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forms either a first defrost operation or a second defrost operation based on a state of the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve during the heating operation. Thus, a heat pump water heater that performs defrost operation with improved durability of a compressor can be provided.

[illegible]

Description

BACKGROUND

1. Technical Field

[0001] The present disclosure relates to a heat pump water heater.

2. Description of the Related Art

[0002] For example, Chinese Examined Utility Model Application Publication No. 201547955 proposes a conventional heat pump water heater that includes a refrigerant circuit including a compressor for compressing a refrigerant, a four-way valve for diverting flow of the refrigerant, a radiator, a decompressor for decompressing the refrigerant, and an evaporator; a tank for storing water heated by the radiator; and a controller. In the conventional heat pump water heater noted above, the radiator is located on the periphery of the tank, and the refrigerant circuit is configured such that, when heating operation to heat water in the tank is performed, the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator and the four-way valve.

[0003] In the above prior art, the refrigerant circuit is often configured such that, when defrost operation to melt the frost on the evaporator is performed, the refrigerant flows in sequence through the compressor, the four-way valve, the evaporator, the decompressor, the radiator and the four-way valve. However, details of the technical specifications are not known.

[0004] Additionally, as the temperature of the tank for storing the hot water increases during the heating operation, the amount of heat dissipation from the radiator is reduced. Thus, the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve contains more liquid refrigerant in a gas-liquid two-phase state.

[0005] When the defrost operation is performed in the gas-liquid two-phase state where more liquid refrigerant is present, the pressures of a high-pressure refrigerant and a low-pressure refrigerant are equalized by switching the four-way valve, so that the liquid refrigerant may be sucked into the compressor. This results in the possibility that the durability of the compressor may be reduced.

SUMMARY

[0006] The present disclosure, which solves the problems in the prior art described above, is directed to a heat pump water heater that performs defrost operation with improved durability of a compressor.

[0007] In order to solve the problems in the prior art described above, a heat pump water heater according to the present disclosure includes a refrigerant circuit in-

cluding a compressor for compressing a refrigerant, a four-way valve for diverting flow of the refrigerant, a radiator, a decompressor for decompressing the refrigerant, and an evaporator; a tank for storing water heated by the radiator; and a controller. The radiator is located on a periphery of the tank. When heating operation to heat the water in the tank is performed, the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator, and the four-way valve. When defrost operation to melt frost on the evaporator is performed, the controller selects and performs either a first defrost operation where the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the evaporator, the decompressor, the radiator and the four-way valve or a second defrost operation where the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator and the four-way valve.

[0008] Thus, either the first defrost operation or second defrost operation is selected based on the state of the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve during the heating operation. Accordingly, the heat pump water heater that performs defrost operation with improved durability of the compressor can be provided.

[0009] The present disclosure can provide a heat pump water heater that performs defrost operation with improved durability of a compressor.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

FIG. 1 is a schematic diagram of a heat pump water heater according to a first exemplary embodiment of the present disclosure;

FIG. 2 is a control flow diagram for switching defrost operation of the heat pump water heater;

FIG. 3 illustrates a refrigerant circuit during a first defrost operation of the heat pump water heater; and FIG. 4 illustrates a refrigerant circuit during a second defrost operation of the heat pump water heater.

DETAILED DESCRIPTION

[0011] A heat pump water heater according to a first aspect of the present disclosure includes a refrigerant circuit including a compressor for compressing a refrigerant, a four-way valve for diverting flow of the refrigerant, a radiator, a decompressor for decompressing the refrigerant, and an evaporator; a tank for storing water heated by the radiator; and a controller. The radiator is located on a periphery of the tank. When heating operation to heat the water in the tank is performed, the refrigerant

circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator, and the four-way valve. When defrost operation to melt frost on the evaporator is performed, the controller selects and performs either a first defrost operation where the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the evaporator, the decompressor, the radiator and the four-way valve or a second defrost operation where the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator and the four-way valve.

[0012] Thus, either the first defrost operation or second defrost operation is selected based on the state of the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve during the heating operation. Accordingly, the heat pump water heater that performs defrost operation with improved durability of the compressor can be provided.

