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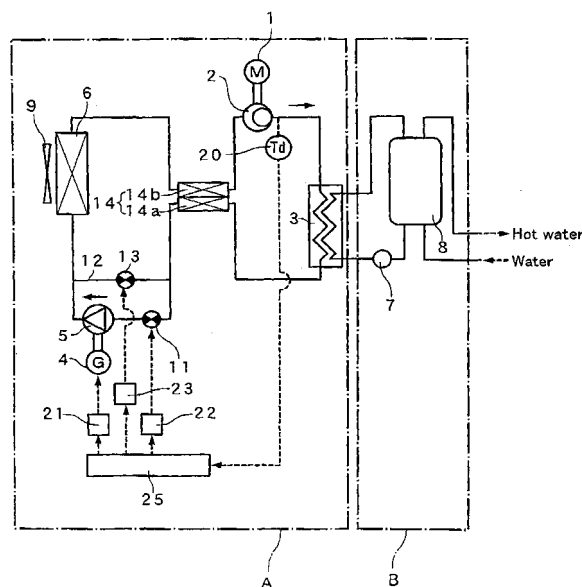
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(54) **Refrigeration cycle apparatus**

(57) In a refrigeration cycle apparatus having an expansion mechanism whose number of revolutions can be changed independently from the number of revolutions of a compressing mechanism, it is an object of the invention to adjust a circulation amount of a refrigerant flowing into the expansion mechanism in a wider range without deteriorating the reliability of the expansion mechanism, and to operate the refrigeration cycle apparatus efficiently. The refrigeration cycle apparatus comprises a compressing mechanism 2, a heat source-side heat exchanger 6, an expansion mechanism 5 which collects power and has the number of revolutions that can be changed independently from the number of revolutions of the compressing mechanism 2, a utilizing-side heat exchanger 3, and a pre-expansion valve 11 for decompressing a refrigerant flowing into the expansion mechanism 5. With this refrigeration cycle apparatus, when the high pressure-side pressure can not be adjusted to a preferable pressure without bringing the number of revolutions of the expansion mechanism 5 out from its using range, the high pressure-side pressure can be adjusted by operating an opening of the pre-decompressor. Therefore, the refrigeration cycle apparatus can be operated efficiently without deteriorating the reliability of the expansion mechanism.

Fig. 1



Description

Technical Field

[0001] The present invention relates to a refrigeration cycle apparatus having an expansion mechanism which collects power.

Background Technique

[0002] There is proposed a refrigeration cycle apparatus in which an expansion mechanism is provided instead of a decompressor, pressure energy at the time of expansion is collected as power, and COP is enhanced (see patent document 1 for example). Such expansion mechanisms can roughly be divided into two types due to a difference in power collecting method. One of the types is a type (mechanical energy collecting type, hereinafter) in which an expansion mechanism and a rotation shaft of a compressing mechanism are connected to one shaft, and power generated by the expansion mechanism is transferred to the compressing mechanism as mechanical energy (rotation energy). The other type is a type (electric energy collecting type, hereinafter) in which a generator is connected to a rotation shaft of an expansion mechanism, and power generated in the expansion mechanism is collected as electric energy.

[0003] In the following description, Hzc represents the number of revolutions of the compressing mechanism, Hze represents the number of revolutions of the expansion mechanism, both the compressing mechanism and expansion mechanism are of positive-displacement type, VC represents a cylinder capacity of a compressor, VE represents a cylinder capacity of the expansion mechanism, DC represents density of refrigerant flowing into the compressing mechanism, and DE represents density of refrigerant flowing into the expansion mechanism. Since the mass circulation amounts flowing through the compressing mechanism and the expansion mechanism are equal to each other, a relation " $VC \times DC \times Hzc = VE \times DE \times Hze$ ", i.e., " $VC / VE = (DE / DC) \times (Hze / Hzc)$ " is established. Since VC / VE (design capacity ratio) is a constant which is determined when the equipment is designed, the refrigeration cycle tries to balance such that the product of DE / DC (density ratio) and Hze / Hzc (ratio of the number of revolutions) always becomes constant.

[0004] In the case of the electric energy collecting type, since the number of revolutions Hze of the expansion mechanism can be set irrespective of the number of revolutions Hzc of the compressing mechanism, there is proposed a method to adjust the number of revolutions Hze of the expansion mechanism (i.e., torque of the generator), thereby optimally adjusting the high pressure-side pressure of the refrigeration cycle apparatus. Alternatively, there are also proposed a structure and a control method in which heat is exchanged using an internal heat exchanger, thereby changing the density of refrigerant flowing into the expansion mechanism, and a circulation

amount flowing into the expansion mechanism is controlled, thereby adjusting the pressure to the optimal high pressure-side pressure (e.g., see patent document 1).

[0005] In the case of the mechanical energy collecting type, the compressing mechanism and the expansion mechanism rotate at the same number of revolutions. Since the mass circulation amounts flowing through the compressing mechanism and expansion mechanism are equal to each other, a relation " $VC \times DC = VE \times DE$ ", i.e., " $VC / VE = DE / DC$ " is established. Since VC / VE (design capacity ratio) is a constant which is determined when equipment is designed, the refrigeration cycle tries to balance such that the product of DE / DC (density ratio) always becomes constant (this is called "constraint of constant density ratio").

[0006] However, the using condition of the refrigeration cycle apparatus is not always constant, if a design capacity ratio which was assumed at the time of designing and a density ratio of the actual operating state are different from each other, it becomes difficult to adjust the pressure to the optimal high pressure-side pressure due to the "constraint of constant density ratio".

[0007] Hence, there are proposed a structure and a control method in which a bypass flow path bypassing the expansion mechanism is provided, and a decompressor is provided upstream or downstream of the expansion mechanism, a circulation amount flowing into the expansion mechanism is controlled, thereby adjusting the pressure to the optimal high pressure-side pressure. There are proposed a structure and a control method in which heat is exchanged using an internal heat exchanger, thereby changing the density of refrigerant flowing into the expansion mechanism, and a circulation amount flowing into the expansion mechanism is controlled, thereby adjusting the pressure to the optimal high pressure-side pressure (e.g., see patent document 2).

[0008] [Patent Document 1] Japanese Patent Application Laid-open No.S56-112896

[0009] [Patent Document 2] Japanese Patent Application Laid-open No.2000-329416

[0010] In the patent document 1, a concrete adjusting method of the high pressure-side pressure is not described. In the patent document 2, in the case of the electric energy collecting type, there is no description concerning how the high pressure-side pressure should be adjusted when the number of revolutions of the expansion mechanism is out of a using range (less than lowest number of revolutions or more than highest number of revolutions which are preset in view of reliability of the expansion mechanism). Therefore, there is a problem that the refrigeration cycle apparatus can not efficiently be operated while securing the reliability of the expansion mechanism.

[0011] In the patent document 2, in the case of the mechanical energy collecting type, there is described a method utilizing variation in a heat-exchanging amount of the internal heat exchanger, a method for providing a pre-decompressor upstream of the expansion mecha-

nism, and a method for providing a bypass flow path for bypassing the expansion mechanism, as an adjusting method for adjusting the high pressure-side pressure. However, in the case of the electric energy collecting type, there is no description concerning the combination of these methods. In the case of the mechanical energy collecting type also, there is no description concerning how these methods should be properly used or combined with each other. Thus, there is a problem that the high pressure-side pressure can not be adjusted using the optimal method, and the refrigeration cycle apparatus can not efficiently be operated in some cases.

[0012] Hence, to solve the above object, in a refrigeration cycle apparatus having an electric energy collecting type expansion mechanism, it is an object of the present invention to adjust the circulation amount flowing into the expansion mechanism in a wider range than the conventional technique without deteriorating the reliability of the expansion mechanism, and to operate the refrigeration cycle apparatus efficiently.

Disclosure of the Invention

[0013] To solve the conventional problem, the refrigeration cycle apparatus of the present invention comprises a compressing mechanism, a heat source-side heat exchanger, an expansion mechanism which collects power and has number of revolutions which can be changed independently from number of revolutions of the compressing mechanism, a utilizing-side heat exchanger, and a pre-decompressor for decompressing a refrigerant flowing into the expansion mechanism. With this structure, when the high pressure-side pressure can not be adjusted to a preferable pressure without operating such that the number of revolutions of the expansion mechanism goes out from its using range, the high pressure-side pressure can be adjusted by operating the opening of the pre-decompressor. Therefore, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0014] According to the present invention, in a refrigeration cycle apparatus having an electric energy collecting type expansion mechanism, it is possible to adjust the circulation amount flowing into the expansion mechanism in a wider range than that of the conventional technique, and to efficiently operate the refrigeration cycle apparatus.

Brief Description of the Drawings

[0015]

Fig. 1 is a diagram showing a structure of a refrigeration cycle apparatus of a first embodiment of the present invention;

Fig. 2 is a flowchart of control of an expansion mechanism of the first embodiment of the invention;

Fig. 3 is a diagram showing a relation of control

means of control in the first embodiment of the invention;

Fig. 4 is a diagram showing a structure of a refrigeration cycle apparatus of a second embodiment of the present invention;

Fig. 5 is a flowchart of control of an expansion mechanism of the second embodiment of the invention;

Fig. 6 is a diagram showing a relation of control means of control in the second embodiment of the invention;

Fig. 7 is a diagram showing a structure of a refrigeration cycle apparatus of a third embodiment of the present invention;

Fig. 8 is a flowchart of control of an expansion mechanism of the third embodiment of the invention;

Fig. 9 is a diagram showing a relation of control means of control in the third embodiment of the invention;

Fig. 10 is a diagram showing a structure of a refrigeration cycle apparatus of a fourth embodiment of the present invention;

Fig. 11 is a flowchart of control of an expansion mechanism of the fourth embodiment of the invention; and

Fig. 12 is a diagram showing a relation of control means of control in the fourth embodiment of the invention.

Best Mode for Carrying Out the Invention

[0016] According to a first aspect of the invention, there is provided a refrigeration cycle apparatus comprising at least a compressing mechanism, a heat source-side heat exchanger, an expansion mechanism which collects power and has number of revolutions which can be changed independently from number of revolutions of the compressing mechanism, a utilizing-side heat exchanger, and a pre-decompressor for decompressing a refrigerant flowing into the expansion mechanism. With the first aspect, when the high pressure-side pressure can not be adjusted to a preferable pressure without operating such that the number of revolutions of the expansion mechanism goes out from its using range, the high pressure-side pressure can be adjusted by operating the opening of the pre-decompressor. Therefore, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0017] In a second aspect of the invention, the refrigeration cycle apparatus further includes a bypass circuit through which a portion of the refrigerant flowing into the expansion mechanism bypasses directly to a low pressure-side flow path. With the second aspect, when the high pressure-side pressure can not be adjusted to a preferable pressure without operating such that the number of revolutions of the expansion mechanism goes out from its using range, the high pressure-side pressure can be adjusted by operating the refrigeration cycle apparatus flowing into the bypass circuit. Therefore, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

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[0018] In a third aspect of the invention, when any one of a high pressure-side pressure, a discharge temperature of the compressing mechanism, and a sucked superheat of the compressing mechanism does not reach a preset target value even if the number of revolutions of the expansion mechanism reaches a preset lowest number of revolutions, the refrigerant is decompressed by the pre-decompressor. With this, the high pressure-side pressure can be adjusted to a preferable pressure, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0019] In a fourth aspect of the invention, when any one of a high pressure-side pressure, a discharge temperature of the compressing mechanism, and a sucked superheat of the compressing mechanism exceeds a preset target value even if the number of revolutions of the expansion mechanism reaches a preset highest number of revolutions, a portion of the refrigerant flowing into the expansion mechanism is allowed to bypass. With this, the high pressure-side pressure can be adjusted to a preferable pressure, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0020] In a fifth aspect of the invention, the refrigeration cycle apparatus further comprises an internal heat exchanger for cooling the refrigerant flowing into the expansion mechanism. With this, the high pressure-side pressure can be adjusted, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0021] In a sixth aspect of the invention, when any one of a high pressure-side pressure, a discharge temperature of the compressing mechanism, and a sucked superheat of the compressing mechanism does not reach a preset target value even if the number of revolutions of the expansion mechanism reaches a preset lowest number of revolutions, the internal heat exchanger is not substantially operated. With this, the high pressure-side pressure can be adjusted to a preferable pressure, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0022] In a seventh aspect of the invention, when any one of a high pressure-side pressure, a discharge temperature of the compressing mechanism, and a sucked superheat of the compressing mechanism exceeds a preset target value even if the number of revolutions of the expansion mechanism reaches a preset highest number of revolutions, the internal heat exchanger is substantially operated. With this, the high pressure-side pressure can be adjusted to a preferable pressure, refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0023] According to an eighth aspect of the invention,

in a refrigeration cycle apparatus having a compressing mechanism, a heat source-side heat exchanger, an expansion mechanism for collecting power, a utilizing-side heat exchanger, and an internal heat exchanger for cooling a refrigerant flowing into the expansion mechanism, only when any one of a high pressure-side pressure, a discharge temperature of the compressing mechanism, and a sucked superheat of the compressing mechanism does not reach a preset target value even if the internal heat exchanger is not substantially operated, the number of revolutions of the expansion mechanism is reduced. With this, the possibility of reduction in the number of revolutions of the expansion mechanism that may deteriorate the reliability of the expansion mechanism can be lowered. Thus, the refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0024] In a ninth aspect of the invention, only when any one of a high pressure-side pressure, a discharge temperature of the compressing mechanism, and a sucked superheat of the compressing mechanism exceeds a preset target value even if the internal heat exchanger is substantially operated, the number of revolutions of the expansion mechanism is increased. With this, the possibility of reduction in the number of revolutions of the expansion mechanism that may deteriorate the reliability of the expansion mechanism can be lowered. Thus, the refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism.

