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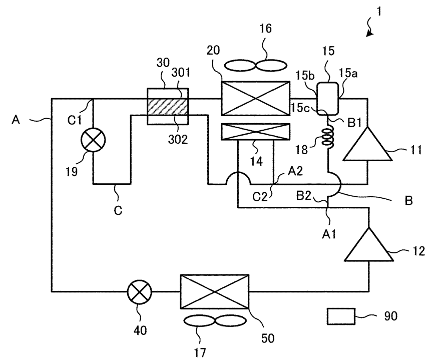
# (54) REFRIGERATION CYCLE DEVICE

(57) A refrigeration cycle apparatus includes: a main circuit in which a low-stage compressor, an oil cooler, a high-stage compressor, an oil separator, a condenser, a first expansion valve, and an evaporator are sequentially connected by refrigerant pipes, and refrigerant flows through the low-stage compressor, the oil cooler, the high-stage compressor, the oil separator, the condenser, the first expansion valve, and the evaporator in this order; and an oil return circuit having one end that is connected to the oil separator and another end that is connected to a first junction between a discharge side of the low-stage compressor and an inlet side of the oil cooler. The oil return circuit causes oil separated by the oil separator to return to the main circuit.

FIG. 1



## Description

### Technical Field

**[0001]** The present disclosure relates to a refrigeration cycle apparatus that includes an oil cooler.

### Background Art

**[0002]** In a refrigeration cycle apparatus, oil is contained in a compressor which is sealed, in order to lubricate the compressor. Since oil is discharged along with refrigerant from the compressor, in a given adopted technique, in an oil separator, the oil is separated from the refrigerant discharged from the compressor, and is then returned to the compressor. However, since the refrigerant discharged from the compressor has a high temperature, if oil having a high temperature is returned to the compressor as it is, the temperature of refrigerant which is discharged from the compressor is raised, thus deteriorating the performance of the compressor.
**[0003]** In view of the above, Patent Literature 1, for example, proposes a technique in which oil separated from refrigerant is cooled by an air-cooled heat exchanger which is referred to as an "oil cooler", and is then returned to a compressor. With the configuration disclosed in Patent Literature 1, oil is cooled in advance before flowing into the compressor, and the temperature of refrigerant sucked by the compressor is prevented from excessively rising.

### Citation List

#### Patent Literature

**[0004]** Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2007-93182

### Summary of Invention

#### Technical Problem

**[0005]** In the case where a flat tube is used in an oil cooler as a pipe through which oil is caused to flow, in the configuration disclosed in Patent Literature 1, the viscosity of oil separated from refrigerant is increased when the oil is cooled by the oil cooler, and as a result, the flat tube may be clogged with the oil. In addition, from the viewpoint of lubrication, it is preferable that oil have a high viscosity. Accordingly, it is not preferable that the viscosity of oil be decreased even if it is intended to prevent occurrence of clogging with oil.
**[0006]** The present disclosure is applied to solve the above problem, and relates to a refrigeration cycle apparatus in which an oil cooler is not clogged with oil.

#### Solution to Problem

**[0007]** A refrigeration cycle apparatus according to an embodiment of the present disclosure includes: a main circuit in which a low-stage compressor, an oil cooler, a high-stage compressor, an oil separator, a condenser, a first expansion valve, and an evaporator are sequentially connected by refrigerant pipes, and refrigerant flows through the low-stage compressor, the oil cooler, the high-stage compressor, the oil separator, the condenser, the first expansion valve, and the evaporator in this order; and an oil return circuit having one end that is connected to the oil separator and another end that is connected to a first junction between a discharge side of the low-stage compressor and an inlet side of the oil cooler, the oil return circuit being configured to cause oil separated by the oil separator to return to the main circuit.

#### Advantageous Effects of Invention

**[0008]** In the refrigeration cycle apparatus according to the embodiment of the present disclosure, oil separated by the oil separator is returned to the main circuit at a location upstream of the oil cooler, thus increasing the flow rate of fluid that flows into the oil cooler. Accordingly, a fluid shearing force that is generated in oil that stays in the oil cooler is increased, and clogging of the oil cooler with the oil is eliminated.

### Brief Description of Drawings

**[0009]**

[Fig. 1] Fig. 1 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus according to the embodiment.
[Fig. 2] Fig. 2 is a perspective view illustrating an example of the configuration of a heat inter changer (HIC) provided in the refrigeration cycle apparatus according to the embodiment.
[Fig. 3] Fig. 3 is a perspective view of an oil cooler and a condenser of the refrigeration cycle apparatus according to the embodiment.
[Fig. 4] Fig. 4 is a front view of the oil cooler and the condenser of the refrigeration cycle apparatus according to the embodiment.
[Fig. 5] Fig. 5 is a schematic sectional view of the oil cooler and the condenser of the refrigeration cycle apparatus according to the embodiment.
[Fig. 6] Fig. 6 is a schematic sectional view of a flat tube of the refrigeration cycle apparatus according to the embodiment.
[Fig. 7] Fig. 7 is a refrigerant circuit diagram illustrating a configuration of a refrigeration cycle apparatus of a comparative example.

Description of the embodiments

**[0010]** A refrigeration cycle apparatus according to an embodiment will be described with reference to drawings. In each of figures that will be referred to below, the relative relationships in size between components, the shapes of the components, etc., may be different from those of actual components. In each of the figures, components that are the same as or equivalent to those in a previous figure or previous figures are denoted by the same reference signs. The same is true of the entire text of the specification. Furthermore, alphabets attached as suffixes to numerals in reference signs in the figures may be omitted in the description. In order that the embodiment be easily understood, for example, the terms "up", "down", "right", "left", "front" and "rear" are use as appropriate. However, these terms indicating directions are used as a matter of convenience for explanation, and do not limit the location and direction of a device or devices or a component or components.

