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(72) Inventors:
• **Moriwaki, Shunji**
Osaka, 540-6207 (JP)
• **Aoyama, Shigeo**
Osaka, 540-6207 (JP)

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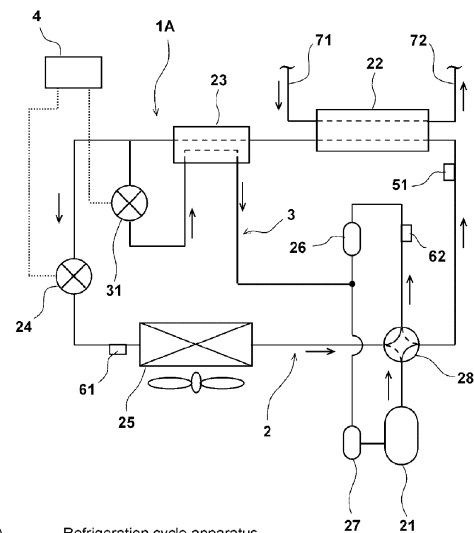
(74) Representative: **Eisenführ Speiser**
Patentanwälte Rechtsanwälte PartGmbB
Postfach 31 02 60
80102 München (DE)

(71) Applicant: **Panasonic Corporation**
Kadoma-shi
Osaka 571-8501 (JP)

(54) **Refrigeration cycle apparatus and hot water generator provided with the same**

(57) A supercooling heat exchanger 23 is configured such that a heat exchange ratio which is a ratio of a heat exchange amount in the supercooling heat exchanger 23 to a heat exchange amount in a radiator 22 becomes 0.1 or more and 0.6 or less, when dryness fraction of refrigerant which flows out from an evaporator 25 is adjusted to 0.8 or more and less than 1.0. According to this configuration, an amount of gas phase refrigerant which flows into the evaporator 25 is reduced, a pressure loss in a low pressure side pipe is reduced, and excessive rise of discharge temperature of a compressor 21 is suppressed in a state where the evaporator 25 is efficiently used. Therefore, even at the time of a high air heating load, it is possible to realize energy saving and low global warming potential.

[Fig. 1]



- 1A Refrigeration cycle apparatus
- 2 Refrigerant circuit
- 21 Compressor
- 22 Radiator
- 23 Supercooling heat exchanger
- 24 Main expansion valve (main expansion means)
- 25 Evaporator
- 3 Bypass passage
- 31 Bypass expansion valve (bypass expansion means)
- 4 Control device
- 51 Pressure sensor (condensation temperature detecting means)
- 61 First temperature sensor (evaporation temperature detecting means)
- 62 Second temperature sensor

Description**[TECHNICAL FIELD]**

[0001] The present invention relates to a refrigeration cycle apparatus using R32 as refrigerant, and to a hot water generator using the refrigeration cycle apparatus.

[BACKGROUND TECHNIQUE]

[0002] In a conventional refrigeration cycle apparatus and a conventional hot water generator, a supercooling heat exchanger is provided downstream of a radiator of a refrigerant circuit, and expanded refrigerant is made to flow into the supercooling heat exchanger, thereby supercooling the refrigerant which flows out from the radiator (see patent document 1 for example).

[0003] Fig. 9 shows the conventional refrigeration cycle apparatus described in patent document 1.

[0004] As shown in Fig. 9, the refrigeration cycle apparatus 100 includes a refrigerant circuit 110 through which refrigerant circulates and a bypass passage 120.

[0005] The refrigerant circuit 110 is configured by annularly connecting a compressor 111, a radiator 112, a supercooling heat exchanger 113, a main expansion valve 114 and an evaporator 115 to one another through pipes.

[0006] The bypass passage 120 branches off from the refrigerant circuit 110 between the supercooling heat exchanger 113 and the main expansion valve 114, and is connected to the refrigerant circuit 110 between the evaporator 115 and the compressor 111 through the supercooling heat exchanger 113. The bypass passage 120 is provided with a bypass expansion valve 121 upstream of the supercooling heat exchanger 113.

[0007] It is described in patent document 1 that to enhance refrigeration capacity and operation efficiency, the supercooling heat exchanger 113 is configured so that a ratio of a heat exchange amount between refrigerant which is decompressed by the bypass expansion valve 121 in the supercooling heat exchanger 113 and refrigerant which flows out from the radiator 112 with respect to a heat exchange amount between refrigerant which flows into the radiator 112 and to-be heated fluid in the radiator 112 becomes 0.2 or more and 0.8 or less, when an opening degree of the bypass expansion valve 121 is adjusted such that dryness fraction of refrigerant which flows out from the supercooling heat exchanger 113 in the bypass passage 120 becomes 0.8 or more and less than 1.0.

[0008] According to another conventional refrigeration cycle apparatus, R32 having low global warming potential is used as refrigerant which circulates through the refrigeration cycle apparatus, thereby realizing low global warming potential (see patent document 2 for example).

[PRIOR ART DOCUMENTS]**[0009]**

[Patent Document 1] Japanese Patent Application Laid-open No.2011-80634

[Patent Document 2] Japanese Patent Application Laid-open No.2001-194015

[SUMMARY OF THE INVENTION]**[PROBLEM TO BE SOLVED BY THE INVENTION]**

[0010] To realize efficient operation in the above-described refrigeration cycle apparatuses, it is preferable that the evaporator is utilized with high heat exchanging efficiency. To that end, it is generally known that it is necessary to operate the refrigeration cycle apparatus in a state where an average heat-transfer coefficient in refrigerant of the evaporator is high, i.e., it is necessary to operate the refrigeration cycle apparatus such that refrigerant dryness fraction at an outlet of the evaporator becomes about 0.9.

[0011] According to a configuration of patent document 1, however, when R32 having a higher specific heat ratio than conventional R410A is used as refrigerant of the refrigeration cycle apparatus and the refrigeration cycle apparatus is operated such that dryness fraction of refrigerant at an outlet of the evaporator becomes about 0.9 and dryness fraction of refrigerant at an outlet of the supercooling heat exchanger becomes 0.8 or more and less than 1.0, temperature of refrigerant discharged from the compressor excessively rises under a condition that outside air temperature is low (under this condition, compression ratio of compressor becomes large), and there is a problem that temperature of refrigerant discharged from the compressor excessively rises and reliability of the compressor is deteriorated.

[0012] The present invention has been accomplished to solve the problem of the conventional techniques, and it is an object of the invention to provide a refrigeration cycle apparatus which can efficiently be operated while suppressing excessive temperature rise of refrigerant discharged from a compressor even if refrigerant having a large specific heat ratio is used.

[MEANS FOR SOLVING THE PROBLEM]

[0013] The present invention provides a refrigeration cycle apparatus comprising: a refrigerant circuit configured by annularly connecting a compressor, a radiator, a supercooling heat exchanger, a main expansion means and an evaporator to one another through refrigerant pipes; a bypass passage which branches off from the refrigerant circuit at a location between the radiator and the main expansion means and which extends through the supercooling heat exchanger to be connected to a compression chamber of the compressor or to the refrigerant circuit.

erant circuit between the evaporator and the compressor; a bypass expansion means connected to an upstream side of the supercooling heat exchanger in the bypass passage; and a control device, wherein R32 is used as refrigerant which circulates through the refrigerant circuit, and the supercooling heat exchanger is configured so that a heat exchange ratio Q_{sc}/Q_c which is a ratio of a heat exchange amount Q_{sc} between the refrigerant which is decompressed by the bypass expansion means and the refrigerant which flows out from the radiator in the supercooling heat exchanger with respect to a heat exchange amount Q_c between to-be heated fluid and the refrigerant in the radiator becomes equal to 0.1 or more and equal to 0.6 or less, when opening degrees of the main expansion means and the bypass expansion means are adjusted by the control device such that dryness fraction of the refrigerant which flows out from the evaporator becomes equal to 0.8 or more and less than 1.0.

[0014] According to this, by keeping the refrigerant dryness fraction at an outlet of the bypass passage at a low level and by bringing enthalpy of refrigerant sucked by the compressor into a low level, it is possible to suppress excessive temperature rise of refrigerant discharged from the compressor. It is possible to reduce an amount of gas phase refrigerant which flows into the evaporator, and to increase a refrigerant enthalpy difference between an inlet and an outlet of the evaporator. Hence, it is possible to enhance endothermic performance of the evaporator.

[EFFECT OF THE INVENTION]

[0015] According to the present invention, even if refrigerant having a large specific heat ratio is used, discharge temperature of the compressor can appropriately be maintained in a state where the evaporator is efficiently used. Therefore, it is possible to avoid deterioration in reliability of the compressor and to provide a refrigeration cycle apparatus which realizes energy saving and low global warming potential.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0016]

Fig. 1 is a schematic block diagram of a refrigeration cycle apparatus according to an embodiment of the present invention;

Fig. 2(a) is a correlation diagram of a local evaporation heat-transfer coefficient in refrigerant R32 and dryness fraction of refrigerant, and Fig. 2(b) is a correlation diagram of a local evaporation heat-transfer coefficient in refrigerant R32 and refrigerant R410A and dryness fraction of refrigerant;

Fig. 3 is a correlation diagram of dryness fraction of refrigerant at an inlet of an evaporator and a heat exchange ratio;

Fig. 4(a) is a Mollier diagram of the refrigeration cycle apparatus when refrigerant dryness fraction at an inlet of the evaporator is 0.43, and Fig. 4(b) is a Mollier diagram of the refrigeration cycle apparatus when refrigerant dryness fraction at the inlet of the evaporator is 0;

Fig. 5 is a correlation diagram of refrigerant dryness fraction at an outlet of a bypass passage and a heat exchange ratio;

Fig. 6 is a correlation diagram of discharged refrigerant temperature of the compressor and a heat exchange ratio;

Fig. 7 is a correlation diagram of evaporation temperature and a heat exchange ratio showing a relation which is changed depending upon refrigerant condensation temperature at the radiator;

Fig. 8 is a flowchart of operation control of the refrigeration cycle apparatus according to the embodiment; and

Fig. 9 is a schematic block diagram of a conventional refrigeration cycle apparatus.