[0013] In the first aspect of the present disclosure, a second aspect of the present disclosure further includes a tank temperature sensor for detecting a temperature of hot water in the tank, and the controller selects and performs the first defrost operation when the temperature of the tank is less than or equal to a predetermined value.

[0014] Thus, when the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve during the heating operation contains relatively less liquid refrigerant in a gas-liquid two-phase state, that is, the temperature of the tank is not relatively increased, a high-temperature refrigerant discharged from the compressor flows directly into the evaporator through the four-way valve during the defrost operation. As such, suction of the liquid refrigerant into the compressor can be prevented and the high-temperature refrigerant discharged from the compressor can flow into the evaporator without heat dissipation, so that frost can be removed. Accordingly, the heat pump water heater can be provided that performs defrost operation with improved durability of the compressor.

[0015] In the first aspect of the present disclosure, a third aspect of the present disclosure further includes a tank temperature sensor for detecting a temperature of hot water in the tank, and the controller selects and performs the second defrost operation when the temperature of the tank is greater than a predetermined value.

[0016] Suction of the liquid refrigerant into the compressor can be prevented even when the defrost operation is performed in a state where the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve during the heating operation contains more liquid refrigerant in a gas-liquid two-phase state, that is, where the tempera-

ture of the tank is increased. Thus, the heat pump water heater can be provided that performs defrost operation with improved durability of the compressor.

[0017] In the second or third aspect of the present disclosure, a fourth aspect of the present disclosure further includes an ambient temperature sensor for detecting an ambient temperature. The predetermined value to select whether the controller performs the first defrost operation or the second defrost operation is less at low ambient temperature than at high ambient temperature.

[0018] Thus, when ambient temperature is low, that is, when the refrigerant in the refrigerant circuit from the outlet of the radiator to the suction side of the compressor through the decompressor, the evaporator and the four-way valve during the heating operation contains more liquid refrigerant, the temperature of the tank to determine whether the first defrost operation or the second defrost operation is performed is reduced, so that the suction of the liquid refrigerant into the compressor can be further prevented even when the defrost operation is performed. Accordingly, the heat pump water heater that performs defrost operation with improved durability of the compressor can be provided.

[0019] In the second or third aspect of the present disclosure, a fifth aspect of the present disclosure further includes an ambient temperature sensor for detecting an ambient temperature. An operating frequency of the compressor is greater at low ambient temperature than at high ambient temperature.

[0020] Thus, the circulating volume of the refrigerant discharged from the compressor can be increased when the ambient temperature is low. This accelerates the defrosting effect and reduces the defrost operation time.

[0021] Exemplary embodiments according to the present disclosure will now be described with reference to the drawings. These exemplary embodiments do not limit the scope of the present disclosure.

(First exemplary embodiment)

[0022] FIG. 1 is a schematic diagram of a heat pump water heater according to the present exemplary embodiment. As illustrated in FIG. 1, a heat pump water heater includes water storage tank unit 80 and heat pump apparatus 90.

[0023] Water storage tank unit 80 incorporates tank 3 for storing water. A water supply pipe (not shown), into which water is delivered through a water supply pipe or the like, is connected to the lower portion of tank 3.

[0024] A hot water supply pipe (not shown) for supplying hot water in tank 3 is connected to the upper portion of tank 3.

[0025] As the hot water in tank 3 is supplied for use and decreases, water is automatically supplied to tank 3 through the water supply pipe.

[0026] Tank 3 is provided with a first temperature sensor (i.e., tank temperature sensor 7) for detecting the temperature of the hot water in tank 3 (i.e., hot water

storage temperature). In the present exemplary embodiment, tank temperature sensor 7 is configured to have a plurality of sensors arranged vertically of tank 3.

[0027] A refrigerant pipe, which is radiator 4 for heating water in tank 3, is wound around the periphery of tank 3.

[0028] Heat exchange is performed between a high-temperature refrigerant discharged from compressor 1 and the water in tank 3, and thus hot water at high temperature is produced. It is configured such that the high-temperature refrigerant flows around the periphery of tank 3 from bottom to top during heating operation described below.