**[0011]** Fig. 1 is a refrigerant circuit diagram illustrating a configuration of a refrigeration cycle apparatus 1 according to an embodiment. As illustrated in Fig. 1, the refrigeration cycle apparatus 1 according to the embodiment includes a main circuit A, an oil return circuit B, and an injection circuit C.

Configuration of Main Circuit A

**[0012]** In the main circuit A, a low-stage compressor 12, an oil cooler 14, a high-stage compressor 11, an oil separator 15, a condenser 20, a heat inter changer (HIC) 30, an expansion valve 40, and an evaporator 50 are sequentially connected by refrigerant pipes. In the main circuit A, refrigerant flows in the low-stage compressor 12, the oil cooler 14, the high-stage compressor 11, the oil separator 15, the condenser 20, the heat inter changer (HIC) 30, the expansion valve 40, and the evaporator 50 in this order. The expansion valve 40 is an example of a first expansion valve. As the refrigerant, for example, $CO_2$ can be used. In the main circuit A, a first junction A1 is provided between a discharge side of the low-stage compressor 12 and an inlet side of the oil cooler 14. To the first junction A1, the oil return circuit B is connected. In addition, a second junction A2 is provided between an outlet side of the oil cooler 14 and a suction side of the high-stage compressor 11. To the second junction A2, the injection circuit C is connected.

**[0013]** The low-stage compressor 12 is configured to compress refrigerant sucked from a low-stage suction port to change the pressure of the refrigerant from a low pressure to an intermediate pressure, and then discharge the refrigerant as intermediate-pressure refrigerant from a low-stage discharge port. The low-stage compressor 12 is, for example, an inverter compressor. In the case where the low-stage compressor 12 is an inverter compressor, the rotation speed of the low-stage compressor 12 may be arbitrarily changed by a drive circuit including, for example, an inverter circuit, thereby changing a refrigerant discharge capacity of the low-stage compressor 12 per unit time. In this case, the drive circuit is controlled by a control unit 90.

**[0014]** The high-stage compressor 11 is configured to compress the intermediate-pressure refrigerant sucked from a high-stage suction port to change it into high-pressure refrigerant having a pressure higher than the intermediate pressure, and discharge the high-pressure refrigerant from a high-stage discharge port. The refrigerant discharged from the high-stage discharge port flows into the oil separator 15. The high-stage compressor 11 is, for example, an inverter compressor. In the case where the high-stage compressor 11 is an inverter compressor, the rotation speed of the high-stage compressor 11 may be arbitrarily changed by a drive circuit including, for example, an inverter circuit, thereby changing the refrigerant discharge capacity of the high-stage compressor 11 per time unit. In this case, the drive circuit is controlled by the control unit 90.

**[0015]** The oil cooler 14 is connected between a low-stage discharge port of the low-stage compressor 12 and a high-stage suction port of the high-stage compressor 11. The oil cooler 14 is a heat exchanger provided to cool oil which is separated from the discharged high-temperature refrigerant in the oil separator 15.

**[0016]** In each of the low-stage compressor 12 and the high-stage compressor 11, an electric element and a compression element are housed in a sealed container not illustrated, for example. The electric element serves as a drive unit, and the compression element is driven by a rotary shaft of the electric element. Oil for use in lubrication of sliding portions of the compression element is contained in the compression element sealed, and is supplied to the sliding portions of the compression element to maintain the lubricity of the compression element and the airtightness of the low-stage compressor 12 and the high-stage compressor 11. In order to improve the lubricity of the compression element, preferably, the oil should have predetermined viscosity. The oil may have miscibility with refrigerant; however, in the case where the viscosity of the oil is lowered because the refrigerant dissolves in the oil, oil that has immiscibility with the refrigerant, that is, does not dissolve in the refrigerant, should be used. Particularly, in the case where $CO_2$ that has a high pressure and easily dissolve in the oil is used as refrigerant, preferably, an immiscible oil should be used.

**[0017]** The low-stage compressor 12 and the high-stage compressor 11 may have the same configuration or may have different configurations. The low-stage compressor 12 and the high-stage compressor 11 may be provided as separate bodies, and the low-stage discharge port of the low-stage compressor 12 and the high-stage suction port of the high-stage compressor 11 may be connected with each other by pipes, with the oil cooler 14 interposed between the low-stage compressor 12 and the high-stage compressor 11. Each of the low-stage compressor 12 and the high-stage compressor 11 may be, for example, a reciprocating compressor, a scroll compressor, a rotary compressor, a screw compressor, or a centrifugal compressor.

**[0018]** The oil separator 15 is connected downstream of the high-stage compressor 11. The oil separator 15 is provided to separate oil contained in a refrigerant gas discharged from the high-stage compressor 11, to thereby return the oil to the high-stage compressor 11, and to reduce the amount of oil that circulates in the main circuit A. The oil separator 15 has an oil separator inlet 15a. Through the oil separator inlet 15a, refrigerant and oil that flow out from the high-stage discharge port of the high-stage compressor 11 flow into the oil separator 15. The oil separator 15 also has a refrigerant outlet 15b and an oil outlet 15c. From the refrigerant outlet 15b, remaining refrigerant from which oil is separated flows out; and from the oil outlet 15c, separated oil flows out. The refrigerant outlet 15b is located at a position higher than the oil outlet 15c in the direction of gravity. The refrigerant outlet 15b is connected to the condenser 20 by the refrigerant pipe.

