the first inlet (6p);
a condenser (3) that condenses the gas refrigerant discharged from the second outlet (6s); and
a second vapor path (5b) through which the gas refrigerant discharged from the second outlet (6s) is guided to the condenser (3), the second vapor path (5b) connecting the second outlet (6s) with the condenser (3).

FIG. 1

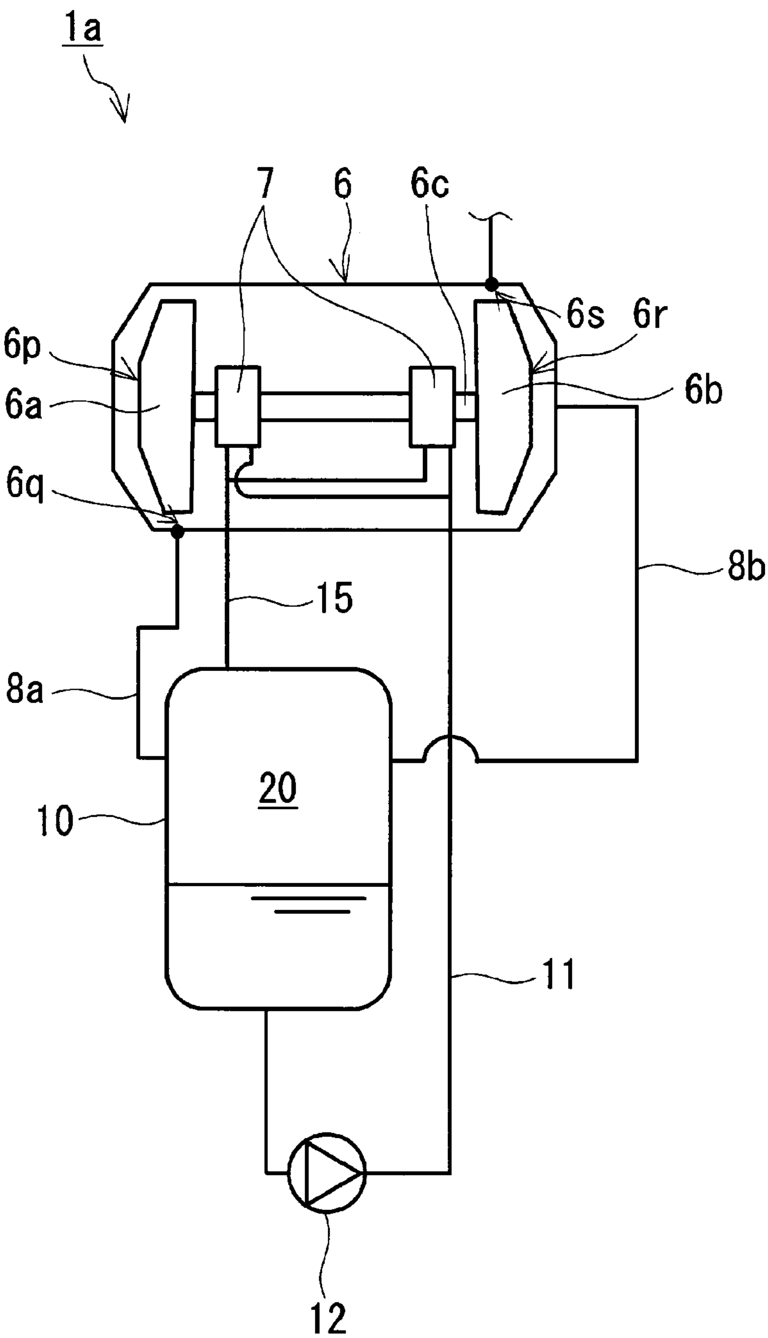


FIG. 2

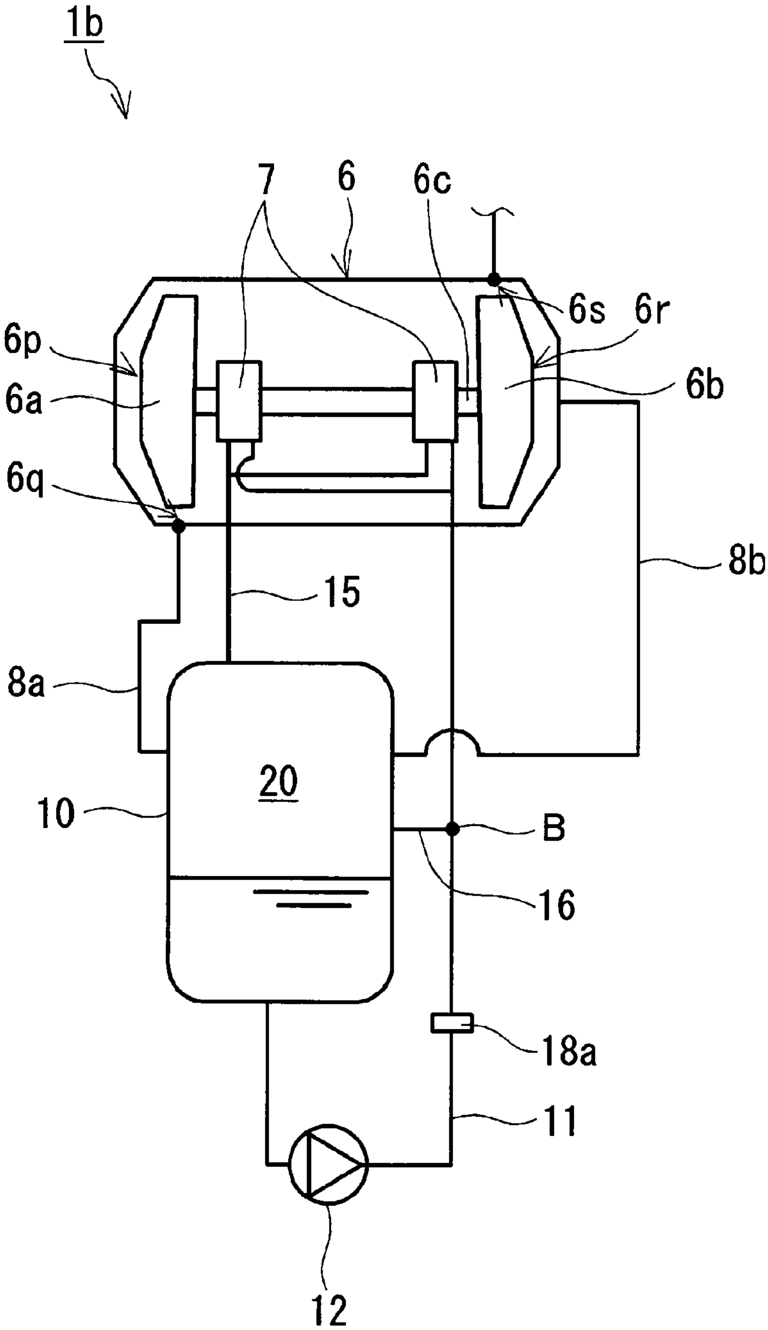


FIG. 3