[0025] Embodiments of the present invention will be explained with reference to the drawings. The invention is not limited to the embodiments. Although the following embodiments are based on a water heater, the invention is not limited to the water heater, and the invention may be applied to an air conditioner for example.

(First Embodiment)

[0026] A refrigeration cycle apparatus of a first embodiment of the present invention will be explained using Fig. 1 which schematically shows a structure thereof. The refrigeration cycle apparatus shown in Fig. 1 includes a compressing mechanism 2 driven by an electric motor 1, a refrigerant flow path of a radiator 3 as a utilizing-side heat exchanger, an expansion mechanism 5 whose power is collected by a generator 4, an evaporator 6 as a heat source-side heat exchanger, a refrigerant circuit A into which CO₂ refrigerant is charged as a refrigerant, and a fluid circuit B comprising a water supply pump 7 as utilizing fluid transfer means, a fluid flow path of the radiator 3, and a boiler 8. The refrigerant circuit A includes the following constituent elements. An air blowing apparatus 9 as heat source fluid transfer means blows heat source fluid (e.g., outside air) to the evaporator 6. A pre-expansion valve 11 as a pre-decompressor previously decompresses refrigerant flowing into the expansion mechanism 5, and reduces the density of the refrigerant

flowing into the expansion mechanism 5.

[0027] A first bypass flow path 12 connects a refrigerant outlet of the radiator 3 and an inlet of the expansion mechanism 5 with each other, and an outlet of the expansion mechanism 5 and an inlet of the compressing mechanism 2 with each other, so that refrigerant flowing through the expansion mechanism 5 bypasses. The first bypass flow path 12 includes a first bypass valve 13 which adjusts a circulation amount of refrigerant to be bypassed. An internal heat exchanger 14 is arranged so that refrigerant from the refrigerant outlet of the radiator 3 flowing through a high pressure-side flow path 14a to an inlet of the expansion mechanism 5 is cooled by refrigerant from the refrigerant outlet of the evaporator 6 flowing through a low pressure-side flow path 14b to an inlet of the compressing mechanism 2.

[0028] Discharge temperature detecting means 20 is disposed on a refrigerant pipe from discharge of the compressing mechanism 2 to a refrigerant inlet of the radiator 3, and the discharge temperature detecting means 20 detects the discharge temperature of the compressing mechanism 2. Expansion mechanism revolution number control means 21 controls the number of revolutions of the generator 4. Pre-expansion valve opening control means 22 adjusts the opening of the pre-expansion valve 11. First bypass valve opening control means 23 adjusts the opening of the first bypass valve 13. Electronic control means 25 determines a state of the refrigeration cycle from a signal from the discharge temperature detecting means 20 and the like, and sends instructions to the expansion mechanism revolution number control means 21, the pre-expansion valve opening control means 22 and the first bypass valve opening control means 23.

[0029] Next, the operation when the refrigeration cycle apparatus having the above-described structure is operated will be explained. First, a product X (Hze / Hzc) of a density ratio and a ratio of the number of revolutions (DE / DC) X (Hze / Hzc) in the actual operating state is substantially equal to a design capacity ratio (VC / VE) which was assumed at the time of designing.

[0030] In the refrigerant circuit A, CO_2 refrigerant is compressed by the compressing mechanism 2 to a pressure (high pressure-side pressure) exceeding critical pressure. The compressed refrigerant is brought into a high temperature and high pressure state, and when the refrigerant flows through the refrigerant flow path of the radiator 3, the refrigerant radiates heat to water flowing through the fluid flow path of the radiator 3 and is cooled. Then, the refrigerant flows into the high pressure-side flow path 14a of the internal heat exchanger 14, and is further cooled by low pressure and low temperature refrigerant flowing through the low pressure-side flow path 14b. In this case, the first bypass valve 13 is in its fully closed state, the refrigerant does not through the first bypass flow path 12, and all of refrigerants flow into the expansion mechanism 5 through the fully-opened pre-expansion valve 11. Thereafter, the refrigerant is decompressed by the expansion mechanism 5 and is brought

into a low temperature and low pressure gas/liquid two-phase state.

[0031] At that time, in the expansion mechanism 5, pressure energy of the refrigerant is converted into power, and the power is converted into electricity by the generator 4. In this manner, the pressure energy at the time of expansion can be collected as electricity and the COP can be enhanced. Refrigerant decompressed by the expansion mechanism 5 is supplied to the evaporator 6. In the evaporator 6, the refrigerant is heated by the outside air sent by the air blowing apparatus 9, and the refrigerant is brought into a gas/liquid two-phase state or a gaseous state. Refrigerant which flows out from the evaporator 6 is heated by the low pressure-side flow path 14b of the internal heat exchanger 14 and then, the refrigerant is again sucked into the compressing mechanism 2.

[0032] In the fluid circuit B, utilizing fluid (e.g., water) sent into a fluid flow path of the radiator 3 from a bottom of the boiler 8 by the water supply pump 7 is heated by refrigerant flowing through the refrigerant flow path of the radiator 3, and becomes high temperature fluid (e.g., hot water), and the high temperature fluid is stored from an apex of the boiler 8 - By repeating such a cycle, the refrigeration cycle apparatus of the embodiment can be utilized as a water heater.

[0033] Next, the product X (Hze / Hzc) of the density ratio and the ratio of the number of revolutions (DE / DC) X (Hze / Hzc) in the actual operating state is different from the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. First, an operation when the product X of the density ratio and the ratio of the number of revolutions in the actual operating state (DE / DC) X (Hze / Hzc) is greater than the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. In this case, if the ratio of the number of revolutions is constant, the refrigeration cycle tries to balance in a state where the high pressure-side pressure is reduced such that the refrigerant density (DE) of the inlet of the expansion mechanism 5 becomes small.

[0034] However, in a state where the high pressure-side pressure is reduced lower than the preferable pressure, the discharge temperature is lowered, the heating ability of the refrigeration cycle apparatus is deteriorated and the efficiency of the refrigeration cycle apparatus is deteriorated. Therefore, first the number of revolutions of the expansion mechanism 5 is operated in the reducing direction, thereby lowering the product X of the density ratio and the ratio of the number of revolutions (DE / DC) X (Hze / Hzc). With this, the high pressure-side pressure is not reduced and the optimal state can be maintained.

[0035] However, the lowest number of revolutions of the expansion mechanism 5 is preset in terms of reliability of the expansion mechanism 5. That is, if the expansion mechanism 5 is operated for a long term with the number of revolutions lower than the preset lowest number of revolutions, oil is less prone to be supplied to a sliding portion of the expansion mechanism, and there is an ad-

verse possibility of inconvenience that the sliding portion is worn.

[0036] Hence, in the case of the embodiment, if the product $(X \text{ (Hze / Hzc)})$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ is still greater than the design capacity ratio (VC / VE) assumed at the time of designing in the actual operating state even when the number of revolutions of the expansion mechanism 5 becomes equal to the preset lowest number of revolutions, the pre-expansion valve 11 is operated in the closing direction, and the refrigerant which flows into the expansion mechanism 5 is decompressed. With this, the number of revolutions of the expansion mechanism 5 becomes lower than the lowest number of revolutions, the refrigerant density (DE) can be made smaller without deteriorating the reliability of the expansion mechanism 5, the high pressure-side pressure is not lowered, and the optimal state can be maintained.

[0037] In this manner, when the number of revolutions of the expansion mechanism 5 becomes equal to the preset lowest number of revolutions, the opening of the pre-expansion valve 11 is operated in the closing direction instead of lowering the number of revolutions of the expansion mechanism 5. With this, it is possible to adjust the high pressure-side pressure to a preferable pressure, and the refrigeration cycle apparatus can be operated efficiently without deteriorating the reliability of the expansion mechanism 5.

[0038] Next, operation when the product X of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is smaller than the design capacity ratio (VC / VE) assumed at the time of designing will be explained. In this case, if the ratio of the number of revolutions is constant, the refrigeration cycle tries to balance in a state where the high pressure-side pressure is increased so that the refrigerant density (DE) of the inlet of the expansion mechanism 5 is increased.

[0039] However, if the high pressure-side pressure is increased higher than a preferable pressure, the operation efficiency of the refrigeration cycle apparatus is lowered. Therefore, first, the number of revolutions of the expansion mechanism 5 is operated in the increasing direction, and the product X of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ is increased. With this, the high pressure-side pressure is not increased and the optimal state can be maintained.

[0040] In terms of the reliability of the expansion mechanism 5, the highest number of revolutions of the expansion mechanism 5 is preset. That is, if the expansion mechanism 5 is operated for a long term with the number of revolutions higher than the preset highest number of revolutions, there is an adverse possibility of inconvenience that the bearing of the expansion mechanism and the sliding portion are worn. Hence, in the case of the embodiment, if the product X of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is still smaller than the design

capacity ratio (VC / VE) assumed at the time of designing even when the number of revolutions of the expansion mechanism 5 becomes equal to the preset highest number of revolutions, the first bypass valve 13 is operated in the opening direction so that a portion of the refrigerant is allowed to flow to the first bypass flow path 12.

[0041] With this, the number of revolutions of the expansion mechanism 5 becomes higher than the highest number of revolutions, the circulation amount of refrigerant flowing into the expansion mechanism 5 can be reduced without deteriorating the reliability of the expansion mechanism 5, the high pressure-side pressure does not rise and the optimal state can be maintained.

[0042] When the number of revolutions of the expansion mechanism 5 becomes equal to the highest number of revolutions, the first bypass valve 13 is operated in the opening direction instead of increasing the number of revolutions of the expansion mechanism 5. With this, the high pressure-side pressure can be adjusted to the preferable pressure. Therefore, the refrigeration cycle apparatus can be operated efficiently without deteriorating the reliability of the expansion mechanism 5.

[0043] Next, the control method will be explained. The compressing mechanism 2, i.e., the electric motor 1 which is substantially a driving source is controlled by the compressing mechanism revolution number control means (not shown) such that the number of revolutions thereof becomes equal to the number of revolutions calculated by the electronic control apparatus 25 from the outside air temperature or the entering-water temperature detected by the outside air temperature detecting means (not shown) or the entering-water temperature detecting means (not shown), or a target billowing temperature which was set by a user (temperature of hot water stored in the boiler, or a target value of fluid outlet side temperature of the radiator 3).

[0044] As a concrete operating method of the expansion mechanism 5, the pre-expansion valve 11 and the first bypass valve 13, the control performed by the electronic control apparatus 25, the expansion mechanism revolution number control means 21, the pre-expansion valve opening control means 22 and the first bypass valve opening control means 23 will be explained based on the flowchart shown in Fig. 2. An expensive sensor is required to measure the high pressure-side pressure. According to the control of this embodiment, the high pressure-side pressure is not measured, and the expansion mechanism 5, the pre-expansion valve 11 and the first bypass valve 13 are controlled using the discharge temperature which can be measured relatively inexpensively using a correlation between the high pressure-side pressure and the discharge temperature.

[0045] When the refrigeration cycle apparatus is operated, a detection value (discharge temperature: T_d) (100) from the discharge temperature detecting means 20 is taken in. A target discharge temperature (target T_d) which is previously stored in a ROM or the like and the taken discharge temperature (T_d) are compared with

each other (110). If the discharge temperature (T_d) is lower than the target discharge temperature (target T_d), there is a tendency that the high pressure-side pressure is lower than the optimal pressure and thus, it is determined whether the first bypass valve 13 is fully closed (120). When the first bypass valve 13 is fully closed, it is determined whether the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset lowest number of revolutions (lowest Hze) (130). If the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset lowest number of revolutions (lowest Hze), the pre-expansion valve 11 is operated in the closing direction (140), refrigerant flowing into the expansion mechanism 5 is decompressed, the refrigerant density is lowered, and the high pressure-side pressure and the discharge temperature are increased.