**[0019]** The condenser 20 is a heat exchanger that causes heat exchange to be performed between air and refrigerant that flows in the condenser 20. High-temperature and high-pressure gas refrigerant obtained through compression by the high-stage compressor 11 and discharged from the high-stage compressor 11 flows into the condenser 20 via the oil separator 15, is changed into high-pressure liquid refrigerant in the condenser 20, and the high-pressure liquid refrigerant then flows out from the condenser 20. The condenser 20 is, for example, an air-cooled heat exchanger. The condenser 20 is, for example, a fin-and-tube heat exchanger or a plate-fin heat exchanger.

**[0020]** It is preferable that the refrigeration cycle apparatus 1 include a first fan 16 that sends air to the condenser 20. When air is sent to the condenser 20 by the first fan 16, heat exchange between the refrigerant and the air is promoted. As the first fan 16, for example, an axial fan, such as a propeller fan, a centrifugal fan, such as a sirocco fan or a turbo fan, a diagonal flow fan, or a cross flow fan can be used.

**[0021]** The heat inter changer (HIC) 30 is provided downstream of the condenser 20. The heat inter changer (HIC) 30 is connected to the condenser 20 by the refrigerant pipe which extends from the outlet of the condenser 20. The heat inter changer (HIC) 30 includes a first flow passage 301 and a second flow passage 302. In the first flow passage 301, refrigerant which flows in the main circuit A flows; and in the second flow passage 302, refrigerant which flows in the injection circuit C flows. The first flow passage 301 is provided downstream of the condenser 20 and upstream of a location at which the injection circuit C is connected to the main circuit A. The heat inter changer (HIC) 30 causes heat exchange to be performed between refrigerant which flows through the first flow passage 301 and refrigerant which flows through the second flow passage 302. After refrigerant flows through the main circuit A and flows into the heat inter changer (HIC) 30 from the inlet of the first flow passage 301 of the heat inter changer (HIC) 30, the refrigerant passes through the first flow passage 301, and then flows out from the heat inter changer (HIC) 30 through the outlet of the first flow passage 301. An outlet of the first flow passage 301 of the heat inter changer (HIC) 30 is connected to an inflow port of the expansion valve 40 by the refrigerant pipe. It should be noted that the refrigeration cycle apparatus 1 may be configured that the heat inter changer (HIC) 30 is not provided. In the case where the heat inter changer (HIC) 30 is not provided, the condenser 20 is directly connected to the expansion valve 40 by the refrigerant pipe.

**[0022]** The expansion valve 40 expands and decompresses high-pressure refrigerant which flows in the main circuit A to change it into low-pressure two-phase refrigerant. As the expansion valve 40, for example, a temperature type automatic expansion valve, a linear electronic expansion valve, or other valves can be used. In the case where the expansion valve 40 is an electronic expansion valve, the opening degree of the expansion valve 40 is adjusted by control performed by the control unit 90. An outflow port of the expansion valve 40 is connected to the evaporator 50 by the refrigerant pipe.

**[0023]** The evaporator 50 is a heat exchanger that causes the low-pressure two-phase refrigerant which flows into the evaporator 50 through the evaporator inlet to flow in the evaporator 50 and causes heat exchange to be performed between the refrigerant and air. The low-pressure two-phase refrigerant which is obtained through decompression by the expansion valve 40 flows into the evaporator 50 from the evaporator inlet, and is evaporated through heat exchange to change into low-temperature and low-pressure two-phase refrigerant, and the low-temperature and low-pressure two-phase refrigerant then flows out from an evaporation outlet of the evaporator 50. The evaporation outlet of the evaporator 50 is connected by the low-stage compressor 12 by the refrigerant pipe. It is preferable that the refrigeration cycle apparatus 1 include a second fan 17 that sends air to the evaporator 50. When air is sent to the evaporator 50 by the second fan 17, heat exchange between the refrigerant and the air is promoted. As the second fan 17, for example, an axial fan, such as a propeller fan, a centrifugal fan, such as a sirocco fan or a turbo fan, a diagonal flow fan, or a cross flow fan can be used. In this regard, the second fan 17 is the same as the first fan 16.

Configuration of Oil Return Circuit B

**[0024]** In the oil return circuit B, a first end portion B1 which is one end of the oil return circuit B is connected to the oil outlet 15c of the oil separator 15, and a second end portion B2 which is the other end of the oil return circuit B is connected to the first junction A1 which is located in the main circuit A and between the discharge side of the low-stage compressor 12 and the oil cooler 14. That is, the second end portion B2 is connected to the main circuit A at a location downstream of the low-stage compressor 12 and upstream of the oil cooler 14. A pressure reducing device 18 is connected between the first end portion B1 and the second end portion B2. In the oil return circuit B, oil separated from refrigerant by the oil separator 15 flows. The oil return circuit B is provided to return the oil separated by the oil separator 15 to the high-stage compressor 11. To the oil return circuit B, the pressure reducing device 18 is connected. The pressure reducing device 18 is, for example, a capillary tube. The pressure reducing device 18 is provided to reduce the pressure of the oil separated by the oil separator 15 and to adjust the amount of oil that joins refrigerant flowing in the main circuit A.

Configuration of Injection Circuit C

**[0025]** The injection circuit C causes refrigerant that flows in the heat inter changer (HIC) 30 to be branched such that part of the refrigerant flows in the injection circuit C. The injection circuit C causes intermediate-pressure refrigerant that flows between the heat inter changer (HIC) 30 and an INJ expansion valve 19 to flow into the high-stage compressor 11, thereby reducing a rise in a discharge temperature of the high-stage compressor 11. The INJ expansion valve 19 is an example of a second expansion valve.