[0029] Heat pump apparatus 90 includes a refrigerant circuit where compressor 1 for compressing a refrigerant, four-way valve 2, an expansion device being decompressor 5 for decompressing the refrigerant, and evaporator 6 for evaporating the refrigerant are annularly connected by refrigerant piping.

[0030] Decompressor 5 may be an electromagnetic expansion valve capable of controlling the degree of opening or a capillary tube.

[0031] Evaporator 6 is an air heat exchanger for heat exchange between air blown by a blower fan (not shown) installed near evaporator 6 and the refrigerant. The refrigerant circulating through the refrigerant circuit includes a Freon (registered trademark) refrigerant, such as R410A, R134a, R22, R32, etc., and other refrigerants. The heat pump apparatus is located outdoors.

[0032] Heat pump apparatus 90 incorporates a second temperature sensor (i.e., ambient temperature sensor 9), located near evaporator 6, for detecting an ambient temperature. Heat pump apparatus 90 also incorporates a third temperature sensor (i.e., evaporator temperature sensor 8) for detecting the temperature of evaporator 6 or of refrigerant piping in the vicinity of and connected to evaporator 6.

[0033] Temperature output signals detected by the temperature sensors are transmitted to controller 10. Controller 10 performs a number of operations. The operations include heating operation for heating the water in tank 3 using radiator 4. The operations also include defrost operation in which, when the evaporator 6 frosts, the frost is melted and removed.

[0034] Controller 10 runs and stops the operations based on operating means (not shown) and the temperatures detected by the temperature sensors. Controller 10 also controls the motions and operations of compressor 1 and decompressor 5 based on the temperatures detected by the temperature sensors.

[0035] The operating means (not shown) has a function for a user to indicate run and stop of the heating operation and a function to set a temperature (setting temperature) of hot water to be stored in tank 3.

[0036] The controller controls heat pump apparatus 90 so that the temperature of the water in tank 3 heated by radiator 4 reaches a setting temperature during the heating operation.

[0037] The heating operation of the heat pump water

heater according to the present exemplary embodiment is described below. In heat pump apparatus 90, the refrigerant flows in the direction of the arrows shown in FIG. 1.

[0038] In heat pump apparatus 90, a high temperature and high pressure refrigerant compressed by and discharged from compressor 1 flows through four-way valve 2, flows into radiator 4, flows around the periphery of tank 3 from bottom to top, and heats the water in tank 3. Thus, hot water at high temperature is produced.

[0039] The refrigerant flowing out from radiator 4 is decompressed by decompressor 5, transitions to a low temperature and low pressure state, and flows into evaporator 6. The refrigerant flowing into evaporator 6 absorbs heat from the air blown by the blower fan (not shown) and evaporates. Then, the refrigerant flows into compressor 1 and is compressed again. Such a process is repeated and the refrigerant circulates through the refrigerant circuit.

[0040] Controller 10 controls heat pump apparatus 90 so that the temperature of the refrigerant discharged from compressor 1 is at a predetermined temperature.

[0041] The heating operation starts when controller 10 detects that the temperature of tank temperature sensor 7 falls below a predetermined temperature (i.e., heating start temperature). The heating operation can be stopped when it is detected that the temperature of tank temperature sensor 7 reaches or exceeds a predetermined temperature (i.e., heating stop temperature).

[0042] In this case, preferably, the heating operation starts when the temperature of tank temperature sensor 7 located relatively upward falls below the heating start temperature, and the heating operation is stopped when the temperature of tank temperature sensor 7 located relatively downward reaches or exceeds the heating stop temperature.

[0043] The defrost operation of the heat pump water heater according to the present exemplary embodiment is then described below.

[0044] FIG. 2 is a control flow diagram for switching the defrost operation. FIG. 3 illustrates a refrigerant circuit during a first defrost operation, and FIG. 4 illustrates a refrigerant circuit during a second defrost operation. In heat pump apparatus 90, the refrigerant flows in the direction of the arrows shown in FIGS. 3 and 4.