[0046] If the number of revolutions (Hze) of the expansion mechanism 5 does not reach the preset lowest number of revolutions (lowest Hze), the number of revolutions (Hze) of the expansion mechanism 5 is operated in the lowering direction (150), the circulation amount of refrigerant flowing through the expansion mechanism 5 is reduced, and the high pressure-side pressure and the discharge temperature are increased. If the first bypass valve 13 is not fully closed in step 120, the first bypass valve 13 is operated in the closing direction (160), the circulation amount of refrigerant which bypasses the expansion mechanism 5 and flows into the first bypass flow path 12 is reduced, and the high pressure-side pressure and the discharge temperature are increased.

[0047] When the discharge temperature (T_d) is higher than the target discharge temperature (target T_d) in step 110, there is a tendency that the high pressure-side pressure is higher than the optimal pressure. Therefore, it is first determined whether the pre-expansion valve 11 is fully opened (170). If the pre-expansion valve 11 is fully opened, it is determined whether the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset highest number of revolutions (highest Hze) (180). When the number of revolutions (Hze) of the expansion mechanism 5 reaches the present highest number of revolutions (highest Hze), the first bypass valve 13 is operated in the opening direction (190), the circulation amount of refrigerant which bypasses the expansion mechanism 5 and flows into the first bypass flow path 12 is increased, and the high pressure-side pressure and the discharge temperature are lowered.

[0048] If the number of revolutions (Hze) of the expansion mechanism 5 does not reach the preset highest number of revolutions (highest Hze), the number of revolutions (Hze) of the expansion mechanism 5 is operated in the increasing direction (200), the circulation amount of refrigerant flowing through the expansion mechanism 5 is increased, and the high pressure-side pressure and the discharge temperature are lowered. When the pre-expansion valve 11 is not fully opened in step 170, the pre-expansion valve 11 is operated in the opening direction (210) so that the refrigerant flowing into the expansion

mechanism 5 is not decompressed, and the refrigerant density is not lowered. With this, the high pressure-side pressure and the discharge temperature are lowered. After the above steps, the procedure is returned to step 100, and steps 100 to 210 are repeated, and the number of revolutions of the expansion mechanism 5, the pre-expansion valve 11 and the opening of the first bypass valve 13 are controlled in liaison with each other as shown in Fig. 3.

[0049] As explained above, according to the refrigeration cycle apparatus of the embodiment including the electric energy collecting type expansion mechanism, even if the number of revolutions of the expansion mechanism 5 is reduced within the using range, if the discharge temperature (T_d) does not reach the target discharge temperature (target T_d), the pre-expansion valve 11 is operated in the closing direction based on the discharge temperature and the refrigerant is decompressed. With this, the pressure can be adjusted to a desired high pressure-side pressure without exceeding the using range of the expansion mechanism 5, and the refrigeration cycle apparatus can be operated without deteriorating its operating efficiency and ability.

[0050] Even if the number of revolutions of the expansion mechanism 5 is increased within the using range, if the discharge temperature (T_d) exceeds the target discharge temperature (target T_d), the first bypass valve 13 is operated in the opening direction based on the discharge temperature to flow a portion of the refrigerant into the first bypass flow path 12. With this, it is possible to reduce the circulation amount of refrigerant flowing into the expansion mechanism 5, to adjust the pressure to a desired high pressure-side pressure without exceeding the using range of the expansion mechanism 5, and to operate the refrigeration cycle apparatus without deteriorating its operating efficiency and ability.

(Second Embodiment)

[0051] A refrigeration cycle apparatus according to a second embodiment of the invention will be explained with reference to Fig. 4. Fig. 4 is a schematic diagram showing a structure of the refrigeration cycle apparatus. In Fig. 4, the same constituent elements as those shown in Fig. 1 are designated with the same symbols, and explanation thereof will be omitted. The refrigeration cycle apparatus shown in Fig. 4 includes a second bypass flow path 31 bypassing the high pressure-side flow path 14a of the internal heat exchanger 14, and a second bypass valve 32 which adjusts a circulation amount of refrigerant flowing through the second bypass flow path 31. A second bypass valve opening control means 33 adjusts the opening of the second bypass valve 32.

[0052] Next, the action of the refrigeration cycle apparatus having the above-described structure when it is operated will be explained based on a case where the product X (Hze / Hzc) of the density ratio and the ratio of the number of revolutions in the actual operating state (DE

/DC) X (Hze / Hzc) is substantially the same as the design capacity ratio (VC / VE) which was assumed at the time of designing.

[0053] In the refrigerant circuit A, CO₂ refrigerant is compressed by the compressing mechanism 2 to a pressure (high pressure-side pressure) exceeding critical pressure. The compressed refrigerant is brought into a high temperature and high pressure state, and when the refrigerant flows through the refrigerant flow path of the radiator 3, the refrigerant radiates heat to water flowing through the fluid flow path of the radiator 3 and is cooled. Then, the refrigerant does not through the second bypass flow path 31 due to the fully closed second bypass valve 32, but flows into the high pressure-side flow path 14a of the internal heat exchanger 14, and the refrigerant is further cooled by a low pressure and low temperature refrigerant which flows through the low pressure-side flow path 14b. In this case, the first bypass valve 13 is also fully closed, the refrigerant does not through the first bypass flow path 12, and all of refrigerants flow into the expansion mechanism 5.

[0054] Thereafter, the refrigerant is decompressed by the expansion mechanism 5 and is brought into a low temperature and low pressure gas/liquid two-phase state. At that time, in the expansion mechanism 5, pressure energy of the refrigerant is converted into power, and the power is converted into electricity by the generator 4. In this manner, the pressure energy at the time of expansion can be collected as electricity and the COP can be enhanced. Refrigerant decompressed by the expansion mechanism 5 is supplied to the evaporator 6. In the evaporator 6, the refrigerant is heated by the outside air sent by the air blowing apparatus 9, and the refrigerant is brought into a gas/liquid two-phase state or a gaseous state. Refrigerant which flows out from the evaporator 6 is heated by the low pressure-side flow path 14b of the internal heat exchanger 14 and then, the refrigerant is again sucked into the compressing mechanism 2.

[0055] Next, the product X of the density ratio and the ratio of the number of revolutions (DE / DC) X (Hze / Hzc) in the actual operating state is different from the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. First, an operation when the product X (Hze / Hzc) of the density ratio and the ratio of the number of revolutions in the actual operating state (DE / DC) X (Hze / Hzc) is greater than the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. In this case, if the ratio of the number of revolutions is constant, the refrigeration cycle tries to balance in a state where the high pressure-side pressure is reduced such that the refrigerant density (DE) of the inlet of the expansion mechanism 5 becomes small. However, in a state where the high pressure-side pressure is reduced lower than the preferable pressure, the discharge temperature is lowered, the heating ability of the refrigeration cycle apparatus is deteriorated and the efficiency of the refrigeration cycle apparatus is deteriorated. Therefore, first the number of revolutions of the ex-

pansion mechanism 5 is operated in the reducing direction, thereby lowering the product (DE / DC) X (Hze / Hzc) of the density ratio and the ratio of the number of revolutions (DE / DC) X (Hze / Hzc). With this, the high pressure-side pressure is not reduced and the optimal state can be maintained.

[0056] However, the lowest number of revolutions of the expansion mechanism 5 is preset in terms of reliability of the expansion mechanism 5. That is, if the expansion mechanism 5 is operated for a long term with the number of revolutions lower than the preset lowest number of revolutions, oil is less prone to be supplied to a sliding portion of the expansion mechanism, and there is an adverse possibility of inconvenience that the sliding portion is worn. Hence, in the case of the embodiment, if the product (X (Hze / Hzc) of the density ratio and the ratio of the number of revolutions (DE / DC) X (Hze / Hzc) in the actual operating state is still greater than the design capacity ratio (VC / VE) assumed at the time of designing even when the number of revolutions of the expansion mechanism 5 becomes equal to the preset lowest number of revolutions, the second bypass valve 32 is operated in the opening direction to flow the refrigerant into the second bypass flow path 31, and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is reduced. With this, the heat exchanging amount at the internal heat exchanger 14 is reduced, and the density (DE) of refrigerant flowing into the expansion mechanism 5 is reduced. Therefore, the number of revolutions of the expansion mechanism 5 becomes lower than the lowest number of revolutions, the refrigerant density (DE) can be reduced without deteriorating the reliability of the expansion mechanism 5, the high pressure-side pressure is not lowered, and the optimal state can be maintained.

[0057] In this manner, when the number of revolutions of the expansion mechanism 5 becomes equal to the preset lowest number of revolutions, the opening of the second bypass valve 32 is operated in the opening direction instead of reducing the number of revolutions of the expansion mechanism 5, and the internal heat exchanging amount is reduced. With this, the high pressure-side pressure can be adjusted to a desired value and thus, the refrigeration cycle apparatus can be operated efficiently without deteriorating the reliability of the expansion mechanism 5.

[0058] The operation when the product X of the density ratio and the ratio of the number of revolutions (DE / DC) X (Hze / Hzc) in the actual operating state is smaller than the design capacity ratio (VC / VE) which was assumed at the time of designing is the same as that explained in the (first embodiment), explanation thereof will be omitted.

[0059] Next, the control method will be explained. As a concrete operating method of the expansion mechanism 5, the first bypass valve 13 and the second bypass valve 32, the control performed by the electronic control apparatus 25, the expansion mechanism revolution

number control means 21, the first bypass valve opening control means 23 and the second bypass valve opening control means 33 will be explained based on the flowchart shown in Fig. 5.

[0060] When the refrigeration cycle apparatus is operated, a detection value (discharge temperature: Td) (300) from the discharge temperature detecting means 20 is taken in. A target discharge temperature (target Td) which is previously stored in a ROM or the like and the taken discharge temperature (Td) are compared with each other (310). If the discharge temperature (Td) is lower than the target discharge temperature (target Td), there is a tendency that the high pressure-side pressure is lower than the optimal pressure and thus, it is determined whether the first bypass valve 13 is fully closed (320). When the first bypass valve 13 is fully closed, it is determined whether the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset lowest number of revolutions (lowest Hze) (330). If the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset lowest number of revolutions (lowest Hze), the second bypass valve 32 is operated in the opening direction (340), and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is reduced. By reducing the heat exchanging amount in the internal heat exchanger 14, the density of refrigerant flowing into the expansion mechanism 5 is lowered, and the high pressure-side pressure and the discharge temperature are increased.

[0061] If the number of revolutions (Hze) of the expansion mechanism 5 does not reach the preset lowest number of revolutions (lowest Hze), the number of revolutions (Hze) of the expansion mechanism 5 is operated in the lowering direction (350), the circulation amount of refrigerant flowing through the expansion mechanism 5 is reduced, and the high pressure-side pressure and the discharge temperature are increased. If the first bypass valve 13 is not fully closed in step 320, the first bypass valve 13 is operated in the closing direction (360), the circulation amount of refrigerant which bypasses the expansion mechanism 5 and flows into the first bypass flow path 12 is reduced, and the high pressure-side pressure and the discharge temperature are increased.

[0062] When the discharge temperature (Td) is higher than the target discharge temperature (target Td) in step 310, there is a tendency that the high pressure-side pressure is higher than the optimal pressure. Therefore, it is first determined whether the second bypass valve 32 is fully closed (370). If the second bypass valve 32 is fully closed, it is determined whether the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset highest number of revolutions (highest Hze) (380). When the number of revolutions (Hze) of the expansion mechanism 5 reaches the present highest number of revolutions (highest Hze), the first bypass valve 13 is operated in the opening direction (390), the circulation amount of refrigerant which bypasses the expansion mechanism 5 and flows into the first bypass flow path 12 is increased,

and the high pressure-side pressure and the discharge temperature are lowered. If the number of revolutions (Hze) of the expansion mechanism 5 does not reach the preset highest number of revolutions (highest Hze), the number of revolutions (Hze) of the expansion mechanism 5 is operated in the increasing direction (400), the circulation amount of refrigerant flowing through the expansion mechanism 5 is increased, and the high pressure-side pressure and the discharge temperature are lowered.

[0063] If the second bypass valve 32 is not fully closed in step 370, the second bypass valve 32 is operated in the closing direction (410), and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is increased. The density of refrigerant flowing into the expansion mechanism 5 is increased by increasing the heat exchanging amount in the internal heat exchanger 14, and the high pressure-side pressure and the discharge temperature are lowered. After the above steps, the procedure is returned to step 300, and steps 300 to 410 are repeated, and the number of revolutions of the expansion mechanism 5, the first bypass valve 13 and the opening of the second bypass valve 32 are controlled in liaison with each other as shown in Fig. 6.