**[0026]** In the injection circuit C, a third end portion C1 which is one end of the injection circuit C is connected to the main circuit A at a location between the heat inter changer (HIC) 30 and the expansion valve 40, that is, at a location downstream of the heat inter changer (HIC) 30 and upstream of the expansion valve 40. Also, in the injection circuit C, a fourth end portion C2 which is the other end of the injection circuit C is connected to the second junction which is located in the main circuit A and between the outlet side of the oil cooler 14 and the suction side of the high-stage compressor 11. That is, the fourth end portion C2 of the injection circuit C is connected to a downstream side relative to the oil cooler 14 and an upstream side relative to the high-stage compressor 11. Part of the injection circuit C forms the second flow passage 302 of the heat inter changer (HIC) 30. The INJ expansion valve 19 is connected between the third end portion C1 of the injection circuit C and the heat inter changer (HIC) 30, that is, connected to a downstream side relative to the third end portion C1 and an upstream side relative to the heat inter changer (HIC) 30.

**[0027]** The INJ expansion valve 19 expands and decompresses refrigerant into which the refrigerant from the main circuit A branches and which flows in the injection circuit C. As the INJ expansion valve 19, for example, a thermostatic expansion valve, a linear electronic expansion valve, or other valves can be used, as well as the expansion valve 40. An opening/closing operation of the INJ expansion valve 19 is controlled by the control unit 90 such that the temperature of refrigerant discharged from the high-stage compressor 11 reaches 100 degrees C or less.

**[0028]** In the case where the main circuit A does not include the heat inter changer (HIC) 30, it suffices that the third end portion C1 of the injection circuit C is connected to a downstream side relative to the condenser 20 and an upstream side relative to the expansion valve 40. In addition, in the case where the main circuit A does not include the heat inter changer (HIC) 30, no injection circuit C may be provided

Configuration of Heat Inter Changer (HIC) 30

**[0029]** As illustrated in Fig. 2, the heat inter changer (HIC) 30 is a double tube, for example. Fig. 2 is a perspective view illustrating an example of the configuration of the heat inter changer (HIC) 30 provided in the refrigeration cycle apparatus 1 according to the embodiment. In Fig. 2, as a matter convenience for explanation, part of the component which cannot be seen from the outside is indicated by broken lines. In the example illustrated in Fig. 2, the heat inter changer (HIC) 30 includes an outer pipe 31 and an inner pipe 32. The outer pipe 31 is located in an outer portion of the heat inter changer (HIC) 30, and the inner pipe 32 is located inward of the outer pipe 31. Refrigerant that flows out from the condenser 20 and that flows in the main circuit A flows through the outer pipe 31, and the outer pipe 31 forms the first flow passage 301. Refrigerant that flows in the injection circuit C flows through the inner pipe 32, and the inner pipe 32 forms the second flow passage 302. As indicated by arrows in Fig. 2, the flow direction of refrigerant flowing through the outer pipe 31 and the flow direction of refrigerant flowing through the inner pipe 32 are opposite to each other, and flow as counterflow. The heat inter changer (HIC) 30 is not limited to that of the example as illustrated in Fig. 2. For example, through the outer pipe 31, refrigerant that flows in the injection circuit C may flow, and through the inner pipe 32, refrigerant that flows out from the condenser 20 may flow.

**[0030]** In the heat inter changer (HIC) 30, refrigerant that flows through the injection circuit C cools refrigerant that flows out from the condenser 20, thus supercooling the refrigerant that flows out from the condenser 20. When the refrigerant that flows out from the condenser 20 is supercooled, the refrigerant is gasified. The gasified refrigerant flows in the injection circuit C and is then guided to the second junction A2 of the main circuit A. As described above, the second junction A2 is provided downstream of the oil cooler 14 and on the suction side of the high-stage compressor 11.

Configuration of Control Unit 90

**[0031]** The control unit 90 is a processing circuit. The processing circuit is dedicated hardware or a processor. The dedicated hardware is, for example, an application specific integrated circuit (ASIC) or a field programmable gate array (FPGA). The processor executes a program stored in a memory. A storage unit not illustrated is provided in the control unit 90, and is the memory. The memory is a nonvolatile or volatile semiconductor memory, such as a random access memory (RAM), a read only memory (ROM), a flash memory, or an erasable programmable ROM (EPROM), or a disk, such as a magnetic disk, a flexible disk, or an optical disk. A detection value from one of a pressure sensor and a temperature sensor not illustrated which are provided in the main circuit A and the injection circuit C is sent to the control unit 90.

Configuration of Oil Cooler 14

**[0032]** Fig. 3 is a perspective view of the oil cooler 14 and the condenser 20 of the refrigeration cycle apparatus 1 according to the embodiment. Outlined arrows in Fig. 3 indicate the flow of air from the first fan 16. Fig. 4 is a front view of the oil cooler 14 and the condenser 20 of the refrigeration cycle apparatus 1 according to the embodiment.

**[0033]** As illustrated in Figs. 3 and 4, the oil cooler 14 is provided below the condenser 20, and is formed integrally with the condenser 20. Alternatively, the oil cooler 14 is provided below the condenser 20 and close to the condenser 20. Since the oil cooler 14 is formed integrally with or provided close to the condenser 20, the condenser 20 and the oil cooler 14 are simultaneously cooled by air sent by a single fan, that is, the first fan 16. The condenser 20 is, for example, a fin-and-tube heat exchanger or a plate-fin heat exchanger that includes a plurality of heat transfer tubes 201 through which refrigerant flowing between a condenser inlet 20a and a condenser outlet 20b flows. It is not indispensable that the oil cooler 14 is formed integrally with or provided close to the condenser 20. In this case, it is preferable that for the oil cooler 14 and the condenser 20, respective fans be provided.