[MODE FOR CARRYING OUT THE INVENTION]

[0017] A first aspect of the present invention provides a refrigeration cycle apparatus comprising: a refrigerant circuit configured by annularly connecting a compressor, a radiator, a supercooling heat exchanger, a main expansion means and an evaporator to one another through refrigerant pipes; a bypass passage which branches off from the refrigerant circuit at a location between the radiator and the main expansion means and extends through the supercooling heat exchanger to be connected to a compression chamber of the compressor or to the refrigerant circuit between the evaporator and the compressor; a bypass expansion means connected to an upstream side of the supercooling heat exchanger in the bypass passage; and a control device, wherein R32 is used as refrigerant which circulates through the refrigerant circuit, and the supercooling heat exchanger is configured so that a heat exchange ratio Q_{sc}/Q_c which is a ratio of a heat exchange amount Q_{sc} between the refrigerant which is decompressed by the bypass expansion means and the refrigerant which flows out from the radiator in the supercooling heat exchanger with respect to a heat exchange amount Q_c between to-be heated fluid and the refrigerant in the radiator becomes equal to 0.1 or more and equal to 0.6 or less, when opening degrees of the main expansion means and the bypass expansion means are adjusted by the control device such that dryness fraction of the refrigerant which flows out from the evaporator becomes equal to 0.8 or more and less than 1.0.

[0018] According to this, since the refrigerant dryness fraction at the outlet of the evaporator becomes 0.8 or more and less than 1.0 at which an evaporation heat-transfer coefficient becomes maximum and therefore, heat-transfer efficiency of the evaporator is enhanced.

Further, since the heat exchange ratio Q_{sc}/Q_c is set to 0.1 or more, a supercooling degree of refrigerant at the outlet of the supercooling heat exchanger is reliably increased, gas phase refrigerant which flows into the evaporator is reduced, and a pressure loss in a low pressure-side pipe of the refrigeration cycle is reduced. Further, since the heat exchange ratio Q_{sc}/Q_c is set to 0.6 or less, the refrigerant dryness fraction at the outlet of the bypass passage is maintained in a low state.

[0019] Therefore, discharge temperature of the compressor is maintained appropriately in a state where the evaporator is efficiently used. Hence, it is possible to realize energy saving and low global warming potential while avoiding deterioration in performance of the refrigeration cycle and deterioration in reliability of the compressor.

[0020] According to a second aspect of the invention, in the refrigeration cycle apparatus of the first aspect, the control device controls the main expansion means by a temperature difference between temperature of the refrigerant which flows into the evaporator and temperature of the refrigerant which flows out from the evaporator such that dryness fraction of the refrigerant which flows out from the evaporator becomes equal to 0.8 or more and less than 1.0.

[0021] According to this aspect, the refrigerant dryness fraction at the outlet of the evaporator is controlled into an appropriate level in accordance with loads applied to the evaporator and a radiator. Therefore, in a wide operating range, it is possible to obtain an optimal driving state and thus, reliability and energy saving of the refrigeration cycle are enhanced.

[0022] According to a third aspect of the invention, in the refrigeration cycle apparatus of the second aspect, the refrigeration cycle apparatus further comprises an evaporation temperature detecting means which detects evaporation temperature of the refrigerant in the evaporator, and when the evaporation temperature detecting means detects a decrease in the evaporation temperature, the control device controls the bypass expansion means such that the heat exchange ratio becomes greater.

[0023] According to this aspect, it is possible to lower the refrigerant enthalpy at the inlet of the evaporator, and as evaporation temperature is lowered, gas phase refrigerant at the inlet of the evaporator is reduced. Therefore, a pressure loss on the low pressure-side of the refrigerant circuit is reduced. Therefore, it is possible to maintain efficient operation even under such a using condition that temperature variation range of heat source side medium is wide like an air heat source machine in which an evaporator sucks heat from outside air.

[0024] According to a fourth aspect of the invention, in the refrigeration cycle apparatus of the second or third aspect, the refrigeration cycle apparatus further comprises a condensation temperature detecting means which detects condensation temperature of the refrigerant in the radiator, and when the condensation temperature de-

tecting means detects a decrease in the condensation temperature, the control device controls the bypass expansion means such that the heat exchange ratio becomes greater.

[0025] According to this aspect, it is possible to avoid a case where enthalpy of refrigerant at the inlet of the evaporator is increased by condensation temperature rise, and gas phase refrigerant at the inlet of the evaporator is reduced. Hence, a pressure loss on the low pressure-side of the refrigerant circuit is reduced. Therefore, in addition to the effect of the second or the third aspect, efficient operation can be maintained also under such a using condition that temperature variation range of the utilizing heat medium is wide like a case where the radiator dissipates heat to water.

[0026] According to a fifth aspect of the invention, there is provided a hot water generator comprising the refrigeration cycle apparatus according to any one of the first to fourth aspects of the invention, the to-be heated fluid is water or antifreeze liquid, and the to-be heated fluid heated by the radiator is utilized for supplying hot water or for air heating.

[0027] According to this aspect, it is unnecessary to limit a kind of a heat exchanger which supplies hot water or heats a room using to-be heated fluid, i.e., it is unnecessary that such a heat exchanger is limited to a water/air heat exchanger or an antifreeze liquid/water heat exchanger. Therefore, heat medium which is heated by the radiator can widely be used for heating equipment (hot-air type heater, radiator, floor heating panel and the like), a water heater and the like, and the same effects as those of the first to fourth aspects of the invention can be obtained.

[0028] An embodiment of the present invention will be described below with reference to the drawings. The invention is not limited to the embodiment.

[0029] Fig. 1 is a schematic block diagram of a refrigeration cycle apparatus and a hot water generator according to the embodiment of the invention. In Fig. 1, the refrigeration cycle apparatus 1A includes a refrigerant circuit 2 through which refrigerant circulates, a bypass passage 3 and a control device 4. As the refrigerant, R32 which has low global warming potential is used.

[0030] The refrigerant circuit 2 is configured by annularly connecting a compressor 21, a radiator 22, a supercooling heat exchanger 23, a main expansion valve (main expansion means) 24 and an evaporator 25 to one another through refrigerant pipes. In this embodiment, a sub-accumulator 26 and a main accumulator 27 which separate gas and liquid from each other are provided between the evaporator 25 and the compressor 21. The refrigerant circuit 2 is provided with a four-way valve 28 for switching between a normal operation for heating non-heated fluid at the radiator 22 and a defrosting operation for melting frost attached to the evaporator 25.

[0031] In this embodiment, the refrigeration cycle apparatus 1A is used as heating means. As shown in Fig. 1, the hot water generator is configured. The hot water

generator can utilize hot water generated by the refrigeration cycle apparatus 1A for air heating. Hot water is produced in such a manner that the radiator 22 exchanges heat between refrigerant and water (to-be heated fluid). More specifically, a supply pipe 71 and a collecting pipe 72 are connected to the radiator 22, water is supplied to the radiator 22 through the supply pipe 71, and water (hot water) heated by the radiator 22 is collected through the collecting pipe 72. Water (hot water) collected through the collecting pipe 72 is sent to a heater such as a radiator directly or through a hot water tank and according to this, a room is heated and hot water is supplied.

[0032] In this embodiment, the bypass passage 3 branches off from the refrigerant circuit 2 at a location between the supercooling heat exchanger 23 and the main expansion valve 24, and extends through the supercooling heat exchanger 23 to be connected to the refrigerant circuit 2 at a location between the evaporator 25 and the compressor 21. In this embodiment, the bypass passage 3 is connected to the refrigerant circuit 2 at a location between the sub-accumulator 26 and the main accumulator 27. The bypass passage 3 is provided with a bypass expansion valve (bypass expansion means) 31 at a location upstream of the supercooling heat exchanger 23.

[0033] In the normal operation, refrigerant discharged from the compressor 21 flows into the radiator 22 through the four-way valve 28. In the defrost operation, refrigerant discharged from the compressor 21 is sent to the evaporator 25 through the four-way valve 28. Arrows in Fig. 1 show a flowing direction of refrigerant at the time of normal operation. A state variation of refrigerant at the time of normal operation will be described below.

[0034] High pressure refrigerant discharged from the compressor 21 flows into the radiator 22 and dissipates heat to water which passes through the radiator 22. The high pressure refrigerant which flows out from the radiator 22 flows into the supercooling heat exchanger 23, exchanges heat with low pressure refrigerant which is decompressed by a bypass expansion valve 31 and according to this, the refrigerant is supercooled. The high pressure refrigerant which flows out from the supercooling heat exchanger 23 is shunted into the main expansion valve 24 and the bypass expansion valve 31.