[0064] As explained above, according to the refrigeration cycle apparatus of the embodiment including the electric energy collecting type expansion mechanism, even if the number of revolutions of the expansion mechanism 5 is reduced within the using range, if the discharge temperature (Td) does not reach the target discharge temperature (target Td), the second bypass valve 32 is operated in the opening direction based on the discharge temperature to flow a portion of refrigerant into the second bypass flow path 31, thereby reducing the heat exchanging amount in the internal heat exchanger 14 so that the refrigerant is not cooled. With this, it is possible to adjust the pressure to the desired high pressure-side pressure without exceeding the using range of the expansion mechanism 5, and to operate the refrigeration cycle apparatus without deteriorating the operation efficiency and ability.

[0065] Even if the number of revolutions of the expansion mechanism 5 is increased within the using range, if the discharge temperature (Td) exceeds the target discharge temperature (target Td), the first bypass valve 13 is operated in the opening direction based on the discharge temperature to flow a portion of the refrigerant into the first bypass flow path 12. With this, it is possible to reduce the circulation amount of refrigerant flowing into the expansion mechanism 5, to adjust the pressure to a desired high pressure-side pressure without exceeding the using range of the expansion mechanism 5, and to operate the refrigeration cycle apparatus without deteriorating its operating efficiency and ability.

(Third Embodiment)

[0066] A refrigeration cycle apparatus according to a third embodiment of the invention will be explained with reference to Fig. 7. Fig. 7 is a schematic diagram showing a structure of the refrigeration cycle apparatus. In Fig. 7, the same constituent elements as those shown in Figs. 1 and 4 are designated with the same symbols, and explanation thereof will be omitted. First, the action of the refrigeration cycle apparatus when it is operated will be explained based on a case where the product X of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is substantially the same as the design capacity ratio (VC / VE) which was assumed at the time of designing.

[0067] In the refrigerant circuit A, CO₂ refrigerant is compressed by the compressing mechanism 2 to a pressure (high pressure-side pressure) exceeding critical pressure. The compressed refrigerant is brought into a high temperature and high pressure state, and when the refrigerant flows through the refrigerant flow path of the radiator 3, the refrigerant radiates heat to water flowing through the fluid flow path of the radiator 3 and is cooled. Then, the refrigerant does not flow through the high pressure-side flow path 14a of the internal heat exchanger 14 due to the fully opened second bypass valve 32 but flows into the second bypass flow path 31, and flows into the expansion mechanism 5 through the fully opened pre-expansion valve 11. Thereafter, the refrigerant is decompressed by the expansion mechanism 5 and brought into the low temperature and low pressure gas/liquid two-phase state. At that time, in the expansion mechanism 5, the pressure energy of the refrigerant is converted into power and the power is converted into electricity by the generator 4.

[0068] In this manner, the pressure energy at the time of expansion can be collected as electricity and the COP can be enhanced. Refrigerant decompressed by the expansion mechanism 5 is supplied to the evaporator 6. In the evaporator 6, the refrigerant is heated by the outside air sent by the air blowing apparatus 9, and the refrigerant is brought into a gas/liquid two-phase state or a gaseous state. The refrigerant which flows out from the evaporator 6 flows into the low pressure-side flow path 14b of the internal heat exchanger 14, but since almost no refrigerant flows into the high pressure-side flow path 14a, heat is not exchanged substantially, and the refrigerant is sucked into the compressing mechanism 2 again.

[0069] Next, the product X of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is different from the design capacity ratio (VC / VE) which was assumed during designing will be explained. First, the operation when the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is greater than the design capacity ratio (VC / VE) which was assumed at the time of designing is the same as that explained in the

(first embodiment), explanation thereof will be omitted.

[0070] The operation when the product $(DE / DC) \times (Hze / Hzc)$ is smaller than the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. In this case, if the ratio of the number of revolutions is constant, the refrigeration cycle tries to balance in a state where the refrigerant density (DE) is increased so that the refrigerant density (DE) of the inlet of the expansion mechanism 5 is increased. However, in a state where the high pressure-side pressure is increased higher than the preferable pressure, the operating efficiency of the refrigeration cycle apparatus is deteriorated. Therefore, first, the number of revolutions of the expansion mechanism 5 is operated in the increasing direction, and the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ is increased. With this, the high pressure-side pressure is not increased, and the optimal state can be maintained.

[0071] However, the highest number of revolutions of the expansion mechanism 5 is preset in terms of reliability of the expansion mechanism 5. That is, if the expansion mechanism 5 is operated for a long term with the number of revolutions higher than the preset lowest number of revolutions, there is a possibility of inconvenience that the bearing of the expansion mechanism and the sliding portion are worn. Hence, in the case of the embodiment, if the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ is still smaller than the design capacity ratio (VC / VE) assumed at the time of designing even when the number of revolutions of the expansion mechanism 5 becomes equal to the preset highest number of revolutions, the second bypass valve 32 is operated in the closing direction, and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is increased. With this, the heat exchanging amount in the internal heat exchanger 14 is increased, and the density (DE) of refrigerant flowing into the expansion mechanism 5 is increased. Therefore, the number of revolutions exceeds the highest number of revolutions of the expansion mechanism 5, the refrigerant density (DE) can be increased without deteriorating the reliability of the expansion mechanism 5, the high pressure-side pressure is not increased and the optimal state can be maintained.

[0072] In this manner, when the number of revolutions of the expansion mechanism 5 becomes equal to the preset highest number of revolutions, the opening of the second bypass valve 32 is operated in the closing direction instead of increasing the number of revolutions of the expansion mechanism 5, and the internal heat exchanging amount is increased. With this, the high pressure-side pressure can be adjusted to a desired value and thus, the refrigeration cycle apparatus can be operated efficiently without deteriorating the reliability of the expansion mechanism 5.

[0073] Next, the control method will be explained. As a concrete operating method of the expansion mechanism 5, the pre-expansion valve 11 and the second bypass valve 32, the control performed by the electronic control apparatus 25, the expansion mechanism revolution number control means 21, the pre-expansion valve opening control means 22 and the second bypass valve opening control means 33 will be explained based on the flowchart shown in Fig. 8. When the refrigeration cycle apparatus is operated, a detection value (discharge temperature: Td) (500) from the discharge temperature detecting means 20 is taken in. A target discharge temperature (target Td) which is previously stored in a ROM or the like and the taken discharge temperature (Td) are compared with each other (510). If the discharge temperature (Td) is lower than the target discharge temperature (target Td), there is a tendency that the high pressure-side pressure is lower than the optimal pressure and thus, it is determined whether the second bypass valve 32 is fully opened (520). When the second bypass valve 32 is fully opened, it is determined whether the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset lowest number of revolutions (lowest Hze) (530). If the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset lowest number of revolutions (lowest Hze), the pre-expansion valve 11 is operated in the closing direction (540), refrigerant flowing into the expansion mechanism 5 is decompressed, the refrigerant density is lowered, and the high pressure-side pressure and the discharge temperature are increased.

[0074] When the number of revolutions (Hze) of the expansion mechanism 5 does not reach the preset lowest number of revolutions (lowest Hze), the number of revolutions (Hze) of the expansion mechanism 5 is operated in the reducing direction (550), the circulation amount of refrigerant flowing through the expansion mechanism 5 is reduced, and the high pressure-side pressure and the discharge temperature are increased. When the second bypass valve 32 is not fully opened in step 520, the second bypass valve 32 is operated in the opening direction (560), and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is reduced. The density of refrigerant flowing into the expansion mechanism 5 is reduced by reducing the heat exchanging amount in the internal heat exchanger 14, and the high pressure-side pressure and the discharge temperature are increased.

[0075] If the discharge temperature (Td) is higher than the target discharge temperature (target Td) in step 510, there is a tendency that the high pressure-side pressure is higher than the optimal pressure and thus, it is determined whether the pre-expansion valve 11 is fully opened (570). If the pre-expansion valve 11 is fully opened, it is determined whether the number of revolutions (Hze) of the expansion mechanism 5 reaches the preset highest number of revolutions (highest Hze) (580). If the number of revolutions (Hze) of the expansion mechanism 5

reaches the preset highest number of revolutions (highest Hze), the second bypass valve 32 is operated in the closing direction (590), refrigerant flowing into the expansion mechanism 5 is cooled by the internal heat exchanger 14, and the refrigerant density is increased, thereby lowering the high pressure-side pressure and the discharge temperature. If the number of revolutions (Hze) of the expansion mechanism 5 does not reach the preset highest number of revolutions (highest Hze), the number of revolutions (Hze) of the expansion mechanism 5 is operated in the increasing direction (600), the circulation amount of refrigerant flowing through the expansion mechanism 5 is increased, and the high pressure-side pressure and the discharge temperature are lowered.

[0076] If the pre-expansion valve 11 is not fully opened in step 570, the pre-expansion valve 11 is operated in the opening direction (610) so that the refrigerant flowing into the expansion mechanism 5 is not decompressed, and the refrigerant density is not lowered. With this, the high pressure-side pressure and the discharge temperature are lowered. After these steps, the procedure is returned to step 500, and steps 500 to 610 are repeated, and the number of revolutions of the expansion mechanism 5, the pre-expansion valve 11 and the opening of the second bypass valve 32 are controlled in liaison with each other as shown in Fig. 9.

[0077] As explained above, according to the refrigeration cycle apparatus of the embodiment including the electric energy collecting type expansion mechanism, even if the number of revolutions of the expansion mechanism 5 is reduced within the using range, if the discharge temperature (Td) does not reach the target discharge temperature (target Td), the pre-expansion valve 11 is operated in the closing direction based on the discharge temperature, the refrigerant is decompressed. With this, it is possible to adjust the pressure to the desired high pressure-side pressure without exceeding the using range of the expansion mechanism 5, and to operate the refrigeration cycle apparatus without deteriorating the operation efficiency and ability.

[0078] Even if the number of revolutions of the expansion mechanism 5 is increased within the using range, if the discharge temperature (Td) exceeds the target discharge temperature (target Td), the second bypass valve 32 is operated in the closing direction based on the discharge temperature, the heat exchanging amount in the internal heat exchanger 14 is increased and the refrigerant is cooled. With this, it is possible to adjust the pressure to a desired high pressure-side pressure without exceeding the using range of the expansion mechanism 5, and to operate the refrigeration cycle apparatus without deteriorating its operating efficiency and ability.

(Fourth Embodiment)

[0079] A refrigeration cycle apparatus according to a fourth embodiment of the invention will be explained with reference to Fig. 10. Fig. 10 is a schematic diagram show-

ing a structure of the refrigeration cycle apparatus. In Fig. 10, the same constituent elements as those shown in Fig. 4 are designated with the same symbols, and explanation thereof will be omitted. First, the action of the refrigeration cycle apparatus when it is operated will be explained based on a case where the product X of the density ratio and the ratio of the number of revolutions in the actual operating state $(DE / DC) \times (Hze / Hzc)$ is substantially the same as the design capacity ratio (VC / VE) which was assumed at the time of designing.

[0080] In the refrigerant circuit A, CO_2 refrigerant is compressed by the compressing mechanism 2 to a pressure (high pressure-side pressure) exceeding critical pressure. The compressed refrigerant is brought into a high temperature and high pressure state, and when the refrigerant flows through the refrigerant flow path of the radiator 3, the refrigerant radiates heat to water flowing through the fluid flow path of the radiator 3 and is cooled. Thereafter, a portion of the refrigerant flows through the second bypass flow path 31 by a half-opened second bypass valve 32, and other refrigerant flows into the high pressure-side flow path 14a of the internal heat exchanger 14, and the refrigerant is further cooled by a low pressure and low temperature refrigerant flowing through the low pressure-side flow path 14b. Then, the refrigerant flows into the expansion mechanism 5, and is decompressed by the expansion mechanism 5 and brought into the low temperature and low pressure gas/liquid two-phase state. At that time, in the expansion mechanism 5, the pressure energy of the refrigerant is converted into power and the power is converted into electricity by the generator 4.

[0081] In this manner, the pressure energy at the time of expansion can be collected as electricity and the COP can be enhanced. Refrigerant decompressed by the expansion mechanism 5 is supplied to the evaporator 6. In the evaporator 6, the refrigerant is heated by the outside air sent by the air blowing apparatus 9, and the refrigerant is brought into a gas/liquid two-phase state or a gaseous state. The refrigerant which flows out from the evaporator 6 is heated by the low pressure-side flow path 14b of the internal heat exchanger 14 and then, the refrigerant is again sucked into the compressing mechanism 2.