[0045] If the heating operation is performed under the operating condition at a low ambient temperature, moisture around evaporator 6 through which a low temperature and low pressure refrigerant flows is cooled, and the surface of evaporator 6 may be frosted. When controller 10 determines the frosting condition on evaporator 6 based on the fact that the temperature of evaporator temperature sensor 8 is less than or equal to a predetermined temperature, the defrost operation is performed for melting and removing the frost.

[0046] In FIG. 2, the controller determines, during the heating operation, whether the defrost operation is possible or not (step S1). If the defrost operation is not need-

ed ("NO" at step S1), the heating operation is continued. If controller 10 determines that the defrost operation is needed ("YES" at step S1), controller 10 starts the defrost operation.

[0047] When the defrost operation is started, the temperature of hot water in tank 3 is first detected by tank temperature sensor 7. Thus, when the defrost operation is started, controller 10 determines, based on a reading of tank temperature sensor 7, whether the refrigerant in the refrigerant circuit from radiator 4 to evaporator 6 contains more liquid refrigerant in a gas-liquid two-phase state (step S2). If the reading of tank temperature sensor 7 is less than or equal to a predetermined value ("YES" at step S2), controller 10 performs the first defrost operation. If the reading of tank temperature sensor 7 is greater than the predetermined value ("NO" at step S2), controller 10 performs the second defrost operation. After the defrost operation is completed, the heating operation is employed.

[0048] Controller 10 changes the predetermined value described above to a lower value when the ambient temperature detected by ambient temperature sensor 9 is low rather than high, so that the suction of the liquid refrigerant into the compressor can be prevented even at a low ambient temperature at which more liquid refrigerant is present.

[0049] For the first defrost operation, the refrigerant circuit is configured such that the refrigerant flows in sequence through compressor 1, four-way valve 2, evaporator 6, decompressor 5, radiator 4 and four-way valve 2, as illustrated in FIG. 3. This allows a high-temperature refrigerant discharged from the compressor to flow into the evaporator without heat dissipation, and thus frost can be removed.

[0050] For the second defrost operation, the refrigerant circuit is configured such that the refrigerant flows in sequence through compressor 1, four-way valve 2, radiator 4, decompressor 5, evaporator 6 and four-way valve 2, as illustrated in FIG. 4.

[0051] In the first and second defrost operations, controller 10 increases the operating frequency of compressor 1 when the ambient temperature detected by ambient temperature sensor 9 is low rather than high, so that the circulating volume of the refrigerant discharged from compressor 1 is increased when the ambient temperature is low. This accelerates the defrosting effect and reduces the defrost operation time.

[0052] If evaporator 6 is determined to be frosted based on the temperature of evaporator temperature sensor 8, controller 10 transmits a signal to perform the defrost operation and the second defrost operation is started. Thereafter, decompressor 5 is adjusted so that a low temperature and low pressure refrigerant is changed to a high temperature and high pressure refrigerant while maintaining the refrigerant circuit comprised in sequence of compressor 1, four-way valve 2, radiator 4, decompressor 5, evaporator 6, and four-way valve 2.

[0053] This allows the refrigerant flowing into evaporator 6 during the heating operation to flow into evaporator 6 at a high temperature, and thus frost can be removed.

When making the adjustment using decompressor 5, it is preferable to increase the degree of opening as much as possible.

[0054] As the water in tank 3 is heated during the heating operation and the water temperature rises, a state of the refrigerant varies from a state of the gas-liquid two-phase flow to a state where more liquid refrigerant is present in the refrigerant circuit incorporating radiator 4, decompressor 5, and evaporator 6.

[0055] When the first defrost operation is performed in the state where more liquid refrigerant is present, the high pressure refrigerant flows into the low pressure refrigerant and the pressure is equalized, and thus the liquid refrigerant is sucked into compressor 1.

[0056] Due to the above phenomenon, liquid lock is more likely to occur when compressor 1 operates, and there is a possibility that compressor 1 may be stopped or the durability of compressor 1 may be reduced.