[0035] The high pressure refrigerant which flowed into the main expansion valve 24 is decompressed by the main expansion valve 24 and expanded and then, the refrigerant flows into the evaporator 25. The low pressure refrigerant which flowed into the evaporator 25 absorbs heat from air here.

[0036] High pressure refrigerant which flowed into the bypass expansion valve 31 is decompressed by the bypass expansion valve 31 and expanded and then, the refrigerant flows into the supercooling heat exchanger 23. The low pressure refrigerant which flowed into the supercooling heat exchanger 23 is heated by the high pressure refrigerant which flowed out from the radiator 22. Thereafter, the low pressure refrigerant which flowed

out from the supercooling heat exchanger 23 merges with the low pressure refrigerant which flowed out from the evaporator 25 and is again sucked into the compressor 21.

[0037] According to the configuration of the refrigeration cycle apparatus 1A in the embodiment, excessive temperature rise of refrigerant discharged from the compressor 21 generated especially when outside air temperature is lowered is prevented while suppressing deterioration in operation efficiency. Generally, if outside air temperature is lowered, in the evaporator 25 placed outdoors, an amount of heat absorbed by refrigerant from air is decreased. According to this, refrigerant does not sufficiently evaporate in the evaporator 25 and flows out from the evaporator 25 in a state where an amount of liquid-phase portion is large. To improve this state, the control device 4 reduces an opening degree of the main expansion valve 24, reduces a circulation amount of refrigerant which flows into the evaporator 25, and secures an absorption heat amount per unit flow rate in the evaporator 25. If the circulation amount of refrigerant is reduced, a compression ratio of refrigerant in the compressor 21 is increased and discharge temperature gradually rises. It is an object of the present invention to suppress the excessive discharge temperature rise while suppressing deterioration in operation efficiency.

[0038] To achieve this object, refrigerant which flows into the evaporator 25 is supercooled, an enthalpy difference in the evaporator 25 is increased, and wet refrigerant is made to flow into the bypass passage 3. According to this aspect, it is important to lower the sucked refrigerant enthalpy of the compressor 21, and to reduce a pressure loss in a low pressure side portion of the refrigerant circuit 2, i.e., a portion of the refrigerant circuit 2 from the main expansion valve 24 to the compressor 21, especially a portion of the refrigerant circuit 2 from the main expansion valve 24 to a connected portion between the bypass passage 3 and the refrigerant circuit 2.

[0039] If the enthalpy of refrigerant sucked into the compressor 21 is reduced, excessive discharge temperature rise is suppressed. If the pressure loss at the low pressure side portion of the refrigerant circuit 2 is reduced, pressure of refrigerant sucked into the compressor 21 rises, specific volume is reduced and therefore, the circulation amount of refrigerant is increased. If the enthalpy difference in the evaporator 25 is increased, even if refrigerant is made to flow into the bypass passage 3 and a mass flow rate of refrigerant which passes through the evaporator 25 of the refrigerant circuit 2 is reduced, it is possible to secure an absorption heat amount in the evaporator 25. That is, if a supercooling degree of refrigerant and a bypass amount are appropriately adjusted, it is possible to suppress deterioration in operation efficiency of the refrigeration cycle apparatus 1A and to appropriately maintain the discharge temperature of the compressor 21.

[0040] When opening degrees of the main expansion valve 24 and the bypass expansion valve 31 are adjusted

by the control device 4 such that dryness fraction of refrigerant which flows out from the evaporator 25 falls within a range of 0.8 or more and less than 1.0 at which high evaporation performance can be obtained, a heat-transfer area of the supercooling heat exchanger 23 is set such that a heat exchange ratio Q_{sc}/Q_c which is a ratio of a heat exchange amount Q_{sc} between refrigerant which is decompressed by the bypass passage 3 and refrigerant which flows out from the radiator 22 in the supercooling heat exchanger 23 with respect to a heat exchange amount Q_c between water and refrigerant in the radiator 22 becomes 0.1 or more and 0.6 or less. This setting of the heat-transfer area of the supercooling heat exchanger 23 will be described in detail in the embodiment.

[0041] Here, as shown in Figs. 2(a) and 2(b), a local evaporation heat-transfer coefficient in the refrigerant pipe which is placed horizontally becomes a maximum value when dryness fraction is 0.8 or more and less than 1.0. If the dryness fraction of refrigerant which flows out from the evaporator 25 is adjusted in a range of 0.8 or more and less than 1.0 as in this configuration, heat-transfer efficiency of the evaporator becomes high, and operation efficiency of the refrigeration cycle apparatus 1A is enhanced.

[0042] According to this configuration, the heat-transfer area of the supercooling heat exchanger 23 is appropriately set. Therefore, if the circulation amount of refrigerant which passes through the evaporator 25 is adjusted so that dryness fraction of refrigerant at the outlet of the evaporator 25 becomes an appropriate value, a circulation amount of refrigerant which flows through the bypass passage 3 is inevitably adjusted appropriately. As a result, refrigerant which flows through the refrigerant circuit 2 is appropriately supercooled, and dryness fraction of refrigerant at the outlet of the bypass passage 3 flowing out from the supercooling heat exchanger 23 becomes small.

[0043] In this configuration, a heat exchange ratio Q_{sc}/Q_c is set based on a condition that outside air temperature is low and condensation temperature is high, i.e., a condition that it is necessary to maximally secure the heat exchange amount Q_{sc} in the supercooling heat exchanger 23 to secure heating ability in the radiator 22. That is, as shown in Figs. 4 (a) and 4 (b), in the hot water generator, as a lower limit of outside air temperature in a heat pump apparatus, it is assumed that the outside air temperature AT is -25°C . As an upper limit of condensation temperature in a heat pump apparatus using R32, it is assumed that condensation temperature T_c is 60°C . Under such conditions, refrigerant on the side of the outlet of the supercooling heat exchanger 23 of the refrigerant circuit 2 is supercooled, and the heat exchange ratio Q_{sc}/Q_c is set so that the heat exchange amount Q_{sc} in the supercooling heat exchanger 23 can maximally be secured. Under the conditions that the outside air temperature AT is -25°C and condensation temperature T_c of refrigerant in the radiator 22 is 60°C , if the heat ex-

change ratio Q_{sc}/Q_c is in a range of 0.1 or more and 0.6 or less as shown in Fig. 3, dryness fraction X_{ei} of refrigerant which flows into the evaporator 25 falls within a range of 0 or more and less than 0.43. Here, if the dryness fraction X_{ei} of refrigerant which flows into the evaporator 25 is 0.43, dryness fraction of refrigerant (α in the drawing) before the refrigerant is decompressed by the main expansion valve 24 becomes 0 as shown in Fig. 4 (a). Hence, if the heat exchange ratio Q_{sc}/Q_c is set so that the dryness fraction X_{ei} of refrigerant which flows into the evaporator 25 becomes less than 0.43, refrigerant before it is decompressed by the main expansion valve 24, i.e., refrigerant which flows out from the supercooling heat exchanger 23 in the refrigerant circuit 2 can be supercooled. As shown in Figs. 3 and 4(b), if the heat exchange ratio Q_{sc}/Q_c is 0.6, the dryness fraction X_{ei} of refrigerant which flows into the evaporator 25 becomes 0 (β in the drawing), the enthalpy difference in the evaporator 25 is increased, and an absorption heat amount in the evaporator 25 can be secured. If the heat exchange ratio Q_{sc}/Q_c is set such that the dryness fraction X_{ei} of refrigerant which flows into the evaporator 25 becomes greater than 0 and less than 0.43 as described above, refrigerant which flows out from the supercooling heat exchanger 23 in the refrigerant circuit 2 can reliably be supercooled. Also under the conditions that outside air temperature is low and condensation temperature is high, heat exchange amount Q_{sc} in the supercooling heat exchanger 23 can be secured. In this embodiment, the heat exchange ratio Q_{sc}/Q_c is set to 0.1 or more so that refrigerant on the side of the outlet of the supercooling heat exchanger 23 of the refrigerant circuit 2 can reliably be supercooled, i.e., so that the dryness fraction X_{ei} of refrigerant which flows into the evaporator 25 reliably becomes less than 0.43.

[0044] As shown in Fig. 5, there is a tendency that dryness fraction X_{bo} of refrigerant which flows out from the bypass passage 3 becomes greater as the heat exchange ratio Q_{sc}/Q_c becomes greater. Since the enthalpy of sucked refrigerant of the compressor 21 rises by the rise of the dryness fraction X_{bo} , temperature T_d of discharged refrigerant of the compressor 21 rises. However, if the heat exchange ratio Q_{sc}/Q_c is within the range of 0.1 or more and 0.6 or less, the temperature T_d of discharged refrigerant becomes equal to permissible temperature or lower as shown in Fig. 6. In this embodiment, the permissible temperature is set to 100° while taking deterioration of refrigerant oil in the compressor 21 and safety of compressor 21 into consideration. Hence, in this embodiment, the heat-transfer area of the supercooling heat exchanger 23 is set so that the heat exchange ratio Q_{sc}/Q_c falls within the range of 0.1 or more and 0.6 or less. In Figs. 4, P_c represents pressure of refrigerant which passes through the radiator 22 and P_s represents pressure of refrigerant which passes through the evaporator 25.