[0082] Next, the product X of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is different from the design capacity ratio (VC / VE) which was assumed during designing will be explained. First, the operation when the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operating state is greater than the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. In this case, if the ratio of the number of revolutions is constant, the refrigeration cycle tries to balance in a state where the high pressure-side pressure is reduced such that the refrigerant density (DE) of the inlet of the expansion mechanism 5 becomes small. However, if the high pressure-side pressure is reduced lower

than the preferable pressure, the discharge temperature may be lowered, the heating ability of the refrigeration cycle apparatus may be deteriorated and the efficiency of the refrigeration cycle apparatus may be deteriorated.

[0083] Therefore, first, the second bypass valve 32 is operated in the opening direction so that the circulation amount of refrigerant flowing into the second bypass flow path 31 is increased, and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is reduced. With this, the heat exchanging amount in the internal heat exchanger 14 is reduced, the density (DE) of refrigerant flowing into the expansion mechanism 5 can be reduced, the high pressure-side pressure is not lowered, and the optimal state can be maintained. However, if the product $(X (Hze / Hzc))$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operation is still greater than the design capacity ratio (VC / VE) assumed at the time of designing even if the second bypass valve 32 is fully opened, the number of revolutions of the expansion mechanism 5 is operated in the lowering direction, the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions is reduced, and the high pressure-side pressure $(DE / DC) \times (Hze / Hzc)$ is maintained in its optimal state.

[0084] In this manner, the internal heat exchanging amount in the internal heat exchanger 14 is reduced by operating the second bypass valve 32 in the opening direction, and only when the pressure can not be adjusted to the optimal high pressure-side pressure even if the second bypass valve 32 is fully opened, the number of revolutions of the expansion mechanism 5 is operated in the lowering direction. With this, the possibility of reduction in the number of revolutions of the expansion mechanism 5 that may deteriorate the reliability of the expansion mechanism 5 can be lowered. Thus, the refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism 5.

[0085] The operation when the product $(X (Hze / Hzc))$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ is smaller than the design capacity ratio (VC / VE) which was assumed at the time of designing will be explained. In this case, if the ratio of the number of revolutions is constant, the refrigeration cycle tries to balance in a state where the refrigerant density (DE) is increased so that the refrigerant density (DE) of the inlet of the expansion mechanism 5 is increased. However, in a state where the high pressure-side pressure is increased higher than the desired pressure, the operating efficiency of the refrigeration cycle apparatus is deteriorated.

[0086] Therefore, first, the second bypass valve 32 is operated in the closing direction, thereby reducing the circulation amount of refrigerant flowing into the second bypass flow path 31, and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is increased. With this, the heat exchanging amount in the internal heat exchanger

er 14 is increased, the density (DE) of refrigerant flowing into the expansion mechanism 5 can be increased, the high pressure-side pressure is not increased and the optimal state can be maintained. However, if the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ in the actual operation is still smaller than the design capacity ratio (VC / VE) assumed at the time of designing even if the second bypass valve 32 is fully opened, the number of revolutions of the expansion mechanism 5 is operated in the increasing direction, the product $(DE / DC) \times (Hze / Hzc)$ of the density ratio and the ratio of the number of revolutions $(DE / DC) \times (Hze / Hzc)$ is increased, and the high pressure-side pressure is maintained in its optimal state.

[0087] In this manner, the internal heat exchanging amount in the internal heat exchanger 14 is increased by operating the second bypass valve 32 in the closing direction, and only when the pressure can not be adjusted to the optimal high pressure-side pressure even if the second bypass valve 32 is fully closed, the number of revolutions of the expansion mechanism 5 is operated in the increasing direction. With this, the possibility of increase in the number of revolutions of the expansion mechanism 5 that may deteriorate the reliability of the expansion mechanism 5 can be lowered. Thus, the refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism 5.

[0088] As a concrete operating method of the expansion mechanism 5 and the second bypass valve 32, the control performed by the electronic control apparatus 25, the expansion mechanism revolution number control means 21, and the second bypass valve opening control means 33 will be explained based on the flowchart shown in Fig. 11. When the refrigeration cycle apparatus is operated, a detection value (discharge temperature: Td) (700) from the discharge temperature detecting means 20 is taken in. A target discharge temperature (target Td) which is previously stored in a ROM or the like and the taken discharge temperature (Td) are compared with each other (710). If the discharge temperature (Td) is lower than the target discharge temperature (target Td), there is a tendency that the high pressure-side pressure is lower than the optimal pressure and thus, it is determined whether the second bypass valve 32 is fully opened (720).

[0089] When the second bypass valve 32 is fully opened, the number of revolutions (Hze) of the expansion mechanism 5 is operated in the lowering direction (730) to reduce the circulation amount of refrigerant flowing through the expansion mechanism 5, and the high pressure-side pressure and the discharge temperature are increased. When the second bypass valve 32 is not fully opened, the second bypass valve 32 is operated in the opening direction (740), and the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14 is reduced. By re-

ducing the heat exchanging amount in the internal heat exchanger 14, the density of refrigerant flowing into the expansion mechanism 5 is reduced, and the high pressure-side pressure and the discharge temperature are increased.

[0090] When the discharge temperature (Td) is higher than the target discharge temperature (target Td) in step 710, there is a tendency that the high pressure-side pressure is higher than the optimal pressure and thus, it is determined whether the second bypass valve 32 is fully closed (750). When the second bypass valve 32 is fully closed, the number of revolutions (Hze) of the expansion mechanism 5 is operated in the increasing direction (760) to increase the circulation amount of refrigerant flowing through the expansion mechanism 5, and the high pressure-side pressure and the discharge temperature are lowered.

[0091] When the second bypass valve 32 is not fully opened in step 750, the second bypass valve 32 is operated in the closing direction (770) to increase the circulation amount of refrigerant flowing into the high pressure-side flow path 14a of the internal heat exchanger 14. The density of refrigerant flowing into the expansion mechanism 5 is increased by increasing the heat exchanging amount in the internal heat exchanger 14, and the high pressure-side pressure and the discharge temperature are lowered. After the above steps, the procedure is returned to step 700, and steps 700 to 770 are repeated, and the number of revolutions of the expansion mechanism 5 and the opening of the second bypass valve 32 are controlled in liaison with each other as shown in Fig. 12.

[0092] As explained above, according to the refrigeration cycle apparatus of the embodiment having the electric energy collecting type expansion mechanism, the second bypass valve 32 is operated in the opening direction to increase the heat exchanging amount in the internal heat exchanger 14. Next, only when the discharge temperature (Td) does not reach the target discharge temperature (target Td) even when the second bypass valve 32 is fully opened, the number of revolutions of the expansion mechanism 5 is operated in the lowering direction based on the discharge temperature. With this, the possibility of reduction in the number of revolutions of the expansion mechanism 5 that may deteriorate the reliability of the expansion mechanism 5 can be lowered. Thus, the refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism 5.

[0093] Alternatively, the second bypass valve 32 is operated in the closing direction to reduce the heat exchanging amount in the internal heat exchanger 14. Next, only when the discharge temperature (Td) does not reach the target discharge temperature (target Td) even when the second bypass valve 32 is fully closed, the number of revolutions of the expansion mechanism 5 is operated in the increasing direction based on the discharge temperature. With this, the possibility of increase in the

number of revolutions of the expansion mechanism 5 that may deteriorate the reliability of the expansion mechanism 5 can be lowered. Thus, the refrigeration cycle apparatus can be operated efficiently without lowering the reliability of the expansion mechanism 5.

[0094] In the above embodiments, in the determination of the fully opened states or fully closed states of the pre-expansion valve 11, the first bypass valve 13 and the second bypass valve 32, they need not physically fully opened or fully closed, and preset maximum opened state or minimum opened state close to the fully opened or closed state may be employed while taking the reliability of the valves into account. The number of revolutions of the expansion mechanism 5 may be determined based on the actual number of revolutions, or based on a set value of the expansion mechanism revolution number control means 21. Alternatively, to enhance the stability of the refrigeration cycle state, a very small value may be added to or subtracted from the target discharge temperature (target T_d) so that the discharge temperature falls within a constant temperature range.

[0095] In the control of the embodiments, the number of revolutions of the expansion mechanism 5, the pre-expansion valve 11, the first bypass valve 13 and the opening of the second bypass valve 32 are controlled. Alternatively, the high pressure-side pressure may be directed directly, and the control may be performed using this value, or the control may be performed using a detection value obtained by detecting the temperature of the refrigeration cycle apparatus which has a correlation with the high pressure-side pressure or using a calculation value using the detection value. For example, the control may be performed using a degree of sucked superheat of the compressing mechanism 2 or a degree of superheat of an outlet of the evaporator 3.

[0096] In the above description, the refrigerant flowing from a refrigerant outlet of the radiator 3 flowing through the high pressure-side flow path 14a of the internal heat exchanger 14 to the inlet of the expansion mechanism 5 is cooled by a refrigerant flowing from the refrigerant outlet of the evaporator 6 flowing through the low pressure-side flow path 14b to the inlet of the compressing mechanism 2. Alternatively, a refrigerant flowing from the refrigerant outlet of the radiator 3 flowing through the high pressure-side flow path 14a to the inlet of the expansion mechanism 5 may partially branch off from another low pressure refrigerant flowing through the low pressure-side flow path 14b, e.g., from a refrigerant of an inlet of the expansion mechanism 5, and may be cooled by a decompressed low temperature and low pressure refrigerant. Although the second bypass flow path 31 bypasses the high pressure-side flow path 14a of the internal heat exchanger 14, but even when the second bypass flow path 31 bypasses the low pressure-side flow path 14b, the same effect can be obtained.

[0097] Although carbon dioxide (CO_2) is used as the refrigerant, other refrigerant, e.g., R410A or the like may be used, and the same effect can be obtained.

[0098] According to the refrigeration cycle apparatus and the control method of the refrigeration cycle apparatus of the present invention, in the refrigeration cycle apparatus having an expansion mechanism whose number of revolutions can be changed independently from the number of revolutions of the compressing mechanism, the circulation amount of refrigerant flowing into the expansion mechanism can be adjusted in a wider range without deteriorating the reliability of the expansion mechanism, and the refrigeration cycle apparatus can be operated efficiently and thus, the refrigeration cycle apparatus can be applied to a water heater and an air conditioner having the expansion mechanism.

Claims

1. A refrigeration cycle apparatus comprising at least a compressing mechanism, a heat source-side heat exchanger, an expansion mechanism which collects power and has number of revolutions which can be changed independently from number of revolutions of said compressing mechanism, a utilizing-side heat exchanger, and a pre-decompressor for decompressing a refrigerant flowing into said expansion mechanism.
2. The refrigeration cycle apparatus according to claim 1, wherein further comprising a bypass circuit through which a portion of the refrigerant flowing into the expansion mechanism bypasses directly to a low pressure-side flow path.
3. The refrigeration cycle apparatus according to claim 1, wherein when any one of a high pressure-side pressure, a discharge temperature of said compressing mechanism, and a sucked superheat of said compressing mechanism does not reach a preset target value even if the number of revolutions of the expansion mechanism reaches a preset lowest number of revolutions, the refrigerant is decompressed by said pre-decompressor.
4. The refrigeration cycle apparatus according to claim 2, wherein when any one of a high pressure-side pressure, a discharge temperature of said compressing mechanism, and a sucked superheat of said compressing mechanism exceeds a preset target value even if the number of revolutions of the expansion mechanism reaches a preset highest number of revolutions, a portion of the refrigerant flowing into the expansion mechanism is allowed to flow into said bypass circuit.
5. The refrigeration cycle apparatus according to claim 1, further comprising an internal heat exchanger for cooling the refrigerant flowing into said expansion mechanism.

6. The refrigeration cycle apparatus according to claim 5, wherein when any one of a high pressure-side pressure, a discharge temperature of said compressing mechanism, and a sucked superheat of said compressing mechanism does not reach a preset target value even if the number of revolutions of the expansion mechanism reaches a preset lowest number of revolutions, said internal heat exchanger is not substantially operated.
7. The refrigeration cycle apparatus according to claim 5, wherein when any one of a high pressure-side pressure, a discharge temperature of said compressing mechanism, and a sucked superheat of said compressing mechanism exceeds a preset target value even if the number of revolutions of the expansion mechanism reaches a preset highest number of revolutions, said internal heat exchanger is substantially operated.
8. The refrigeration cycle apparatus according to claim 5, wherein when any one of a high pressure-side pressure, a discharge temperature of said compressing mechanism, and a sucked superheat of said compressing mechanism does not reach a preset target value even if said internal heat exchanger is not substantially operated, the number of revolutions of said expansion mechanism is reduced.
9. The refrigeration cycle apparatus according to claim 5, wherein when any one of a high pressure-side pressure, a discharge temperature of said compressing mechanism, and a sucked superheat of said compressing mechanism exceeds a preset target value even if said internal heat exchanger is substantially operated, the number of revolutions of said expansion mechanism is increased.