[0057] Here, when the refrigerant transitions from the state of the gas-liquid two-phase flow to the state where more liquid refrigerant is present, the liquid refrigerant can be prevented from being sucked into compressor 1 by performing the second defrost operation.

[0058] In this manner, the first defrost operation or the second defrost operation is selected based on the state of the refrigerant in the refrigerant circuit from the outlet of radiator 4 to the suction side of compressor 1 through decompressor 5, evaporator 6 and four-way valve 2 during the heating operation, that is, on the temperature of hot water in the tank, so that the heat pump water heater that performs defrost operation with improved durability of the compressor can be provided.

[0059] As described above, a heat pump water heater according to the present disclosure, which performs defrost operation with improved durability of a compressor, is useful not only for a residential heat pump water heater, but also for a commercial heat pump water heater or the like.

Claims

1. A heat pump water heater comprising:

a refrigerant circuit including a compressor for compressing a refrigerant, a four-way valve for diverting flow of the refrigerant, a radiator, a decompressor for decompressing the refrigerant, and an evaporator;
a tank for storing water heated by the radiator; and
a controller,
wherein the radiator is located on a periphery of the tank;
wherein when heating operation to heat the water in the tank is performed, the refrigerant circuit

is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator and the four-way valve; and
 wherein when defrost operation to melt frost on the evaporator is performed, the controller selects and performs either a first defrost operation where the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the evaporator, the decompressor, the radiator and the four-way valve or a second defrost operation where the refrigerant circuit is configured such that the refrigerant flows in sequence through the compressor, the four-way valve, the radiator, the decompressor, the evaporator and the four-way valve.

2. The heat pump water heater according to claim 1, further comprising a tank temperature sensor for detecting a temperature of hot water in the tank, wherein the controller selects and performs the first defrost operation when the temperature of the tank is less than or equal to a predetermined value.
3. The heat pump water heater according to claim 1, further comprising a tank temperature sensor for detecting a temperature of hot water in the tank, wherein the controller selects and performs the second defrost operation when the temperature of the tank is greater than a predetermined value.
4. The heat pump water heater according to claim 2 or 3, further comprising an ambient temperature sensor for detecting an ambient temperature, wherein the predetermined value to select whether the controller performs the first defrost operation or the second defrost operation is less at a low ambient temperature than at a high ambient temperature.
5. The heat pump water heater according to claim 2 or 3, further comprising an ambient temperature sensor for detecting an ambient temperature, wherein an operating frequency of the compressor is greater at a low ambient temperature than at a high ambient temperature.