[0045] Next, control operation performed by the control device 4 will be described.

[0046] As shown in Fig. 1, the refrigerant circuit 2 is provided with a first temperature sensor 61 which detects temperature (evaporator temperature) T_e of refrigerant which flows into the evaporator 25, a second temperature sensor 62 which detects temperature (evaporator outlet temperature) T_{eo} of refrigerant which flows out from the evaporator 25, and a pressure sensor 51 which detects pressure (condensation pressure) P_c of refrigerant which flows into the radiator 22.

[0047] The control device 4 controls the number of rotations of the compressor 21, a switching operation of the four-way valve 28, and opening degrees of the main expansion valve 24 and the bypass expansion valve 31 based on detection values detected by these sensors 51, 61 and 62.

[0048] In this embodiment, the control device 4 controls the main expansion valve 24 so that dryness fraction of refrigerant which flows out from the evaporator 25 becomes 0.8 or more and less than 1.0 in the refrigerant circuit 2 at the time of normal operation. More specifically, an opening degree of the main expansion valve 24 is adjusted so that a temperature difference ΔT_e between evaporation temperature T_e detected by the first temperature sensor 61 and evaporator outlet temperature T_{eo} detected by the second temperature sensor 62 becomes equal to a predetermined temperature difference ΔT_t . Here, to bring the dryness fraction of refrigerant which flows out from the evaporator 25 into a predetermined value, it is preferable that the second temperature sensor 62 is placed downstream of the four-way valve 28, and temperature of refrigerant which flows out from the evaporator 25 after this refrigerant absorbs heat from discharged refrigerant of the compressor 21 in the four-way valve 28 is detected as the evaporator outlet temperature T_{eo} . According to this, the evaporator outlet temperature T_{eo} becomes higher than temperature of refrigerant of the outlet of the evaporator 25. That is, dryness fraction of the refrigerant of the outlet of the evaporator 25 becomes closer to a value less than 1.0 as compared with the refrigerant which absorbs heat from the discharged refrigerant of the compressor 21 in the four-way valve 28. Hence, a temperature difference in which dryness fraction becomes equal to a desired value should be set to ΔT_t while taking a relation between temperature of refrigerant of the outlet of the evaporator 25 and the evaporator outlet temperature T_{eo} into consideration.

[0049] The control device 4 sets the opening degree of the bypass expansion valve 31 to a predetermined set opening degree S_b which is determined by saturated temperature (condensation temperature) T_c calculated based on condensation pressure P_c detected by the pressure sensor 51 and evaporation temperature T_e detected by the first temperature sensor 61. This set opening degree S_b is set such that as the evaporation temperature T_e is lower and as the condensation temperature T_c is higher, the heat exchange ratio Q_{sc}/Q_c becomes greater.

[0050] Generally, when the evaporation temperature

T_e in the evaporator 25 is decreased by a decrease in outside air temperature, or when the condensation temperature T_c in the radiator 22 rises by an increase in water temperature, if a supercooling degree in the supercooling heat exchanger 23 is not varied, dryness fraction of refrigerant which flows into the evaporator 25 becomes greater. Hence, among refrigerant which flows into the evaporator 25, an amount of refrigerant gas component which does not contribute to evaporation is increased. Therefore, heat absorption ability of the evaporator 25 is deteriorated.

[0051] In such a case, as shown in Fig. 7, it is preferable that the control device 4 controls the main expansion valve 24 and the bypass expansion valve 31 such that as the evaporation temperature T_e is lower and as the condensation temperature T_c is higher, the heat exchange ratio Q_{sc}/Q_c is increased.

[0052] According to this, it is possible to increase the supercooling degree of refrigerant in the outlet of the supercooling heat exchanger 23 of the refrigerant circuit 2, and to lower the enthalpy of refrigerant which flows into the evaporator 25. Hence, as compared with a case where the heat exchange ratio Q_{sc}/Q_c is small, it is possible to increase the enthalpy difference of refrigerant in the evaporator 25 and to enhance the heat absorption ability.

[0053] As a result, when outside air temperature decreases or water temperature increases, it is possible to complement a reduced amount of a heat absorption amount of refrigerant in the evaporator 25 caused by increase in enthalpy of refrigerant which flows into the evaporator 25. At this time, since the heat-transfer area of the supercooling heat exchanger 23 is appropriately set, the heat exchange ratio Q_{sc}/Q_c becomes 0.1 or more and 0.6 or less.

[0054] Next, control of the control device 4 performed at the time of normal operation will be described in detail with reference to a flowchart shown in Fig. 8.

[0055] First, the control device 4 detects the evaporation temperature T_e by the first temperature sensor 61 and the evaporator outlet temperature T_{eo} by the second temperature sensor 62 (step S1). Then, the control device 4 calculates the temperature difference ΔT_e by $T_{eo} - T_e$ (step S2). Then, the control device 4 adjusts an opening degree of the main expansion valve 24 so that the temperature difference ΔT_e becomes equal to a target temperature difference ΔT_t which is set such that refrigerant dryness fraction of the outlet of the evaporator 25 becomes an appropriate value (step S3).

[0056] Next, the control device 4 detects condensation pressure P_c by the pressure sensor 51 (step S4), and calculates saturated temperature (condensation temperature) T_c under pressure of refrigerant which flows into the radiator 22 from the detected condensation pressure P_c (step S5). This calculation of the condensation temperature T_c is carried out using a refrigerant physicality equation.

[0057] Thereafter, the control device 4 determines a

set opening degree S_b (step S6) corresponding to the current evaporation temperature T_e and the condensation temperature T_c from a setting opening degree table in which an opening degree of the bypass expansion valve 31 determined by a predetermined evaporation temperature T_e and the condensation temperature T_c is recorded, and the control device 4 adjusts the opening degree of the bypass expansion valve 31 to the set opening degree S_b (step S7).

[0058] That is, when an evaporation temperature detecting means 61 detects evaporation temperature drop, the control device 4 controls the bypass expansion valve 31 such that a heat exchange ratio is increased. When a condensation temperature detecting means 51 detects condensation temperature drop, the control device 4 controls the bypass expansion valve 31 such that the heat exchange ratio is increased.

[0059] As described above, in this embodiment, the supercooling heat exchanger 23 is configured so that the heat exchange ratio which is a ratio of the heat exchange amount between refrigerant decompressed by the bypass expansion valve 31 and refrigerant which flows out from the radiator 22 with respect to the heat exchange amount between water and refrigerant in the radiator 22 becomes 0.1 or more and 0.6 or less, when the opening degrees of the main expansion valve 24 and the bypass expansion valve 31 in the supercooling heat exchanger 23 are adjusted such that dryness fraction of refrigerant which flows out from the evaporator 25 becomes 0.8 or more and less than 1.0.

[0060] According to this, the refrigerant dryness fraction at the outlet of the evaporator 25 becomes 0.8 or more and less than 1.0 at which the local evaporation heat-transfer coefficient in the horizontally placed refrigerant pipe becomes the maximum and therefore, the heat-transfer efficiency of the evaporator 25 is enhanced. Since the heat exchange ratio Q_{sc}/Q_c is set to 0.1 or more, the refrigerant supercooling degree at the outlet of the supercooling heat exchanger 23 is reliably increased, and an amount of gas phase refrigerant which flows into the evaporator 25 is reduced. Since the heat exchange ratio Q_{sc}/Q_c is set to 0.6 or less, refrigerant dryness fraction at the outlet of the bypass passage 3 is maintained at a low level.

[0061] Therefore, a pressure loss in the low pressure-side pipe is reduced, and the discharge temperature of the compressor 21 is appropriately maintained in a state where the evaporator 25 is efficiently used. Hence, it is possible to realize energy saving and low global warming potential while avoiding performance deterioration of the refrigeration cycle and deterioration in reliability of the compressor.

[0062] In this embodiment, the control device 4 controls the main expansion valve 24 such that dryness fraction of refrigerant which flows out from the evaporator 25 at the time of normal operation becomes 0.8 or more and less than 1.0. Therefore, even if loads on the evaporation side and on the condensation side are varied, refrigerant

dryness fraction at the outlet of the evaporator 25 becomes an appropriate value in accordance with the loads. Hence, reliability and energy saving of the refrigeration cycle are always enhanced.

[0063] Further, in this embodiment, the bypass expansion valve 31 is controlled such that as the evaporation temperature T_e in the evaporator 25 becomes lower, and as the condensation temperature T_c in the radiator 22 becomes higher, the heat exchange ratio Q_{sc}/Q_c becomes greater.

[0064] According to this, increase in the refrigerant enthalpy at the inlet of the evaporator 25 caused by decrease in the evaporation temperature T_e and by increase in the condensation temperature T_c is suppressed, gas phase refrigerant at the inlet of the evaporator 25 reliably bypasses through the bypass passage and therefore, a pressure loss on the low pressure side is reduced.

[0065] Therefore, even under the conditions that the outside air temperature is low and the to-be heated fluid temperature is high, efficient operation can be maintained.

[0066] Although the pressure sensor 51 is provided between the four-way valve 28 and the radiator 22 in the refrigerant circuit 2 in Fig. 1, the pressure sensor 51 may be provided at any position of the refrigerant circuit 2 only if the pressure sensor 51 is located between a discharging portion of the compressor 21 and an inlet of the main expansion valve 24. That is, it is only necessary that a pressure loss from the radiator 22 to the pressure sensor 51 is complemented.