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Fig. 1

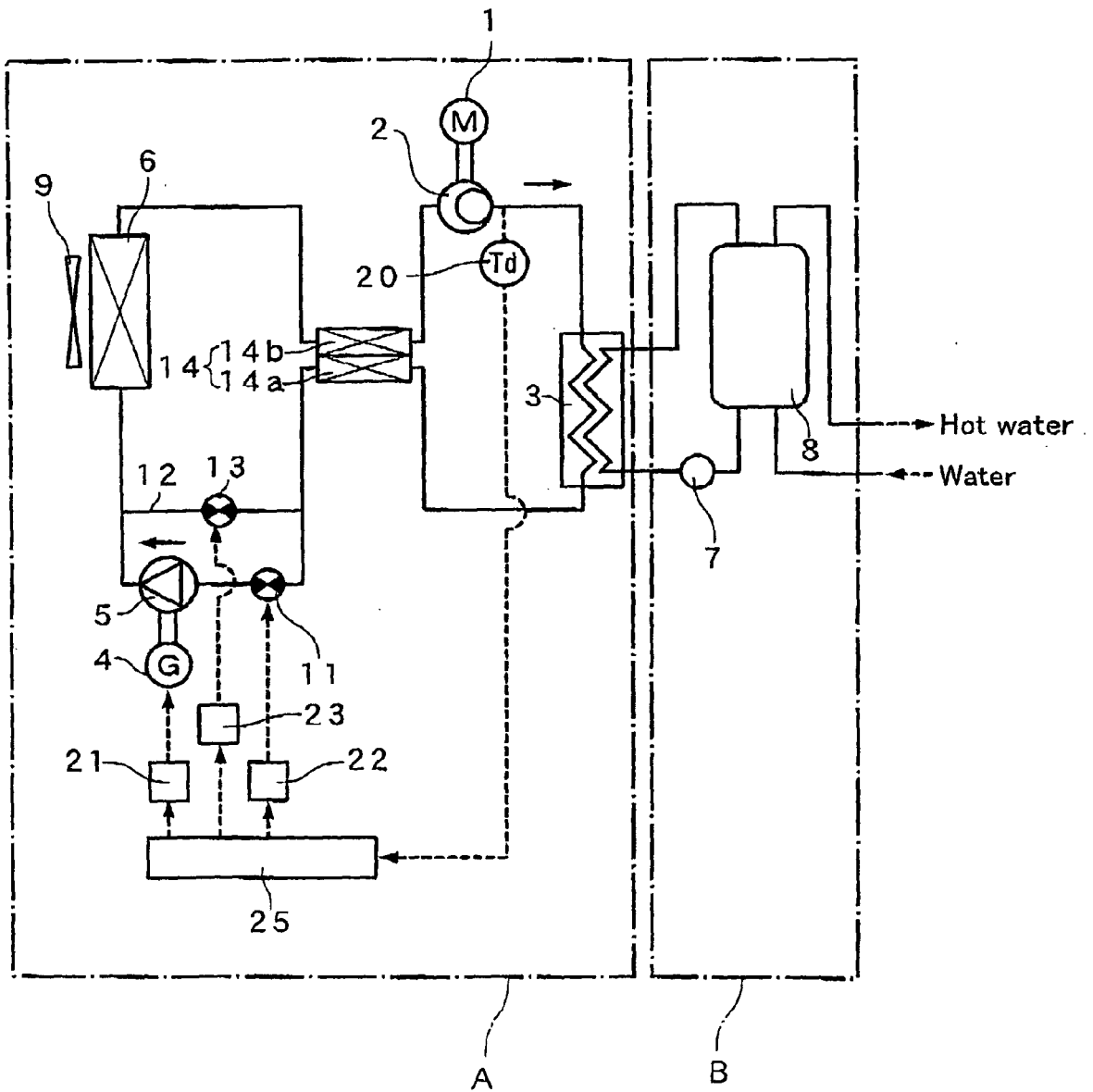


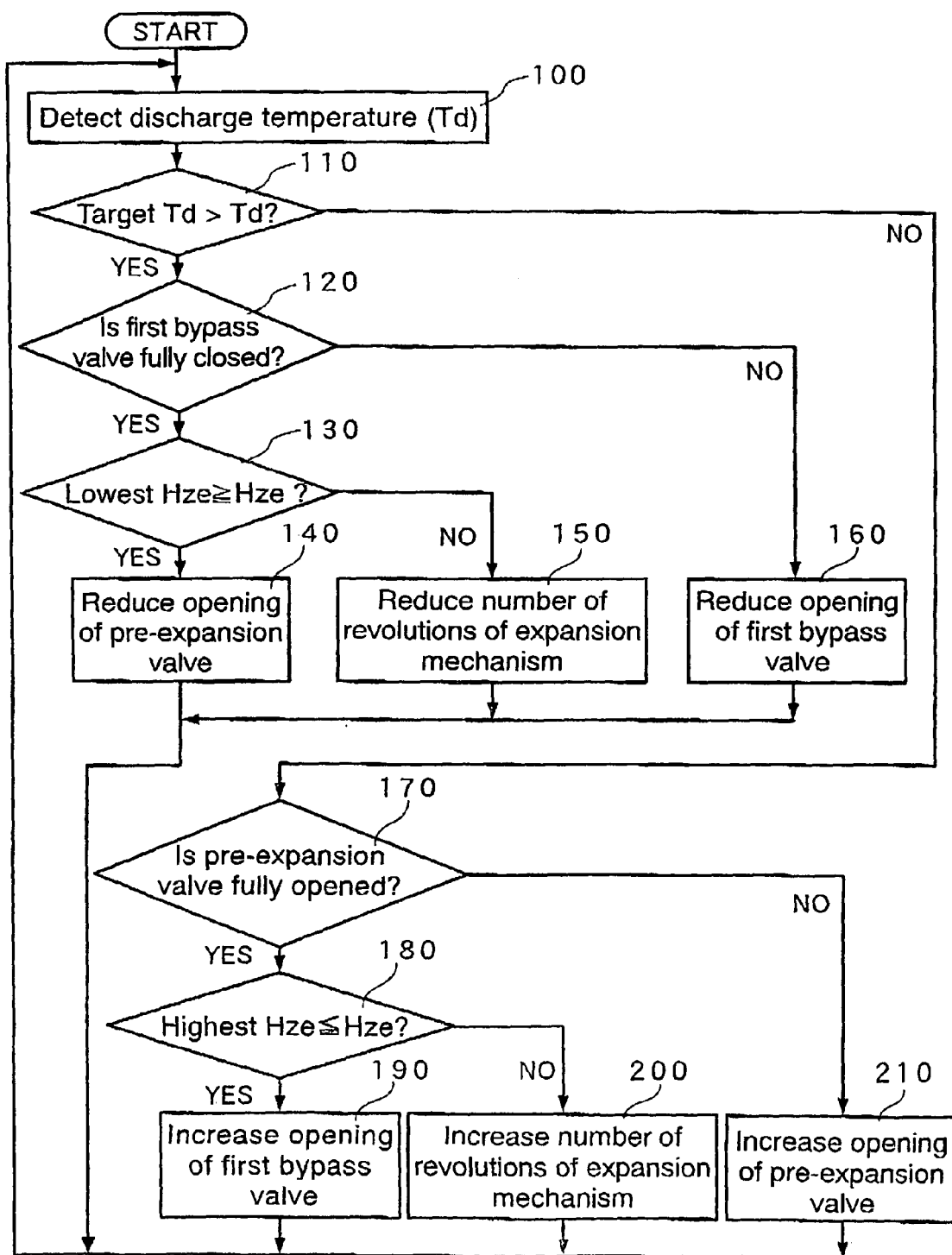
Fig. 2

Fig. 3

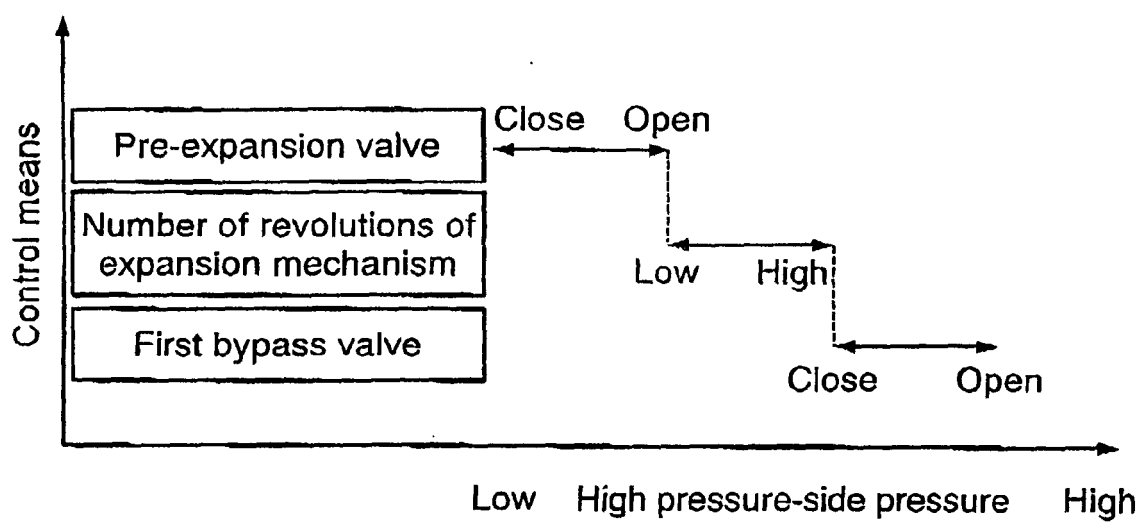


Fig. 4

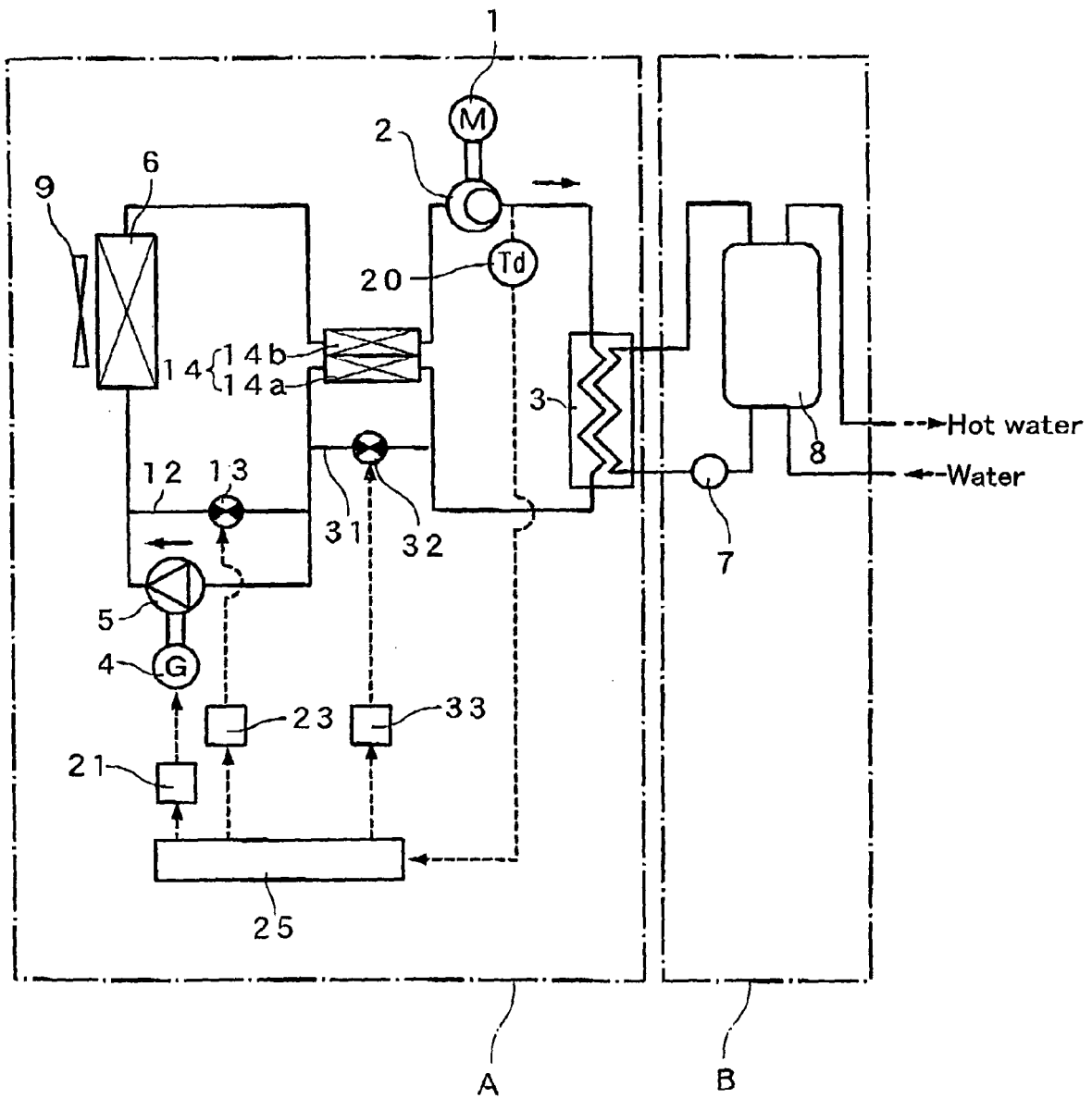