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FIG. 1

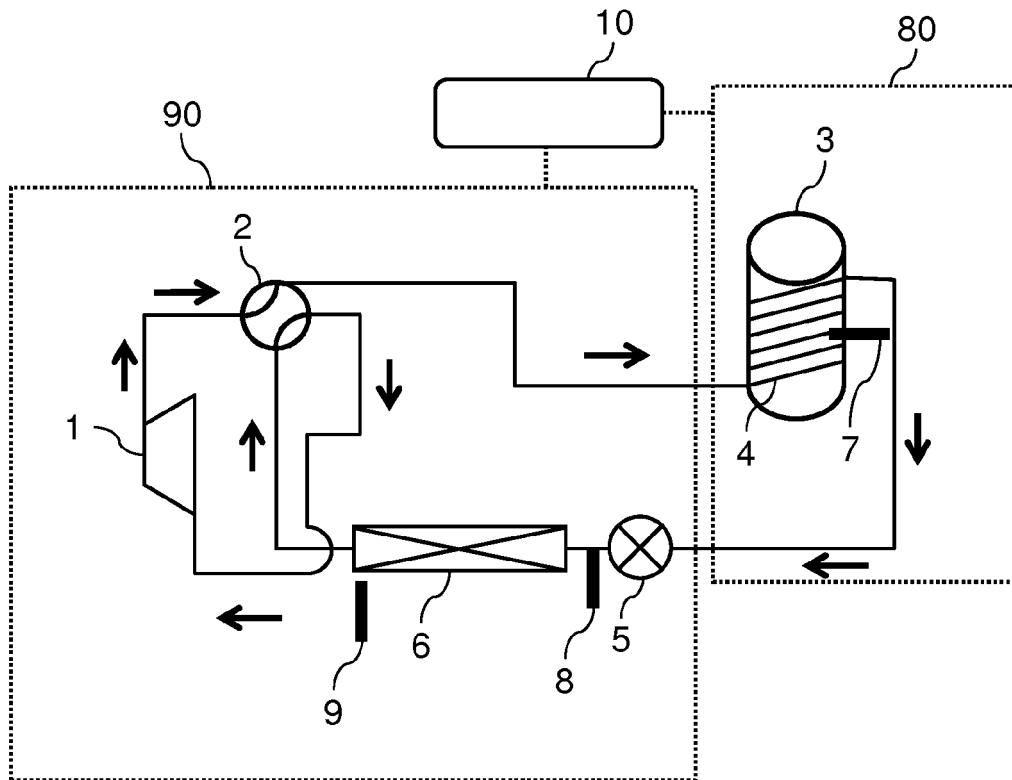


FIG. 2

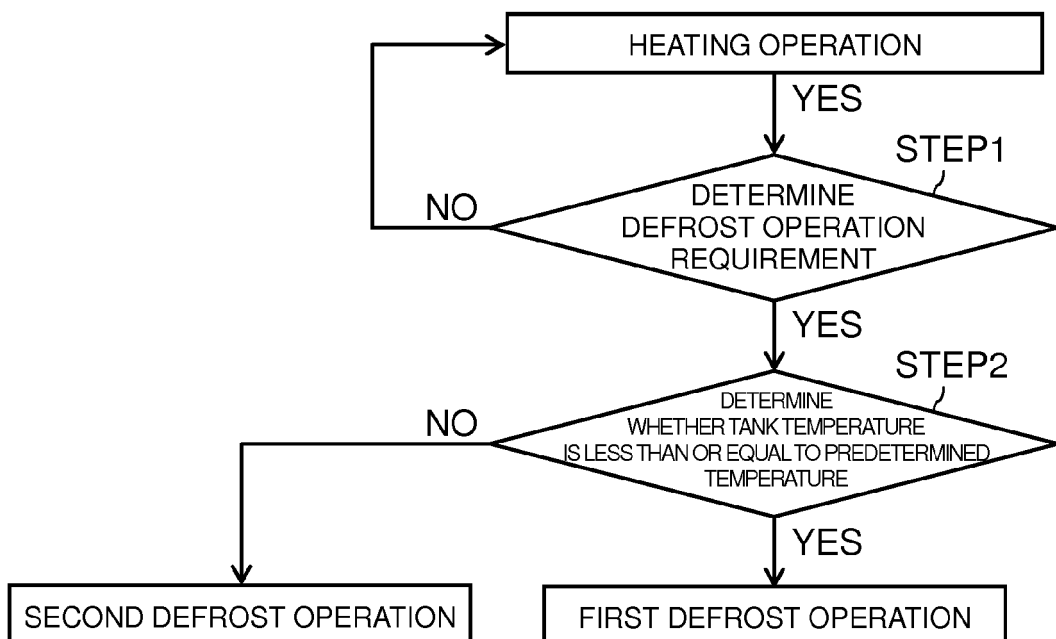


FIG. 3

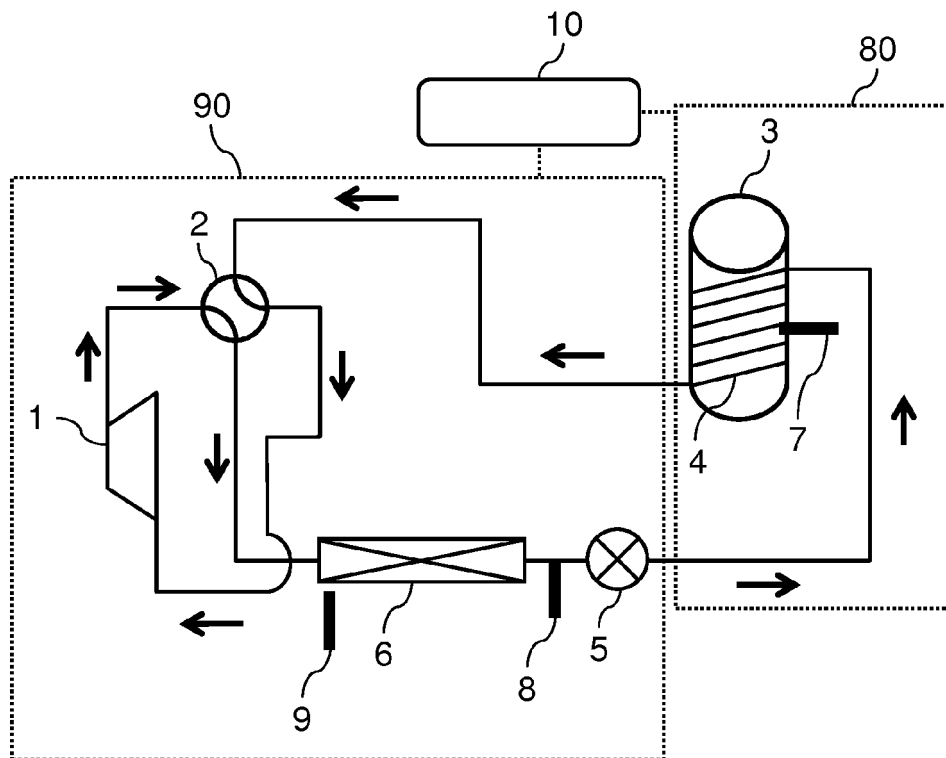
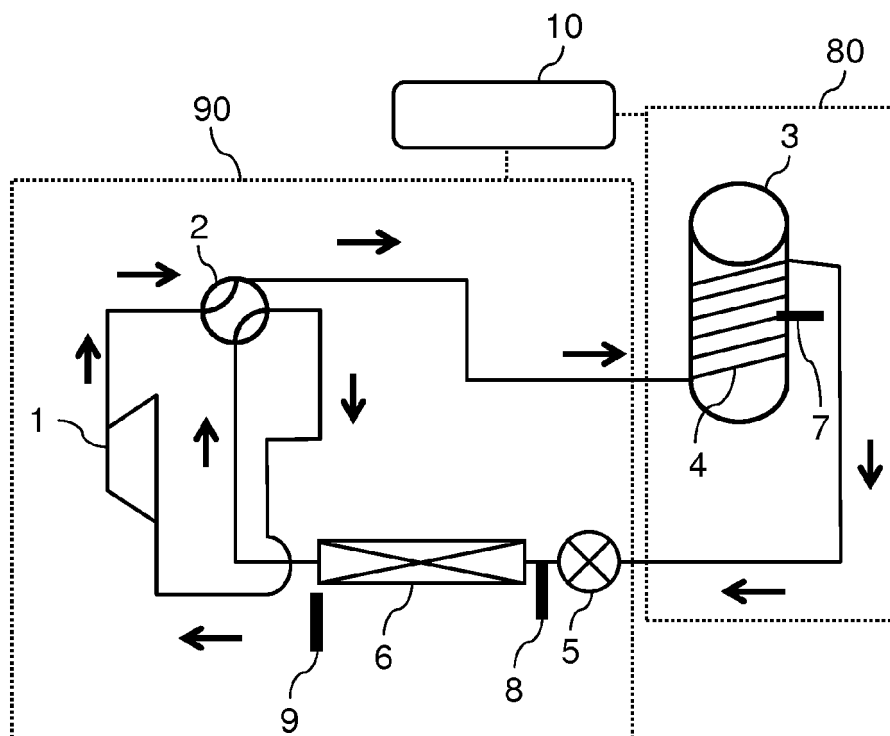


FIG. 4





EUROPEAN SEARCH REPORT

Application Number
EP 17 15 1058

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 26 July 2017	Examiner Ritter, Christoph
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 15 1058

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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