**[0034]** It suffices that the oil cooler 14 has a similar structure to that of a heat exchanger that is used as the condenser 20. As the oil cooler 14, a fin-and-tube heat exchanger or a plate-fin heat exchanger may be used. In this regard, the oil cooler 14 is the same as the condenser 20.

**[0035]** Specifically, the oil cooler 14 has an oil inflow port 14a and an oil outflow port 14b. The oil inflow port 14a is located close to the low-stage compressor 12 in the main circuit A and on an upstream side, and the oil outflow port 14b is located close to the high-stage compressor 11 in the main circuit A and on a downstream side. The oil inflow port 14a is located at a higher position than the oil outflow port 14b. Refrigerant that circulates in the main circuit A and oil that passes through the oil return circuit B join each other at the first junction A1 and flow into the oil cooler 14 through the oil inflow port 14a, and then flow out from the oil cooler 14 through the oil outflow port 14b. In this case, since the oil inflow port 14a is located at a higher position than the oil outflow port 14b, a difference is made between a hydraulic head at the oil inflow port 14a and the hydraulic head at the oil outflow port 14b, and the flow of oil toward the outlet is promoted. The oil inflow port 14a and the oil outflow port 14b are connected with each other by a plurality of flat tubes 141.

**[0036]** Fig. 5 is a schematic sectional view of the oil cooler 14 and the condenser 20 in the refrigeration cycle apparatus 1 according to the embodiment. As illustrated in Fig. 5, the plurality of flat tubes 141 of the oil cooler 14 are inserted in a plurality of cooling fins 142. The plurality of flat tubes 141 are flat tubes each having an elongated cross-section having a long axis and a short axis, and a plurality of flow passages 141a are formed in each of the plurality of flat tubes 141. The plurality of heat transfer tubes 201 of the condenser 20 may be inserted in a plurality of heat radiating fins 202 as in the oil cooler 14. The plurality of heat transfer tubes 201 of the condenser 20, as well as the plurality of flat tubes 141 of the oil cooler 14, may be flat tubes each having an elongated cross-section having a long axis and a short axis, and a plurality of flow passages 141a (see Fig. 6) may be formed in each of the plurality of heat transfer tubes 201.

**[0037]** The plurality of cooling fins 142 of the oil cooler 14 and the plurality of heat radiating fins 202 included in the condenser 20 are provided, with a gap G provided between the plurality of cooling fins 142 and the plurality of heat radiating fins 202. The gap G is 1 cm, for example. Also, in the case where the oil cooler 14 is formed integrally with the condenser 20, the plurality of cooling fins 142 are provided, with the gap provided between the plurality of cooling fins 142 and the plurality of heat radiating fins 202, and are not in contact with the plurality of heat radiating fins 202 included in the condenser 20. With such a configuration, it is possible to prevent heat transfer between the plurality of cooling fins 142 and the plurality of heat radiating fins 202.

**[0038]** Fig. 6 is a schematic sectional view of the flat tube 141 in the refrigeration cycle apparatus 1 according to the embodiment. As illustrated in Fig. 6, the plurality of flow passages 141a of the flat tube 141 each have a rectangular shape in cross section, and are formed in the flat tube 141 such that the plurality of flow passages 141a are arranged in a direction along the long axis of the flat tube 141. Each of the plurality of flow passages 141a of the flat tube 141 has a smaller flow-passage cross-sectional area than that of a common heat transfer tube. In such a manner, since the flat tube 141 has the flow passages 141a which are each formed to have a small cross-sectional area, the surface area of the flat tube 141 is increased. Thus, oil that flows into the oil cooler 14 and that flows together with refrigerant through the flat tube 141 is efficiently cooled. The common heat transfer tube has a circular cross-section having a diameter of 7.95 mm, for example, whereas each of the plurality of flow passages 141a has, for example, a quadrangle having 1 mm square in cross section.

Operation of Refrigeration Cycle Apparatus 1

**[0039]** After the refrigerant is compressed in the high-stage compressor 11 to change into high-temperature and high-pressure refrigerant, the high-temperature and high-pressure refrigerant is discharged from the high-stage discharge port, with oil in the high-stage compressor 11 dissolving in the high-temperature and high-pressure refrigerant. After being discharged from the high-stage compressor 11, the refrigerant in which the oil dissolves flows into the oil separator 15, and is separated from the oil in the oil separator 15.

**[0040]** The high-temperature and high-pressure refrigerant separated by the oil separator 15 flows out from the oil separator 15 through the refrigerant outlet 15b of the oil separator 15, and then flows into the condenser 20. In the condenser 20, the high-temperature and high-pressure refrigerant separated by the oil separator 15 exchanges heat with air around the condenser 20, and is thus cooled and condensed to change into low-temperature refrigerant, and the low-temperature refrigerant then flows out from the condenser 20. The refrigerant that flows out from the condenser 20 arrives at the heat inter changer (HIC) 30, and passes through the first flow passage 301 of the heat inter changer (HIC) 30. The refrigerant exchanges heat with refrigerant that flows through the second flow passage 302 of the heat inter changer (HIC) 30, is thus further cooled and reduced in temperature, and then flows out from the heat inter changer (HIC) 30. The refrigerant that flows out from the heat inter changer (HIC) 30 branches into refrigerant that flows into the injection circuit C and refrigerant that flows into the expansion valve 40.

**[0041]** After flowing into the injection circuit C, part of the refrigerant is expanded and compressed by the INJ expansion valve 19 of the injection circuit C. Thereafter, the refrigerant passes through the second flow passage 302 of the heat inter changer (HIC) 30 and exchanges heat with refrigerant passing through the first flow passage 301 of the heat inter changer (HIC) 30 to evaporate. After the refrigerant evaporates and is gasified in the heat inter changer (HIC) 30, the gasified refrigerant flows into the main circuit A at a location upstream of the high-stage suction port of the high-stage compressor 11.