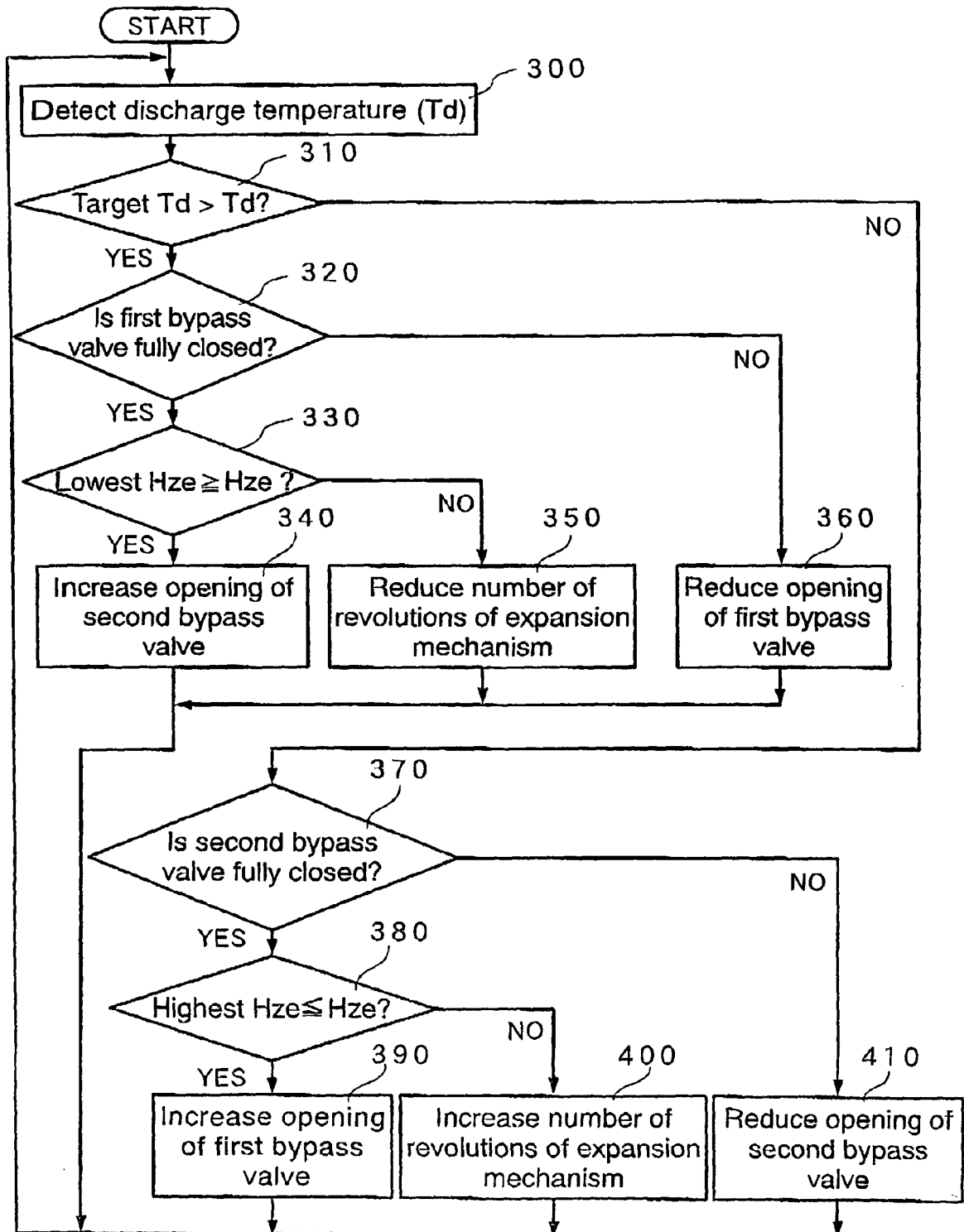
Fig. 5

Fig. 6

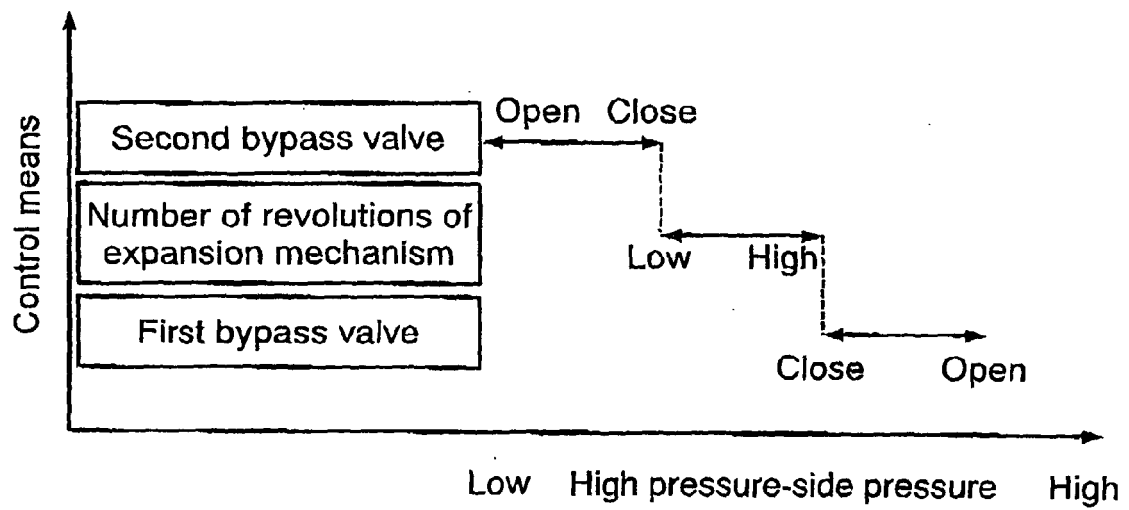


Fig. 7

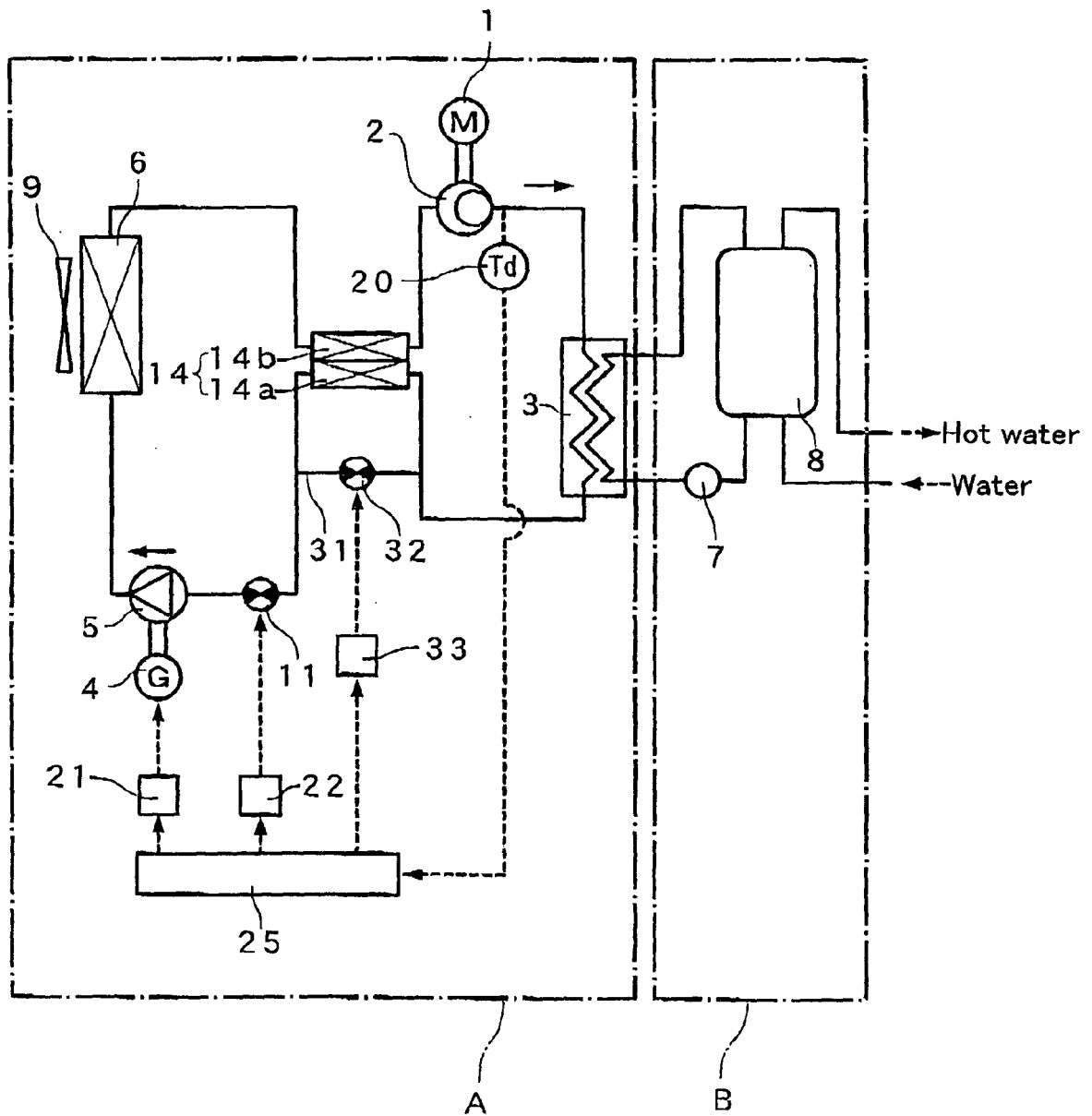


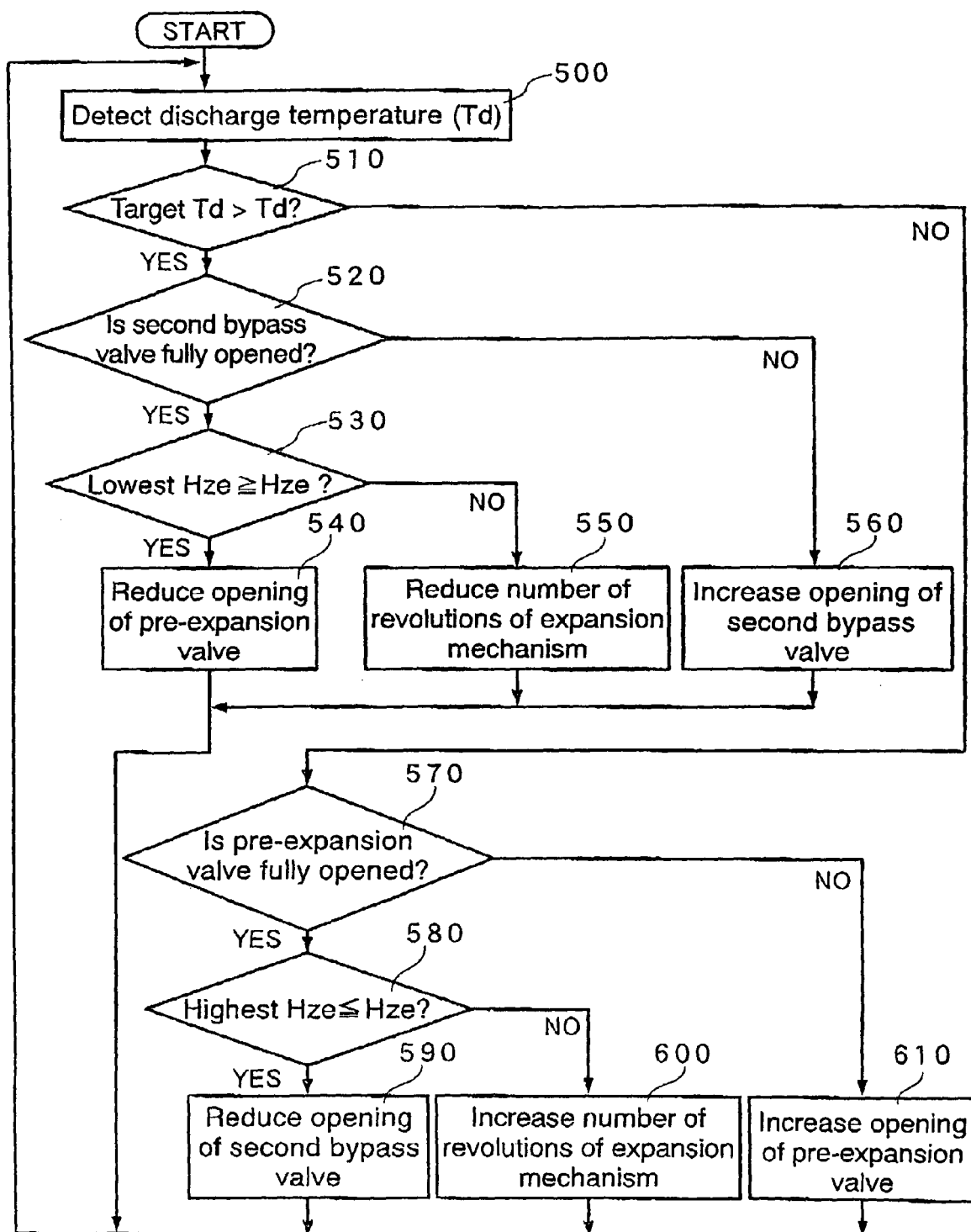
Fig. 8

Fig. 9

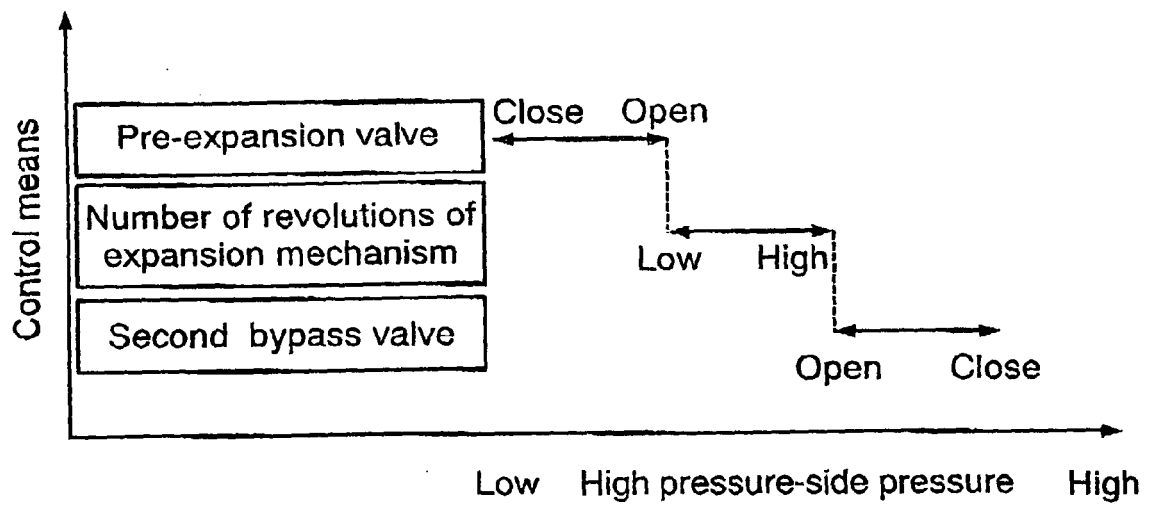