[0067] Instead of providing the pressure sensor 51, it is possible to employ such a configuration that a temperature sensor is placed in the radiator 22 at a location where condensation refrigerant is brought into a two-phase state, and temperature detected by the temperature sensor is used as condensation temperature T_c . That is, condensation temperature detecting means may be configured by appropriately placing the pressure sensor and the temperature sensor.

[0068] Instead of providing the first temperature sensor 61, it is possible to employ such a configuration that a pressure sensor is placed between an outlet of the main expansion valve 24 and a suction portion of the compressor 21, saturated temperature is calculated based on pressure detected by the pressure sensor, and the calculated saturated temperature may be used as the evaporation temperature T_e . That is, it is only necessary that the evaporation temperature detecting means is configured by appropriately placing the pressure sensor and the temperature sensor.

[0069] It is not absolutely necessary that the bypass passage 3 branches off from the refrigerant circuit 2 at a location between the supercooling heat exchanger 23 and the main expansion valve 24, and the bypass passage 3 may branch off from the refrigerant circuit 2 at a location between the radiator 22 and the supercooling heat exchanger 23. In addition to the configuration that

the bypass passage 3 is connected to the pipe between the evaporator 25 and the compressor 21, the bypass passage 3 may be connected directly to a compression chamber of the compressor 21.

[0070] It is not absolutely necessary that the main expansion means and the bypass expansion means of the present invention are expansion valves, and they may be expanding machines which collect power from expanding refrigerant. In this case, the number of rotations of the expanding machine may be controlled by varying a load by a generators connected to the expanding machine.

[0071] It is not absolutely necessary that the to-be heated fluid which is heated by the radiator 22 is water, and the to-be heated fluid may be air. That is, the present invention can be applied also to an air conditioner.

[INDUSTRIAL APPLICABILITY]

[0072] The present invention is especially effective for a hot water generator which heats water by a refrigeration cycle apparatus and which utilizes the heated water for air heating.

[EXPLANATION OF SYMBOLS]

[0073]

1A	refrigeration cycle apparatus	
2	refrigerant circuit	30
21	compressor	
22	radiator	
23	supercooling heat exchanger	
24	main expansion valve (main expansion means)	
25	evaporator	35
3	bypass passage	
31	bypass expansion valve (bypass expansion means)	
4	control device	
51	pressure sensor (condensation temperature detecting means)	40
61	first temperature sensor (evaporation temperature detecting means)	
62	second temperature sensor	45

Claims

1. A refrigeration cycle apparatus comprising: a refrigerant circuit configured by annularly connecting a compressor, a radiator, a supercooling heat exchanger, a main expansion means and an evaporator to one another through refrigerant pipes; a bypass passage which branches off from the refrigerant circuit at a location between the radiator and the main expansion means and extends through the supercooling heat exchanger to be connected to a compression chamber of the compressor or to the

refrigerant circuit between the evaporator and the compressor;

a bypass expansion means connected to an upstream side of the supercooling heat exchanger in the bypass passage; and

a control device, wherein

R32 is used as refrigerant which circulates through the refrigerant circuit, and

the supercooling heat exchanger is configured so that a heat exchange ratio Q_{sc}/Q_c which is a ratio of a heat exchange amount Q_{sc} between the refrigerant which is decompressed by the bypass expansion means and the refrigerant which flows out from the radiator in the supercooling heat exchanger with respect to a heat exchange amount Q_c between to-be heated fluid and the refrigerant in the radiator becomes equal to 0.1 or more and equal to 0.6 or less, when opening degrees of the main expansion means and the bypass expansion means are adjusted by the control device such that dryness fraction of the refrigerant which flows out from the evaporator becomes equal to 0.8 or more and less than 1.0.

2. The refrigeration cycle apparatus according to claim 1, wherein the control device controls the main expansion means by a temperature difference between temperature of the refrigerant which flows into the evaporator and temperature of the refrigerant which flows out from the evaporator such that dryness fraction of the refrigerant which flows out from the evaporator becomes equal to 0.8 or more and less than 1.0.

3. The refrigeration cycle apparatus according to claim 2, further comprising an evaporation temperature detecting means which detects evaporation temperature of the refrigerant in the evaporator, wherein when the evaporation temperature detecting means detects a decrease in the evaporation temperature, the control device controls the bypass expansion means such that the heat exchange ratio becomes greater.

4. The refrigeration cycle apparatus according to claim 2 or 3, further comprising a condensation temperature detecting means which detects condensation temperature of the refrigerant in the radiator, wherein when the condensation temperature detecting means detects a decrease in the condensation temperature, the control device controls the bypass expansion means such that the heat exchange ratio becomes greater.

5. A hot water generator comprising the refrigeration cycle apparatus according to any one of claims 1 to 4, wherein the to-be heated fluid is water or antifreeze liquid, and the to-be heated fluid heated by the radiator is utilized

for supplying hot water or for air heating.

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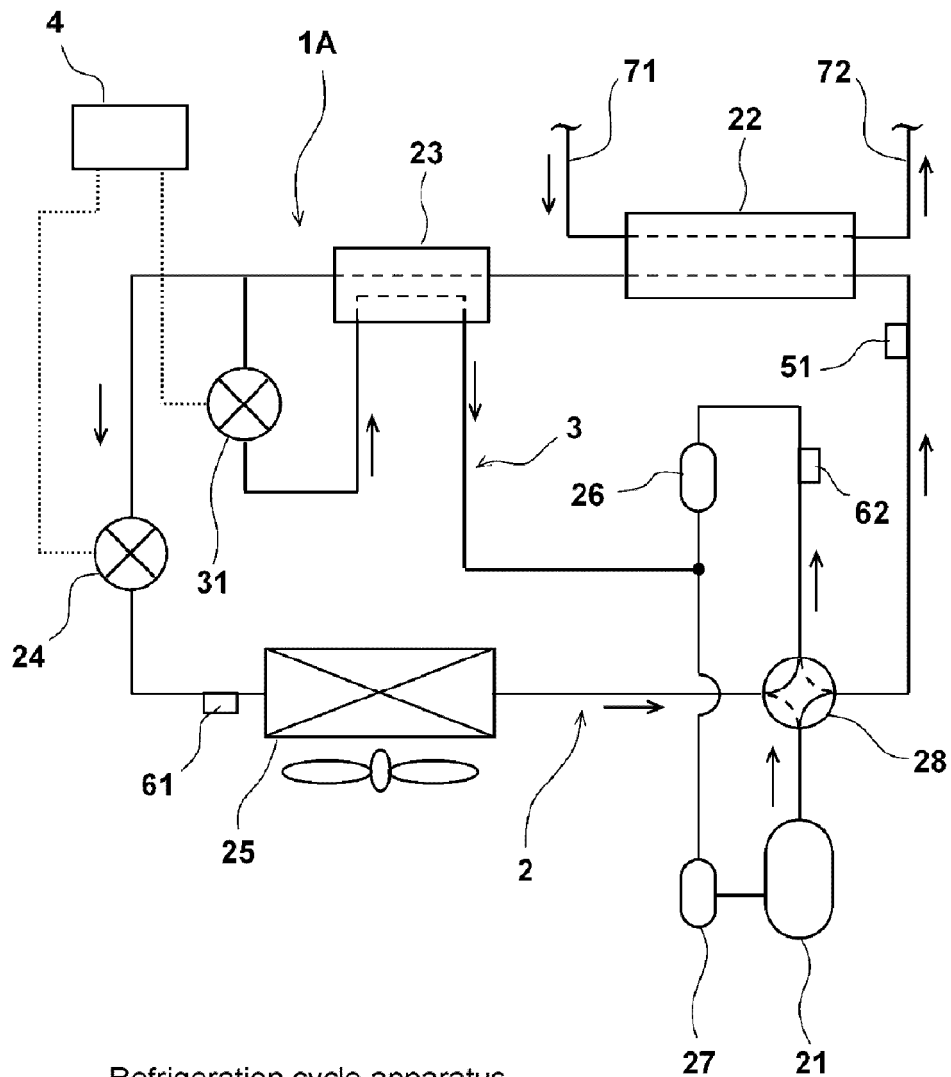
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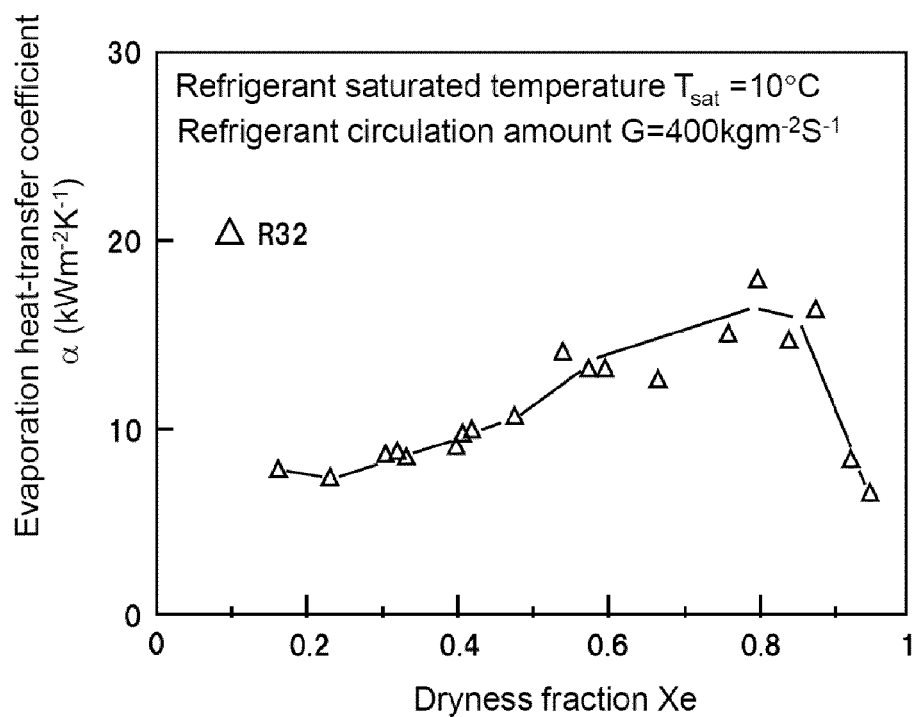
[Fig. 1]