**[0042]** After flowing into the expansion valve 40, remaining part of the refrigerant is compressed to change into low-pressure refrigerant, and the low-pressure refrigerant then flows out from the expansion valve 40. Then, in the evaporator 50, the refrigerant exchanges heat with air around the evaporator 50 to evaporate and change into low-temperature and low-pressure refrigerant. Thereafter, the low-temperature and low-pressure refrigerant is sucked by the low-stage compressor 12, and is compressed until the pressure of the refrigerant changes from a low pressure to an intermediate pressure. The refrigerant is discharged from the low-stage compressor 12 through the low-stage discharge port of the low-stage compressor 12, and then joins oil that passes through the oil return circuit B.

**[0043]** In contrast, oil separated from refrigerant by the oil separator 15 flows out from the oil separator 15 through the oil outlet 15c of the oil separator 15, passes through the oil return circuit B, and flows to a location between the low-stage discharge port of the low-stage compressor 12 of the main circuit A and the oil cooler 14. The oil that passes through the oil return circuit B joins the refrigerant discharged from the low-stage discharge port of the low-stage compressor 12 and flows into the oil cooler 14. In the oil cooler 14, the oil exchanges heat with air around the oil cooler 14, is thus cooled, and then flows out from the oil cooler 14. Thus, the oil that returns to the high-stage compressor 11 is cooled, thereby reducing a rise of the discharge temperature of the high-stage compressor 11. Furthermore, since the oil flows together with the refrigerant into the oil cooler 14, a fluid shearing force that acts on the oil is increased and the oil is pushed out without staying in the oil cooler 14.

Comparative Example

**[0044]** Fig. 7 is a refrigerant circuit diagram illustrating the configuration of a refrigeration cycle apparatus 100 of a comparative example. As illustrated in Fig. 7, the refrigeration cycle apparatus 100 of the comparative example includes a main circuit D, an oil return circuit E, and an injection circuit F provided to supply refrigerant to an injection compressor 10 of the main circuit D. The oil cooler 14 cools oil separated from refrigerant by the oil separator 15 of the main circuit D. The oil cooler 14 is not provided in the main circuit D, but is provided in the oil return circuit E in which oil separated from refrigerant by the oil separator 15 flows. The oil return circuit E is connected to a junction provided in the injection circuit F.

**[0045]** In the comparative example, when flowing into the oil return circuit E, oil separated by the oil separator 15 is cooled by the oil cooler 14. Thereafter, the oil joins refrigerant that flows in the injection circuit F, and then returns to the main circuit D. The oil separated by the oil separator 15 solely flows into the oil cooler 14 and tends to stay in the oil cooler 14 because of the viscosity of the oil. In the case where $CO_2$ is used as the refrigerant, oil having a high viscosity is used in order to ensure that the oil in the compressor has a sufficient viscosity, and the oil thus tends to stay in the oil cooler 14. Particularly, in the case where flat tubes are used in the oil cooler 14 to improve the cooling efficiency of the oil in the oil cooler 14, the flat tubes are easily clogged with oil having a high viscosity. If the oil stays in the oil cooler 14, for example, seizure occurs in the compressor because of shortage of oil in the compressor, thus causing a failure in the compressor.

**[0046]** In contrast, in the refrigeration cycle apparatus 1 according to the embodiment, refrigerant flows together with oil into the oil cooler 14, thus increasing the flow rate of fluid. Therefore, a shearing force is generated in the oil which flows in the oil cooler 14, thus preventing the oil from staying in the pipe.

**[0047]** In the refrigeration cycle apparatus 1 according to the embodiment as described above, the oil return circuit B is connected to the main circuit A at the first junction A1 of the main circuit A, the first junction A1 being located between the discharge side of the low-stage compressor 12 and the oil cooler 14. Therefore, before flowing into the oil cooler 14, oil separated by the separator 15 joins refrigerant which flows in the main circuit A, thus increasing the flow rate of liquid that flows into the oil cooler 14. Thus, a shearing force that acts on oil flowing in the oil cooler 14 is increased and clogging of the oil cooler 14 with the oil can be eliminated. Particularly, it should be noted that the flat tube 141 is easily clogged with oil. However, in the refrigeration cycle apparatus 1 according to the embodiment, it is possible to eliminate clogging of the oil cooler 14 with the oil even in the case where the oil cooler 14 includes the flat tubes 141.

**[0048]** The refrigeration cycle apparatus 1 according to the embodiment includes the heat inter changer (HIC) 30 and the injection circuit C. The heat inter changer (HIC) 30 includes the first flow passage 301 which is connected between the condenser 20 and the expansion valve 40. The injection circuit C is connected to the main circuit A at a location between the heat inter changer (HIC) 30 and the expansion valve 40 and at a location between the outlet side of the oil cooler 14 and the suction side of the high-stage compressor 11. Therefore, a rise in the temperature of refrigerant discharged from the high-stage compressor 11 is reduced, and the flow rate of refrigerant which flows in the injection circuit C is reduced, thus reducing energy which is input to the high-stage compressor 11. Particularly, since refrigerant which flows in the injection circuit C exchanges heat with the refrigerant in the first flow passage 301, in the second flow passage 302 of the heat inter changer (HIC) 30, it is possible to reduce a rise in the temperature of refrigerant discharged from the high-stage compressor 11.

**[0049]** The INJ expansion valve 19 is provided in the injection circuit C, and the flow rate of refrigerant that flows in the injection circuit C is adjusted such that refrigerant discharged from the high-stage compressor 11 has a proper temperature.