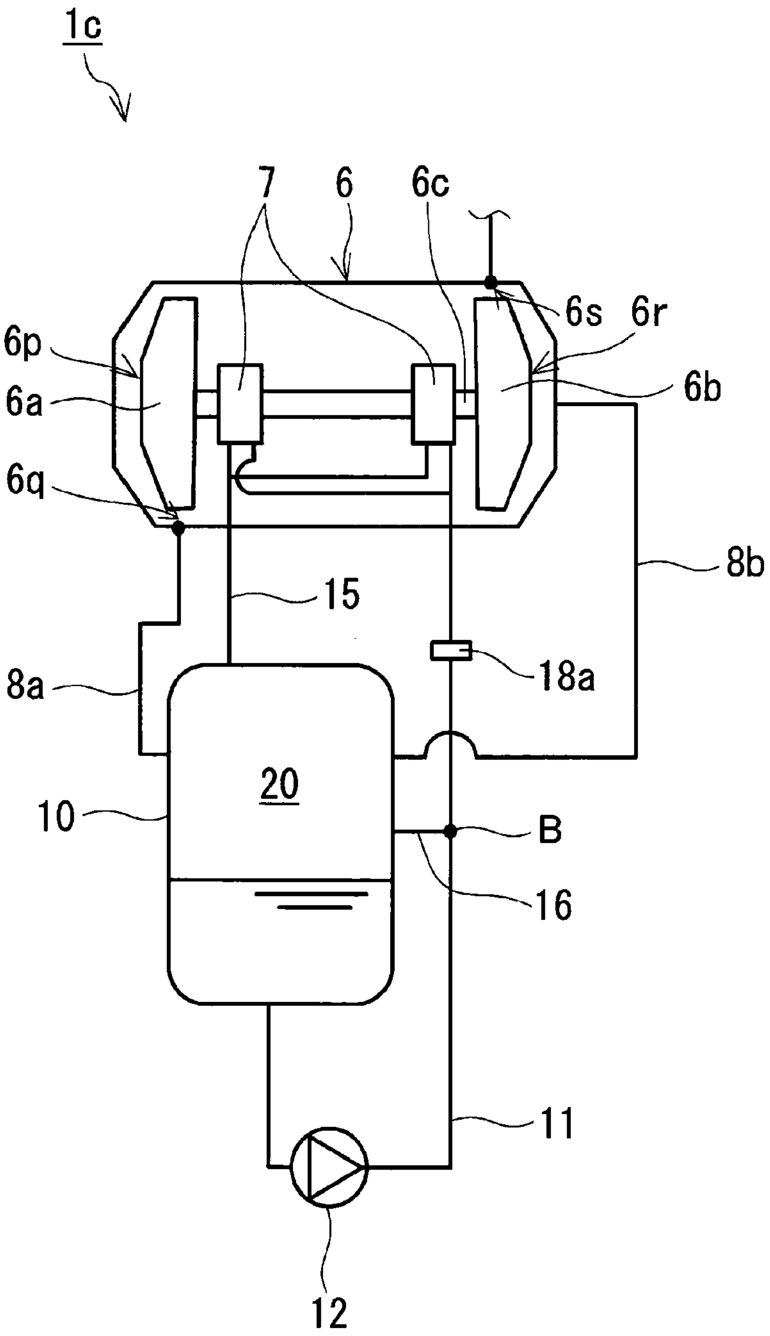


FIG. 4

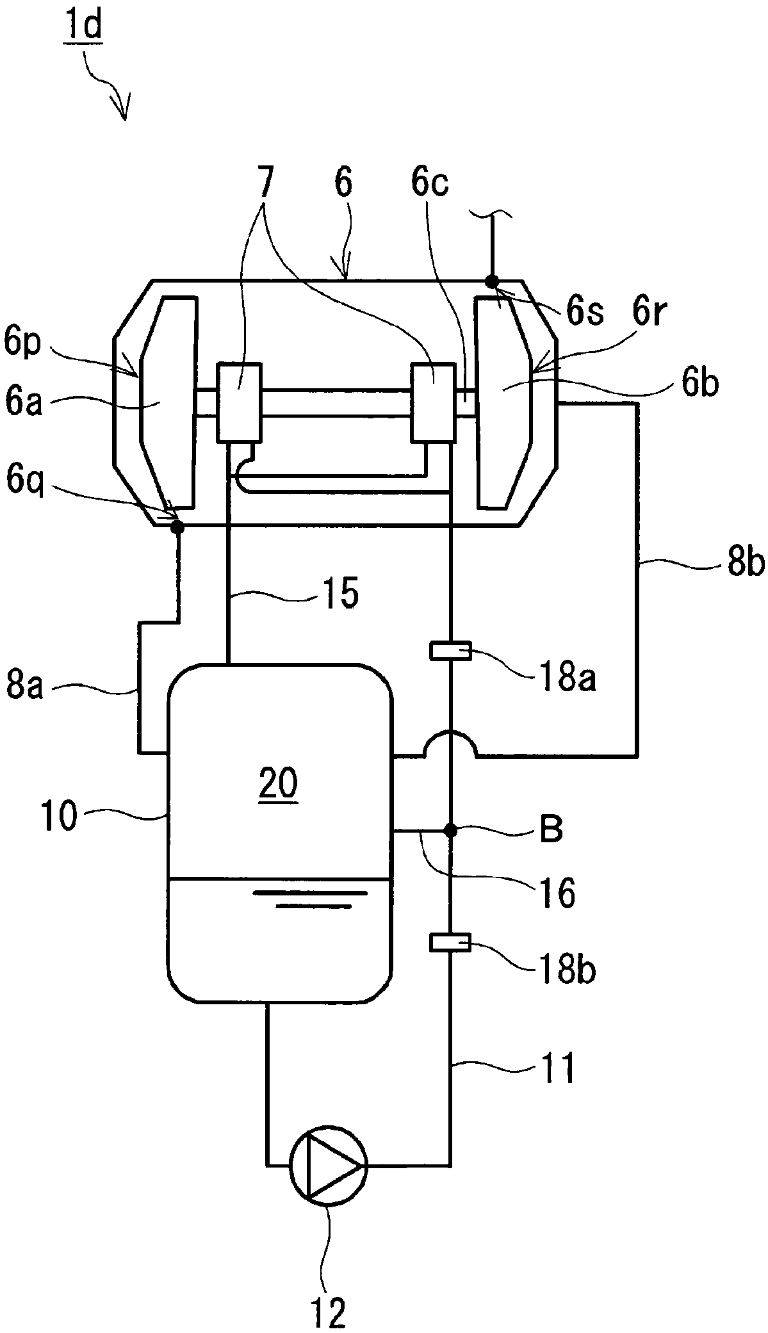


FIG. 5

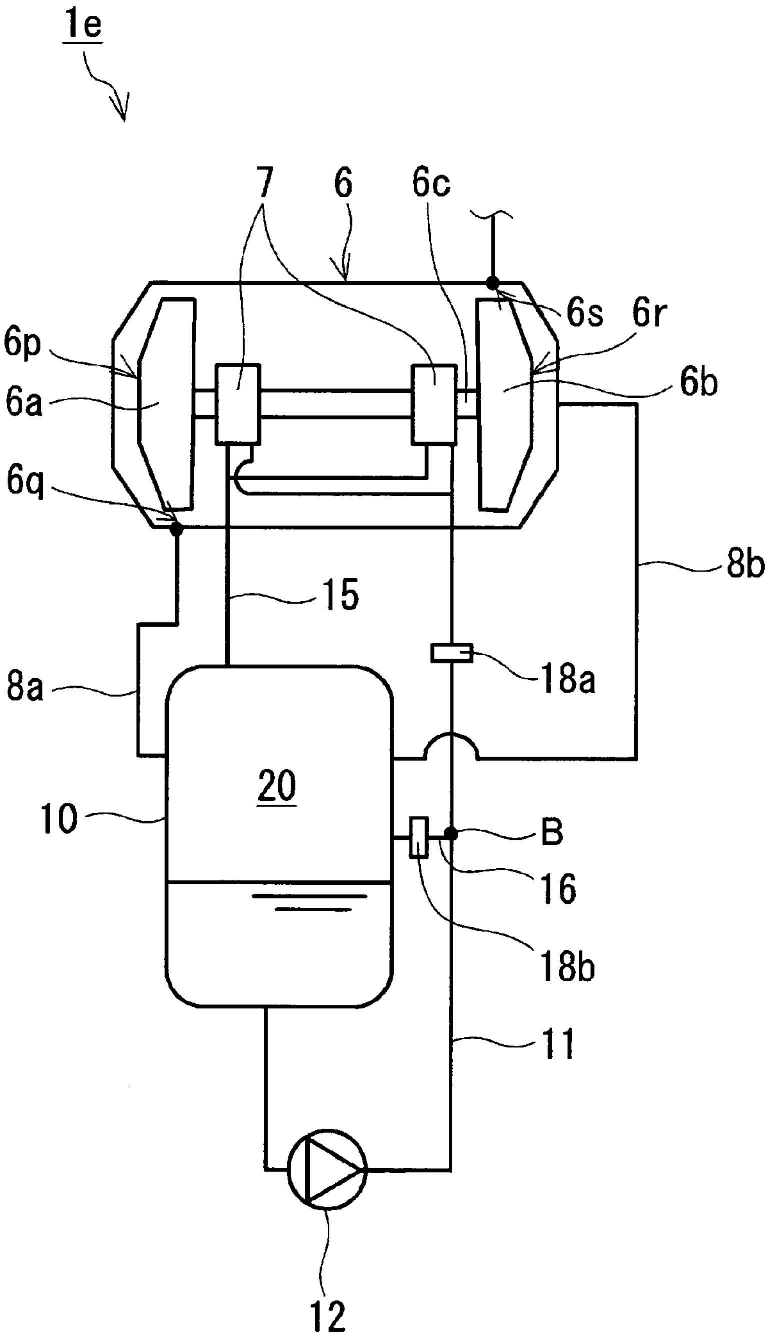