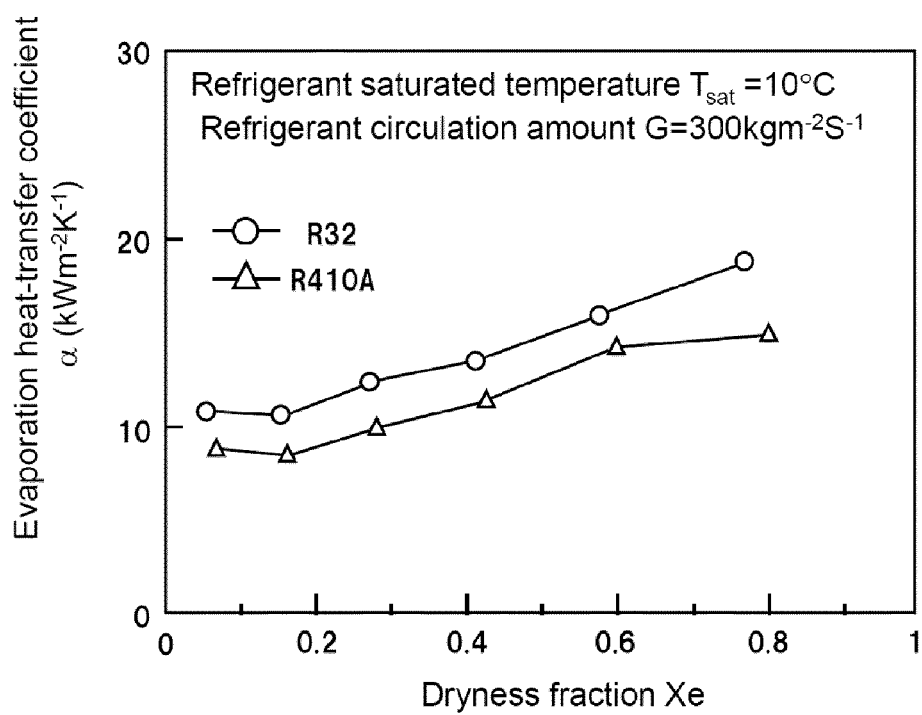
- 1A Refrigeration cycle apparatus
- 2 Refrigerant circuit
- 21 Compressor
- 22 Radiator
- 23 Supercooling heat exchanger
- 24 Main expansion valve (main expansion means)
- 25 Evaporator
- 3 Bypass passage
- 31 Bypass expansion valve (bypass expansion means)
- 4 Control device
- 51 Pressure sensor (condensation temperature detecting means)
- 61 First temperature sensor (evaporation temperature detecting means)
- 62 Second temperature sensor

[Fig. 2]

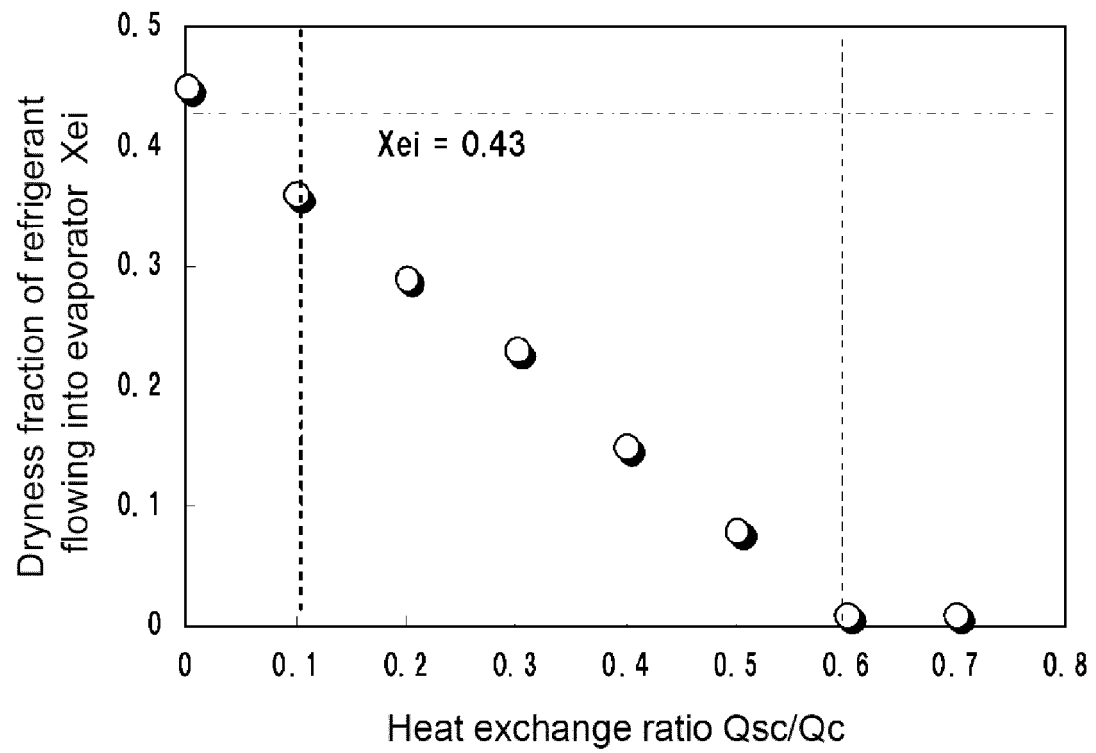
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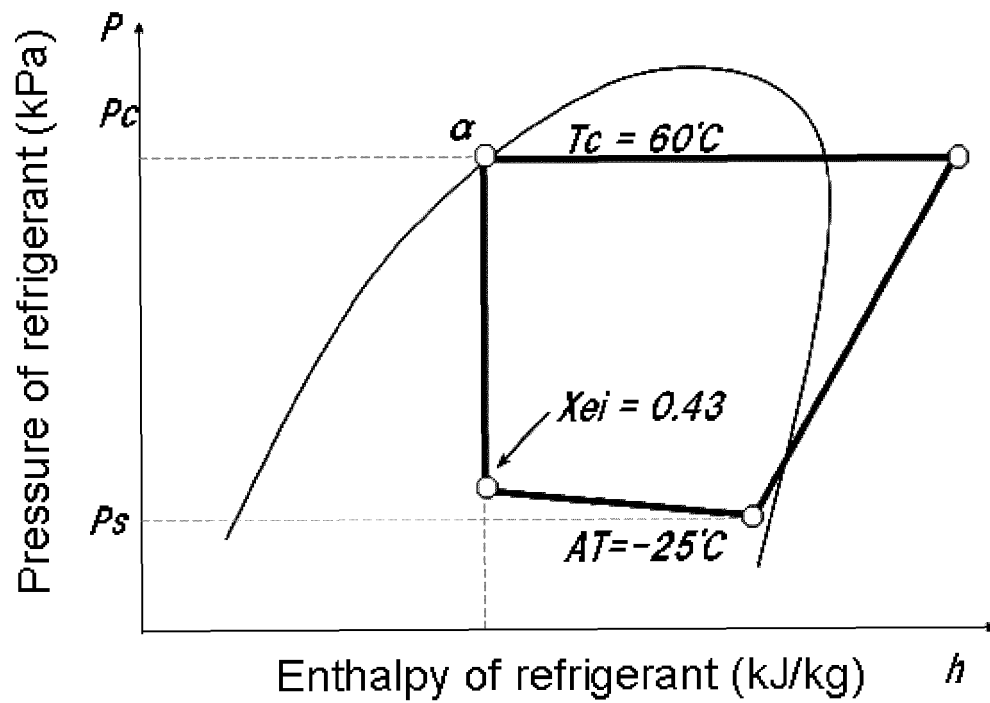


[Fig. 3]