**[0050]** Low-temperature refrigerant subjected to heat exchange in the heat inter changer (HIC) 30 in the injection circuit C flows into the high-stage compressor 11, thereby cooling the high-stage compressor 11, and reducing energy that is input to the high-stage compressor 11.

**[0051]** The oil cooler 14 is cooled together with the condenser 20 by air sent from the first fan 16. Thus, the refrigeration cycle apparatus 1 can be made compact.

**[0052]** The oil cooler 14 and the condenser 20 are provided proximate to each other. Therefore, the refrigeration cycle apparatus 1 can be made compact.

**[0053]** The oil cooler 14 and the condenser 20 may be formed integrally formed with each other. Also, in this case, the refrigeration cycle apparatus 1 can be made compact.

**[0054]** The oil inflow port 14a of the oil cooler 14 is located at a higher position than the oil outflow port 14b. Thus, oil head is generated between the oil inflow port 14a and the oil outflow port 14b, thus promoting the flow of oil into the oil cooler 14.

**[0055]** The cooling fins 142 of the oil cooler 14 are provided apart from the heat radiating fins 202 of the condenser 20. Thus, heat is not easily transferred from the cooling fin 142 to the heat radiating fin 202. Accordingly, it is possible to reduce heat transfer from high-temperature oil that flows into the oil cooler 14, via the heat radiating fin 202 of the condenser 20, to refrigerant cooled by the condenser 20.

**[0056]** Oil contained in the high-stage compressor 11 sealed is immiscible with the refrigerant and has a higher viscosity than the viscosity of the refrigerant. Thus, it is possible to ensure a certain viscosity of the oil, since a drop in the viscosity of the oil that would be caused by dissolution of the oil in the refrigerant does not occur. Therefore, the lubricity of the compression element of the high-stage compressor 11 is maintained.

Reference Signs List

**[0057]** 1: refrigeration cycle apparatus, 10: injection compressor, 11: high-stage compressor, 12: low-stage compressor, 14: oil cooler, 14a: oil inflow port, 14b: oil outflow port, 15: oil separator, 15a: oil separator inlet, 15b: refrigerant outlet, 15c: oil outlet, 16: first fan, 17: second fan, 18: pressure reducing device, 19: INJ expansion valve, 20: condenser, 20a: condenser inlet, 20b: condenser outlet, 30: heat inter changer (HIC), 31: outer pipe, 32: inner pipe, 40: expansion valve, 50: evaporator, 90: control unit, 100: refrigeration cycle apparatus, 141: flat tube, 141a: flow passage, 142: cooling fin, 201: heat transfer tube, 202: heat radiating fin, 301: first flow passage, 302: second flow passage, A: main circuit, A1: first junction, A2: second junction, B: oil return circuit, B1: first end portion, B2: second end portion, C: injection circuit, C1: third end portion, C2: fourth end portion, D: main circuit, E: oil return circuit, F: injection circuit.

## Claims

**1.** A refrigeration cycle apparatus comprising:

a main circuit in which a low-stage compressor, an oil cooler, a high-stage compressor, an oil separator, a condenser, a first expansion valve, and an evaporator are sequentially connected by refrigerant pipes, and refrigerant flows through the low-stage compressor, the oil cooler, the high-stage compressor, the oil separator, the condenser, the first expansion valve, and the evaporator in this order; and an oil return circuit having one end that is connected to the oil separator and an other end that is connected to a first junction between a discharge side of the low-stage compressor and an inlet side of the oil cooler, the oil return circuit being configured to cause oil separated by the oil separator to return to the main circuit.

2. The refrigeration cycle apparatus of claim 1, wherein the oil cooler includes a flat tube.

3. The refrigeration cycle apparatus of claim 2, wherein

the condenser includes a heat transfer tube through which the refrigerant flows and a heat radiating fin attached to the heat transfer tube,
the oil cooler includes a cooling fin attached to the flat tube, and
the heat radiating fin and the cooling fin are provided with a gap provided between the heat radiating fin and the cooling fin.

4. The refrigeration cycle apparatus of any one of claims 1 to 3, further comprising an injection circuit including

a third end portion connected to the main circuit at a location downstream of the condenser and upstream of the first expansion valve,
a fourth end portion connected to a second junction located between an outlet side of the oil cooler and a suction side of the high-stage compressor, the fourth end portion being provided opposite to the third end portion, and
a second expansion valve connected to a downstream side relative to the third end portion.

5. The refrigeration cycle apparatus of claim 4, wherein an opening degree of the second expansion valve is controlled based on a discharge temperature of the high-stage compressor.

6. The refrigeration cycle apparatus of claim 4 or 5, wherein refrigerant that passes through the injection circuit flows into the high-stage compressor to cool the high-stage compressor.

7. The refrigeration cycle apparatus of any one of claims 4 to 6, further comprising a heat inter changer including

a first flow passage connected to a downstream side relative to the condenser and an upstream side in the main circuit relative to a point at which the injection circuit is connected to the main circuit, and
a second flow passage connected to the injection circuit at a location downstream of the second expansion valve and upstream of the fourth end portion.

8. The refrigeration cycle apparatus of any one of claims 1 to 7, further comprising a fan configured to send air to the condenser,
wherein the oil cooler is cooled by the air sent from the fan.

9. The refrigeration cycle apparatus of any one of claims 1 to 8, wherein the oil cooler is provided proximate to the condenser.

10. The refrigeration cycle apparatus of any one of claims 1 to 9, wherein the oil cooler is formed integrally with the condenser.