FIG. 6

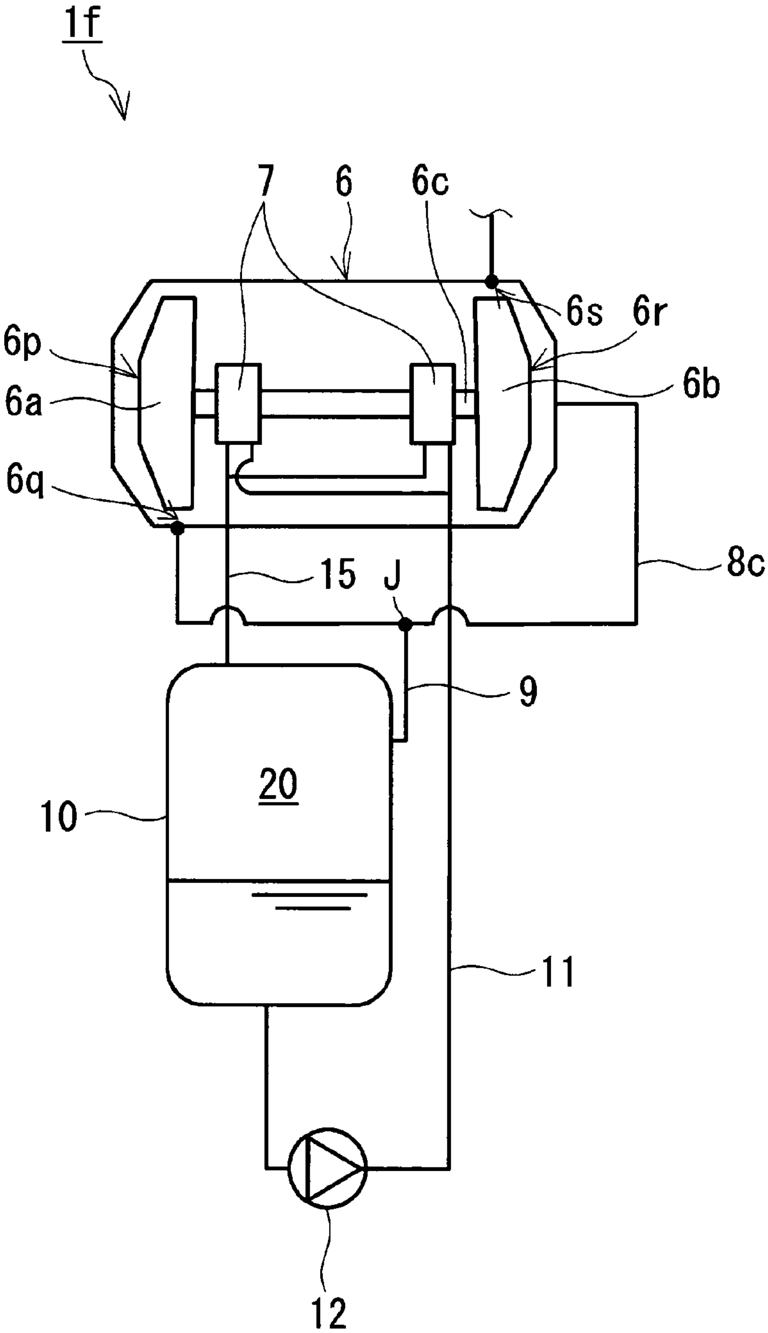


FIG. 7

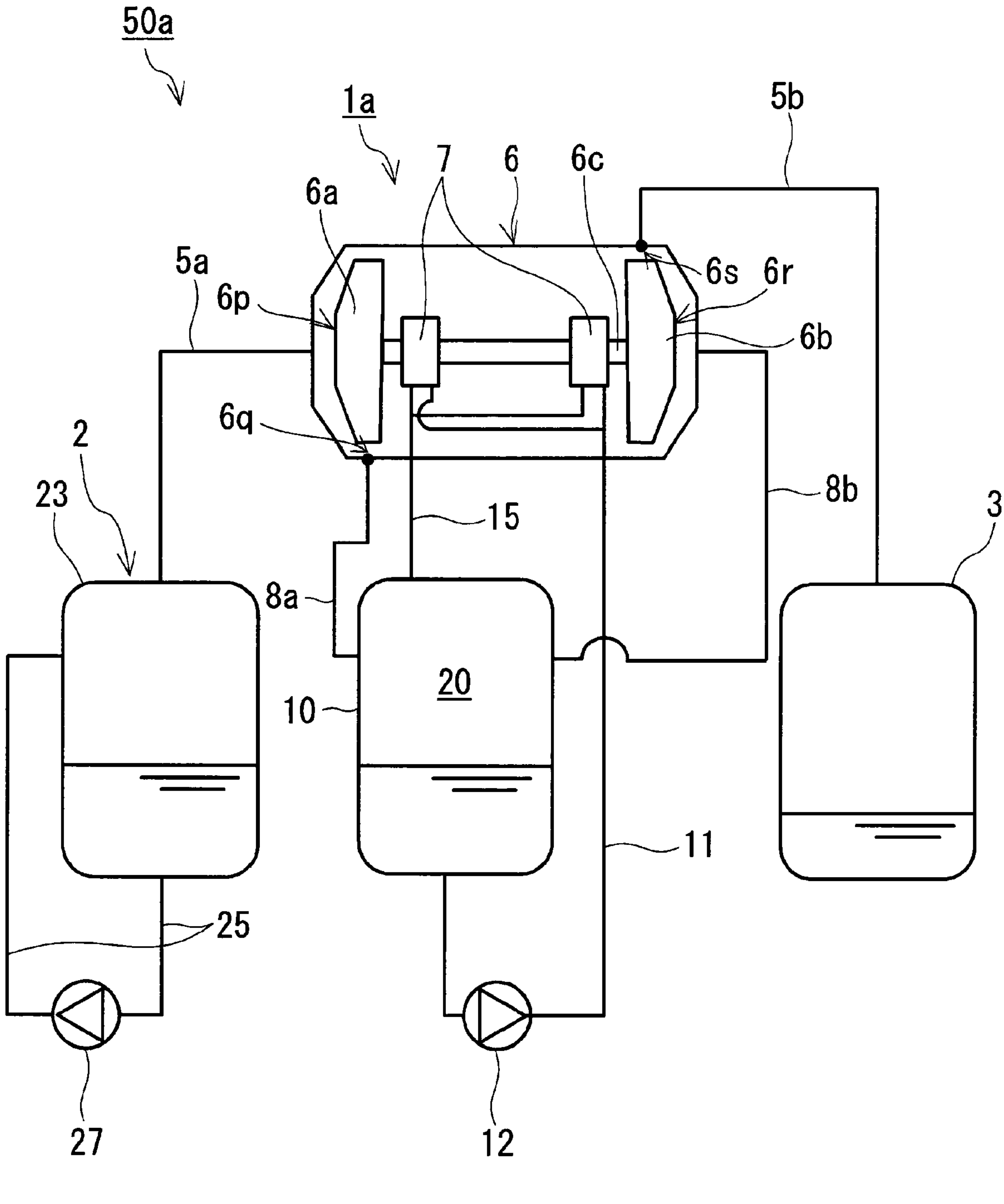


FIG. 8

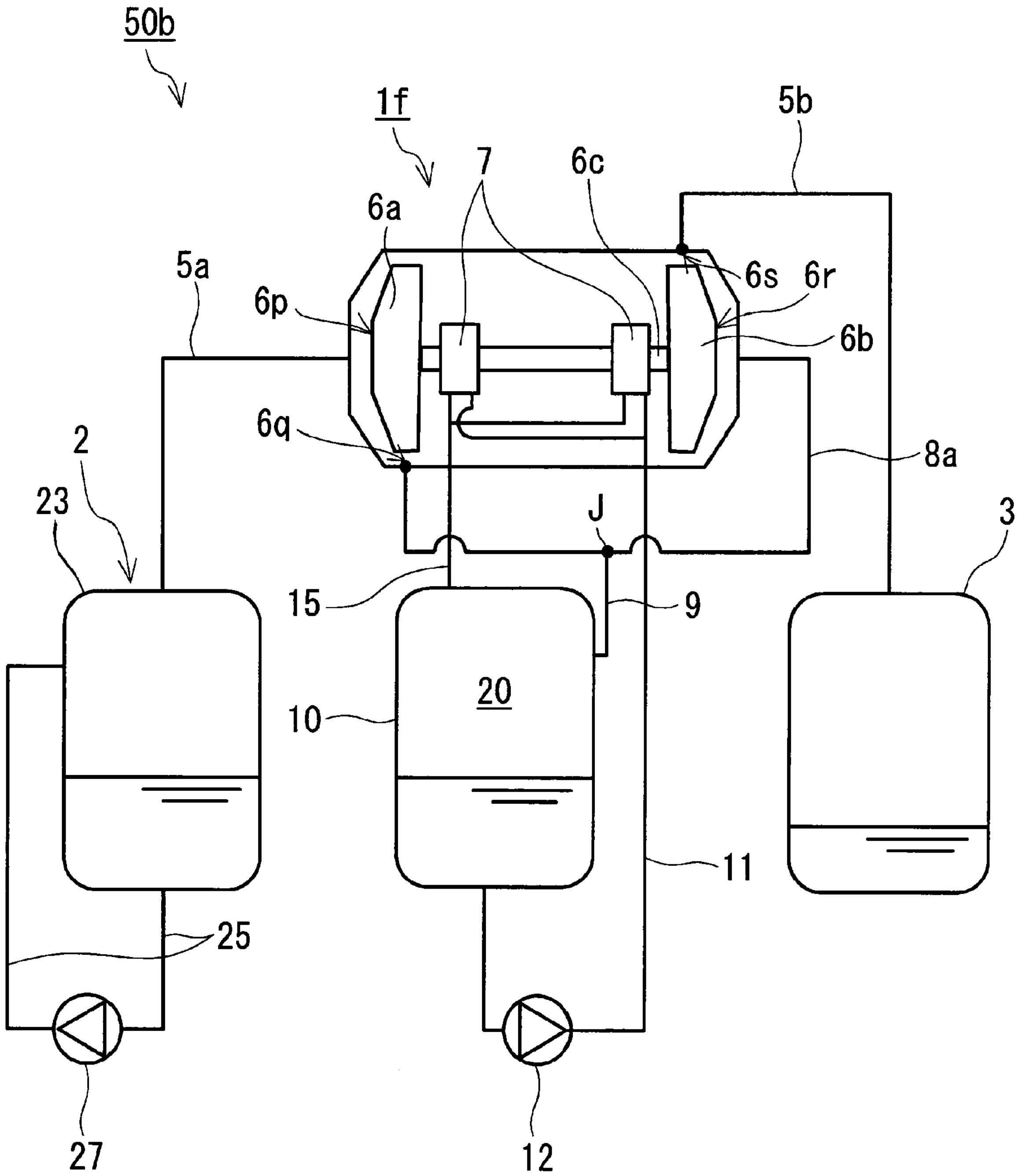