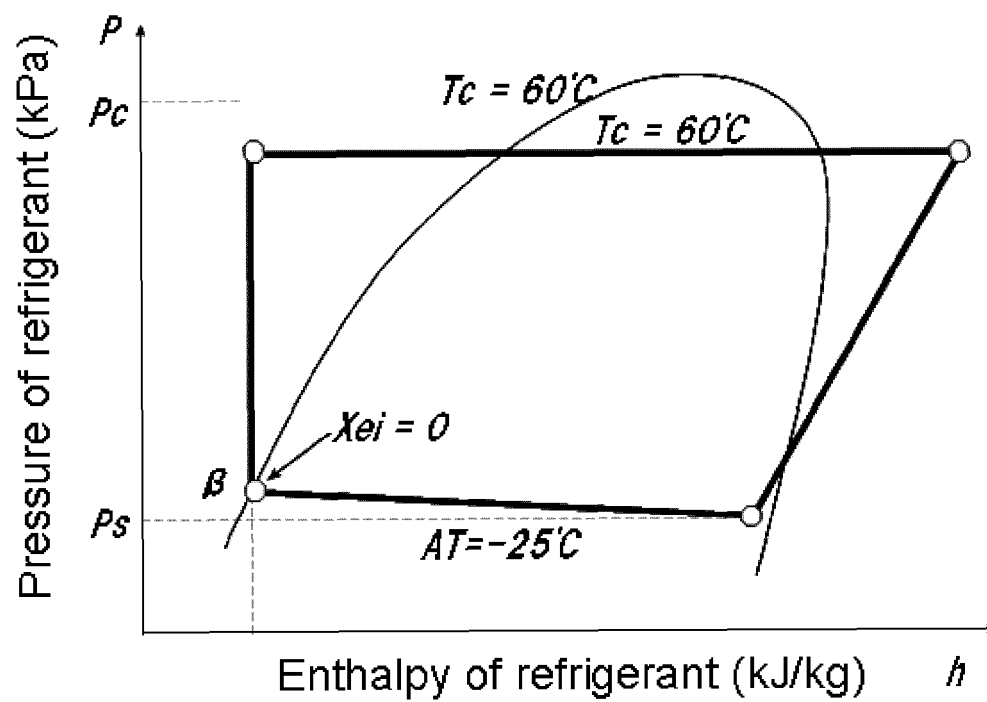


[Fig. 4]

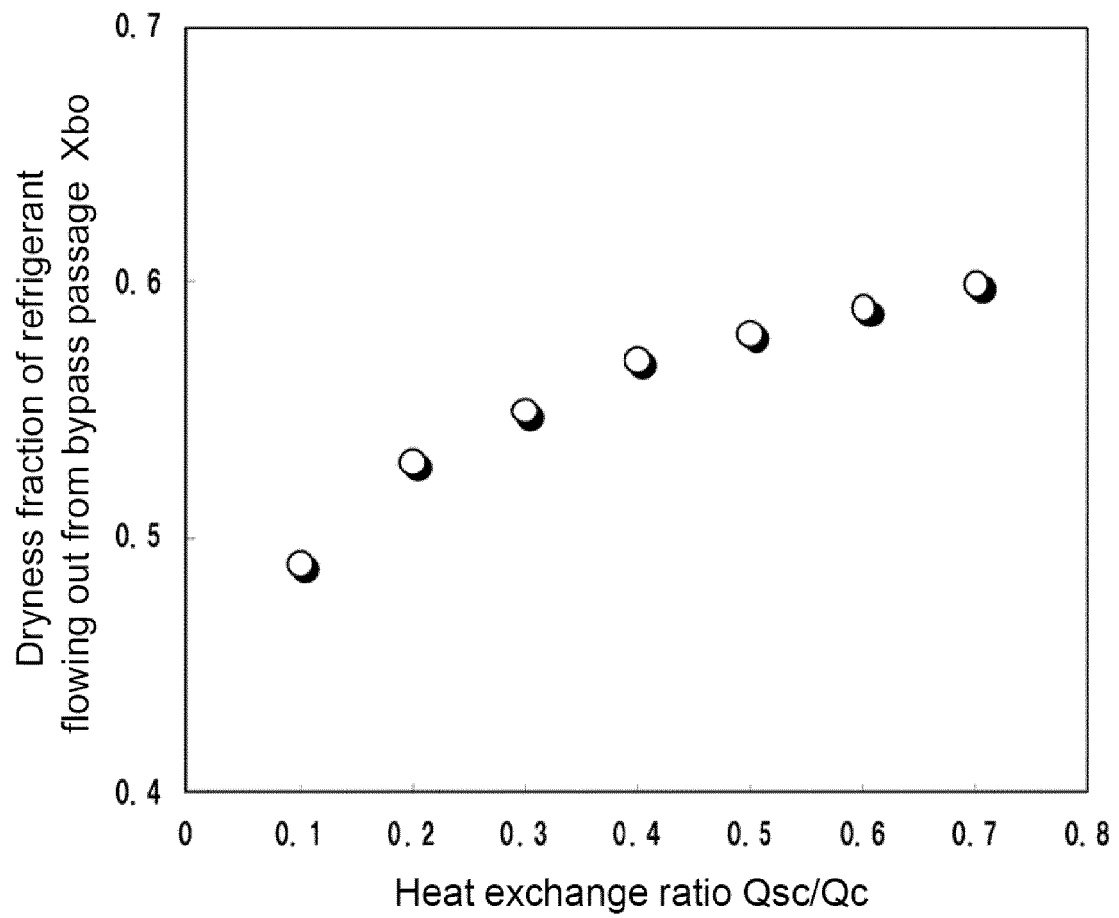
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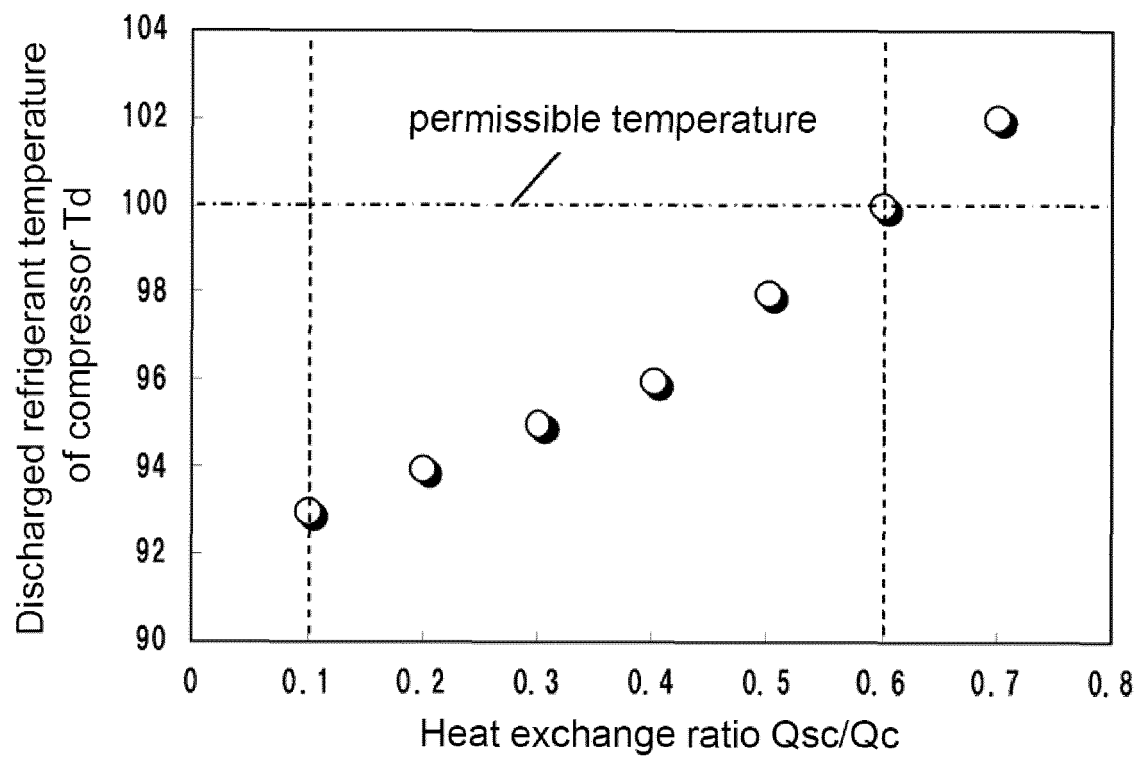
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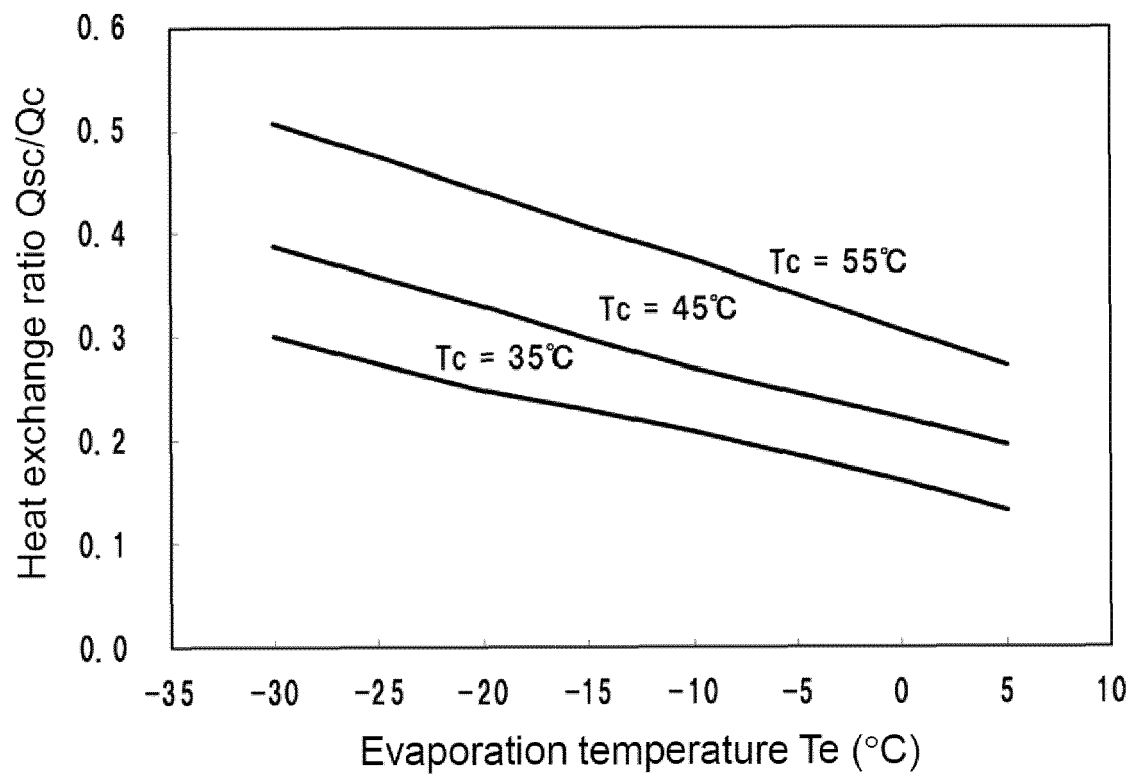
[Fig. 5]