Fig. 10

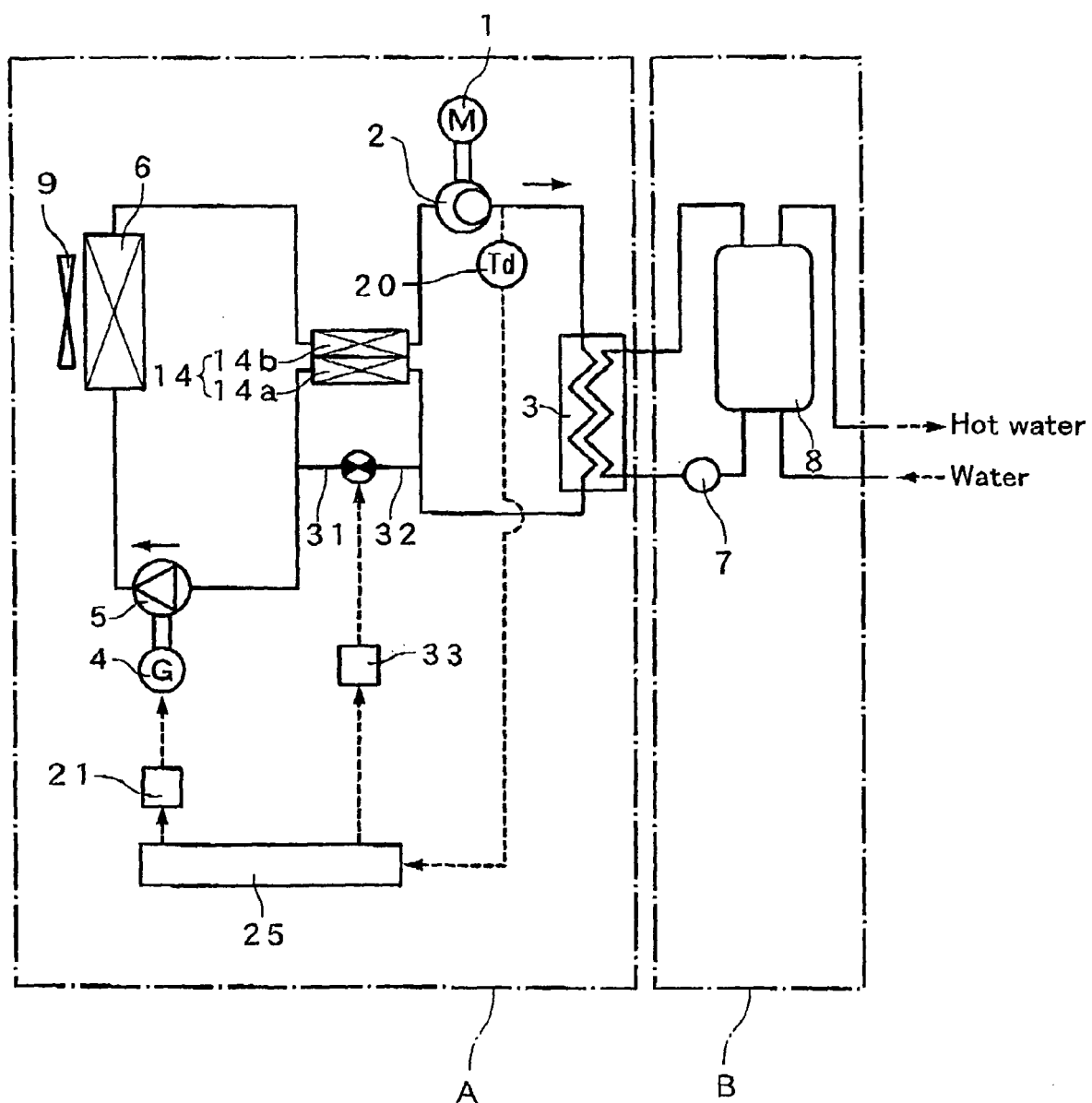


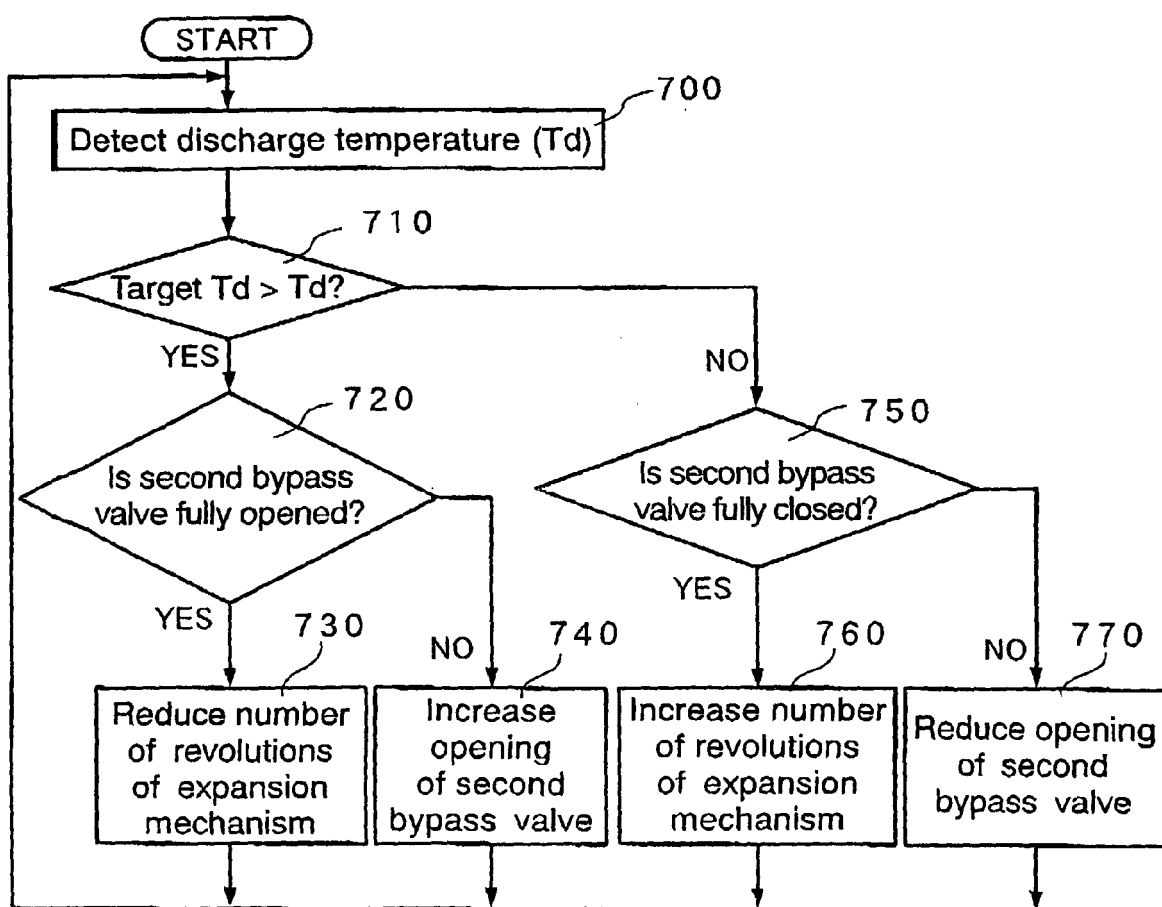
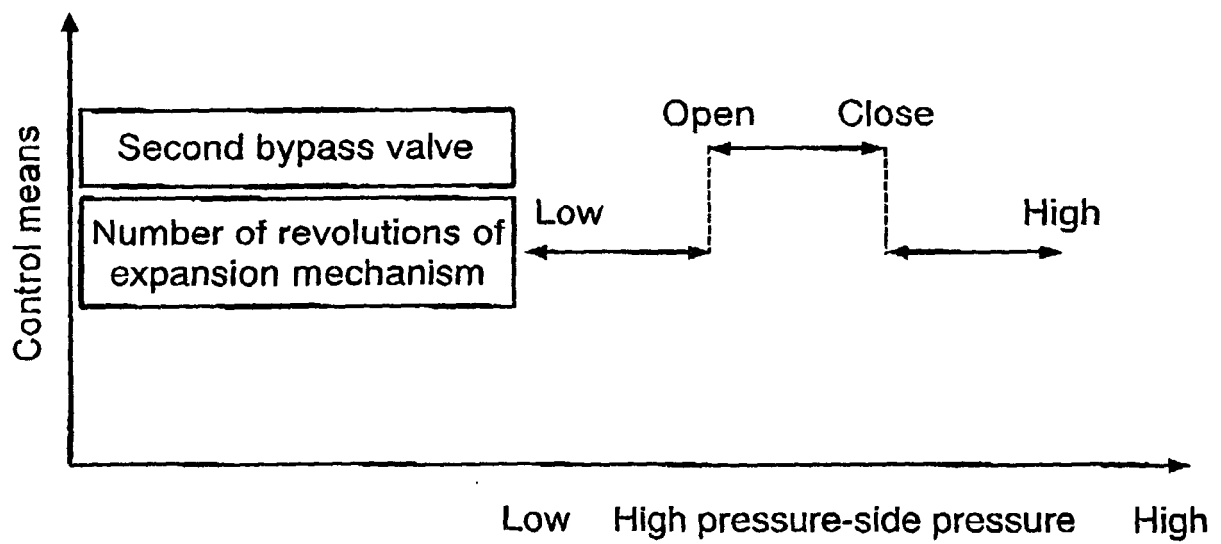
Fig. 11

Fig. 12



REFERENCES CITED IN THE DESCRIPTION

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