FIG. 9

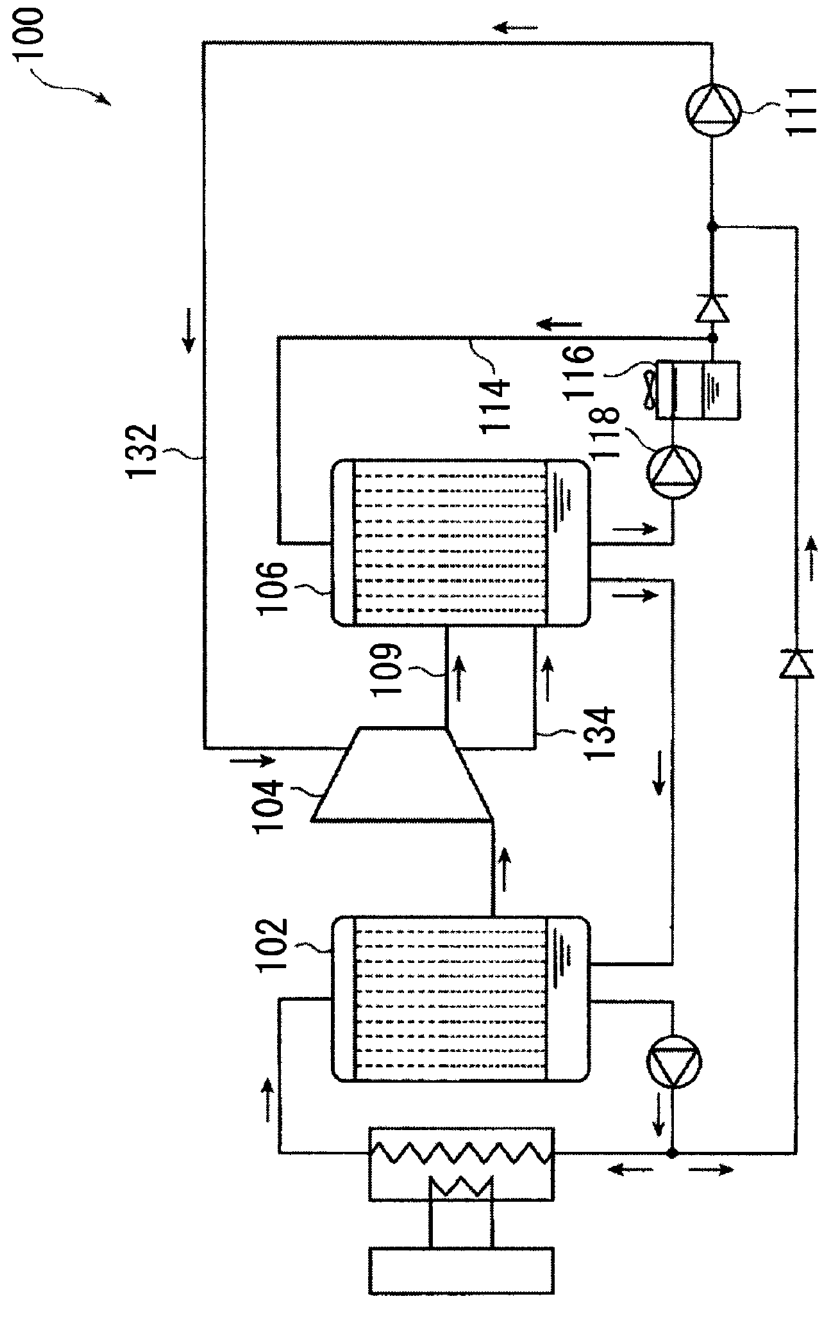
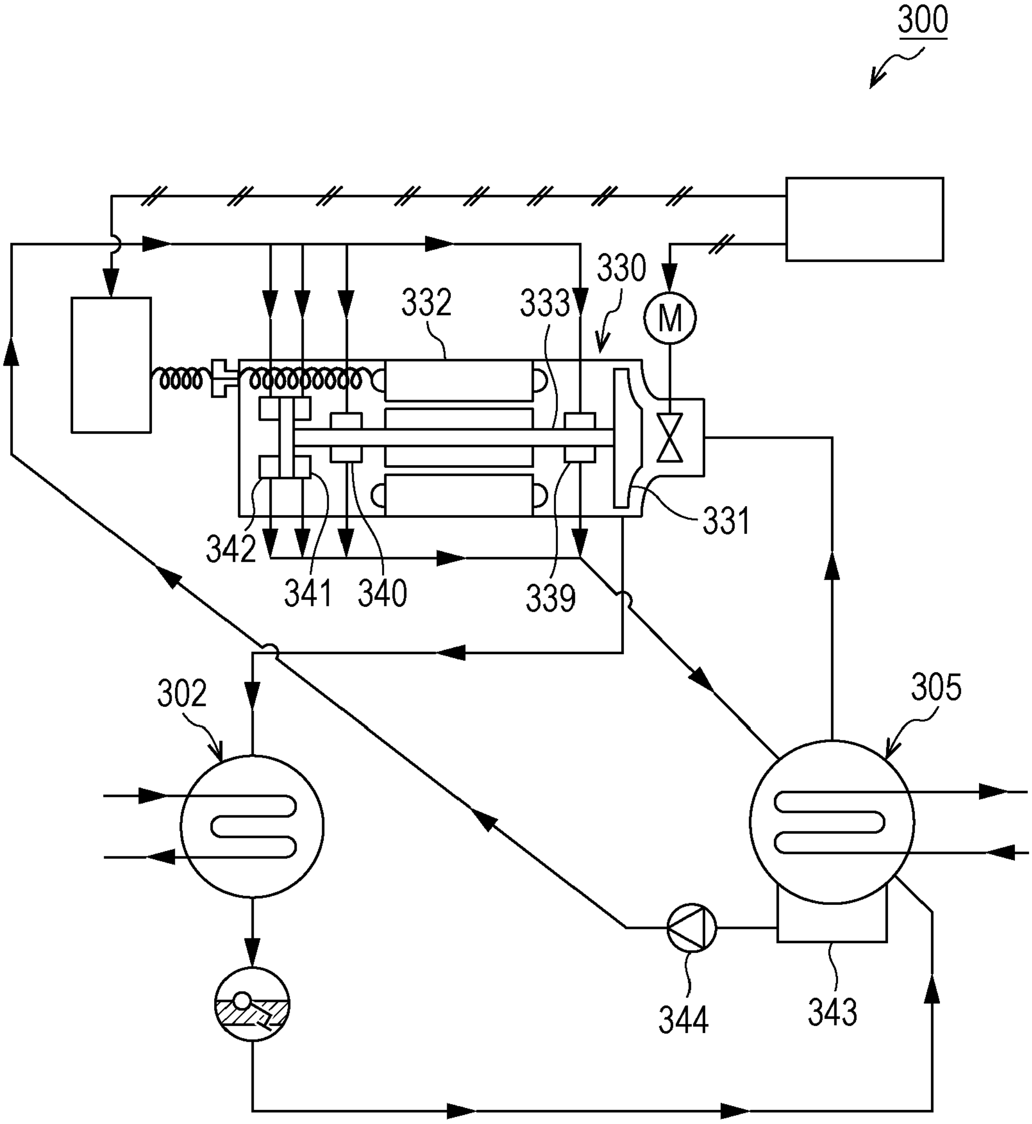


FIG. 10



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EUROPEAN SEARCH REPORT

Application Number
EP 18 15 6399

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The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	5 July 2018	Kolby, Lars

CATEGORY OF CITED DOCUMENTS

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