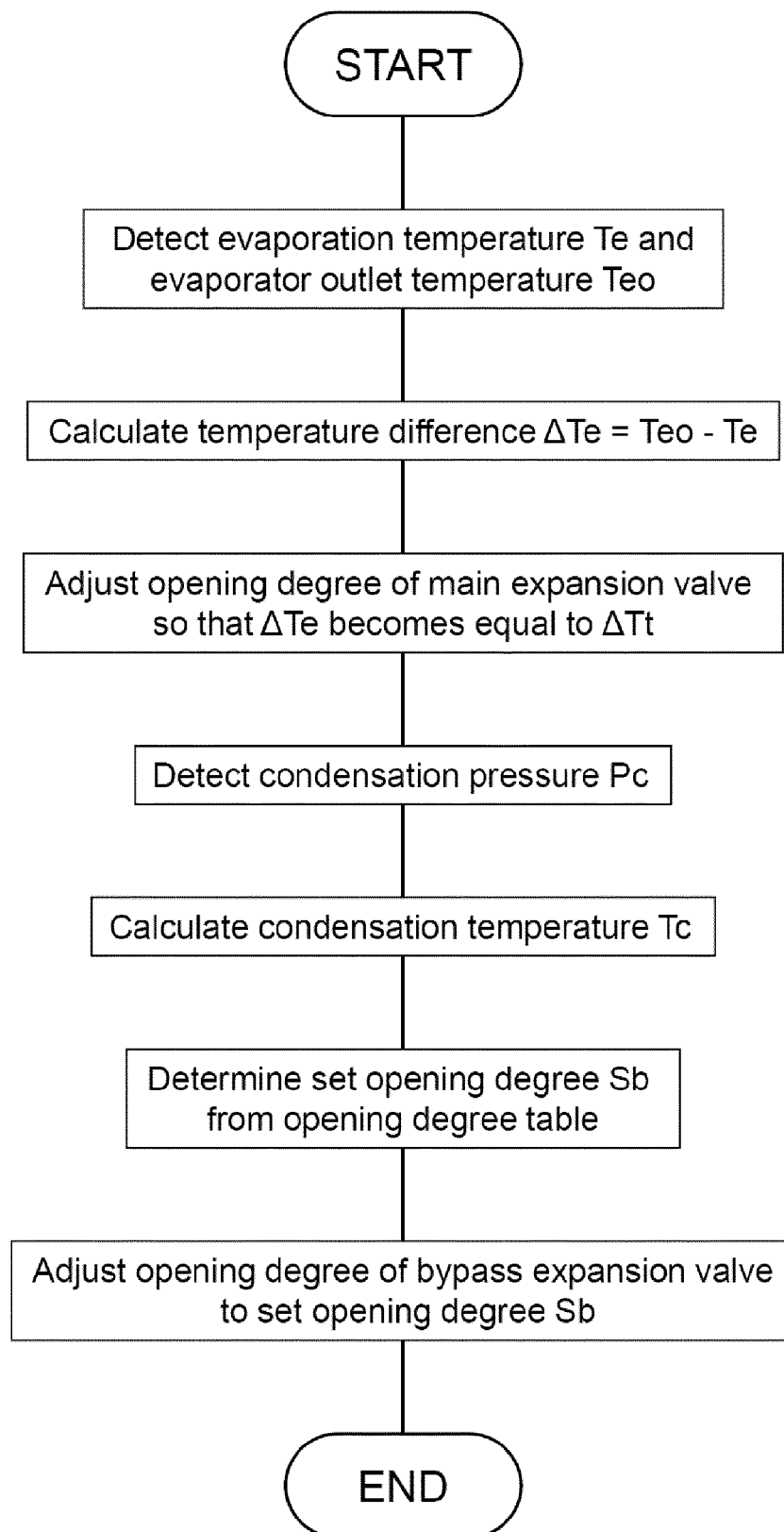
[Fig. 6]



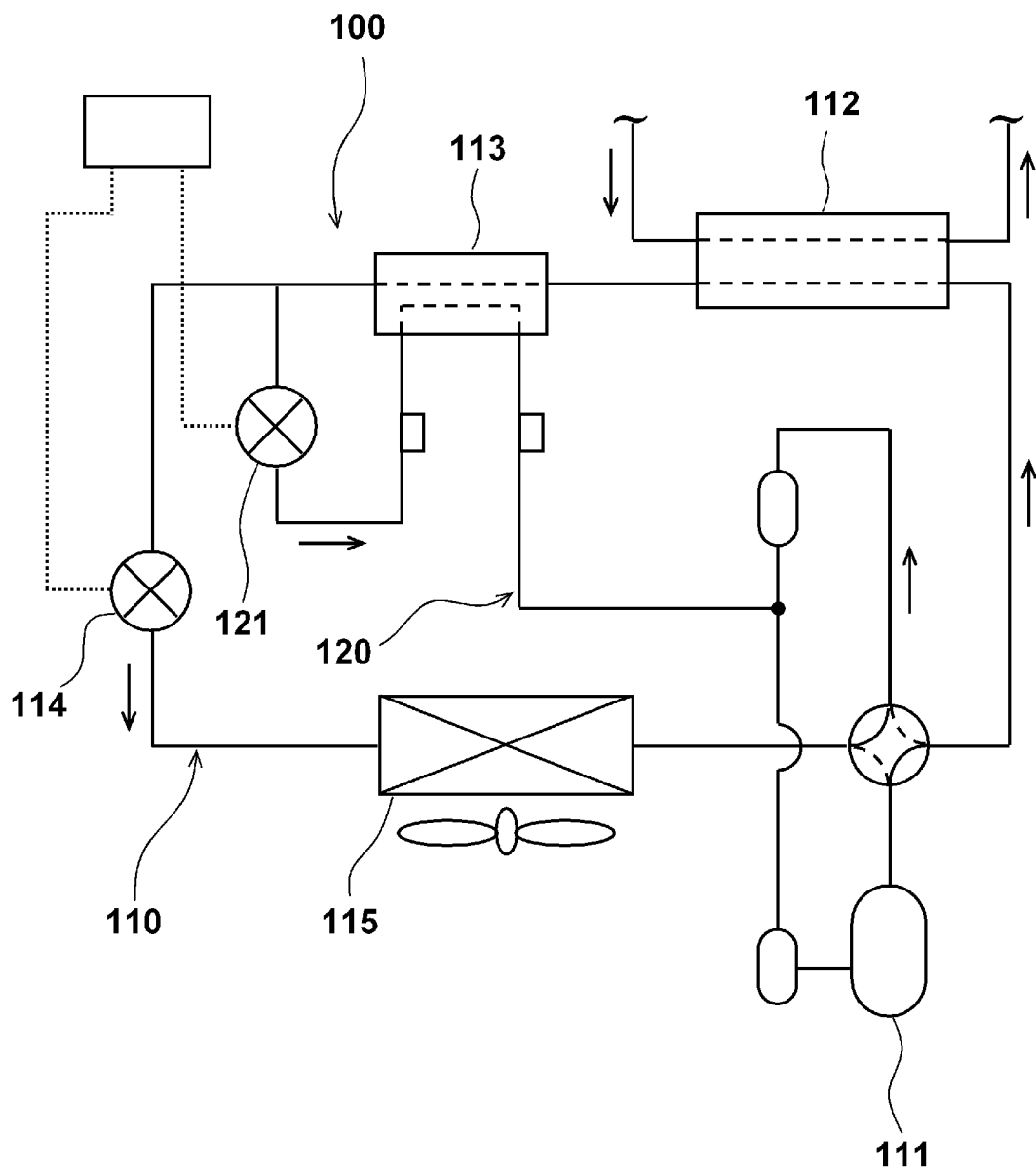
[Fig. 7]



[Fig. 8]



[Fig. 9]





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Application Number
EP 14 15 2911

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Place of search Munich		Date of completion of the search 25 March 2014	Examiner Ritter, Christoph
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