11. The refrigeration cycle apparatus of any one of claims 1 to 10,

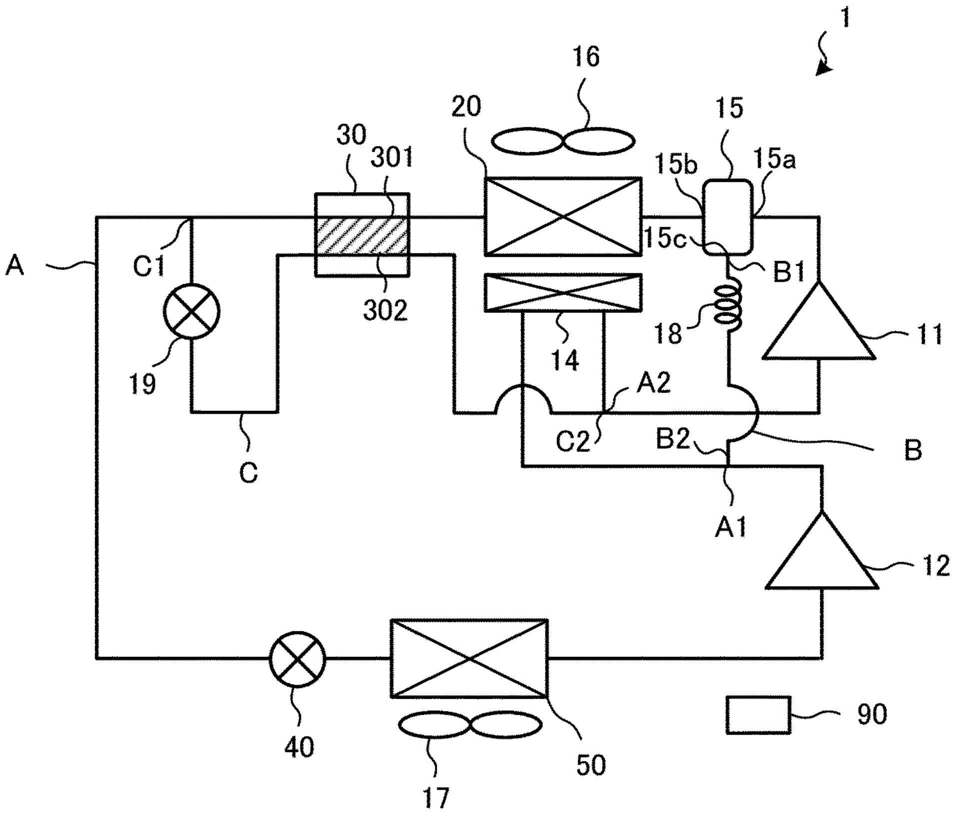
wherein the oil cooler includes

an oil inflow port located on an upstream side and on the low-stage compressor side in the main circuit, and
an oil outflow port located on a downstream side and on the high-stage compressor side in the main circuit, and

wherein the oil inflow port is located at a higher position than the oil outflow port.

12. The refrigeration cycle apparatus of any one of claims 1 to 11, wherein the oil is immiscible with the refrigerant and has a higher viscosity than the refrigerant.

FIG. 1


1
16
20
15
30
301
15b
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15c
A
C1
B1
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17

FIG. 2

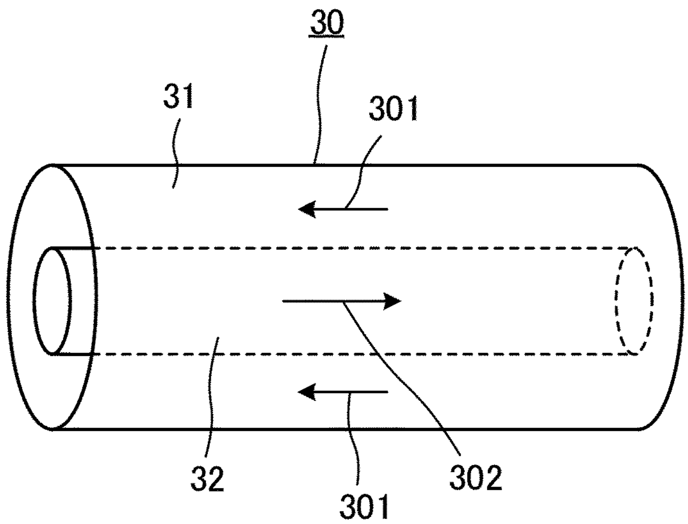


FIG. 3

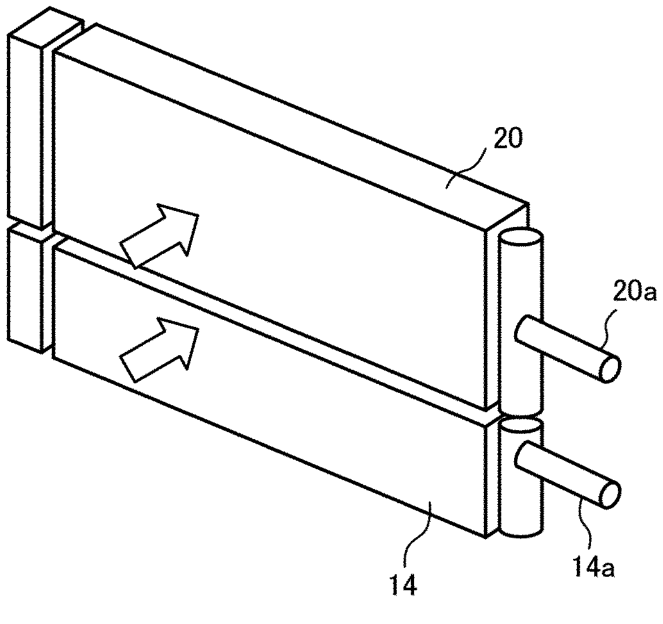


FIG. 4

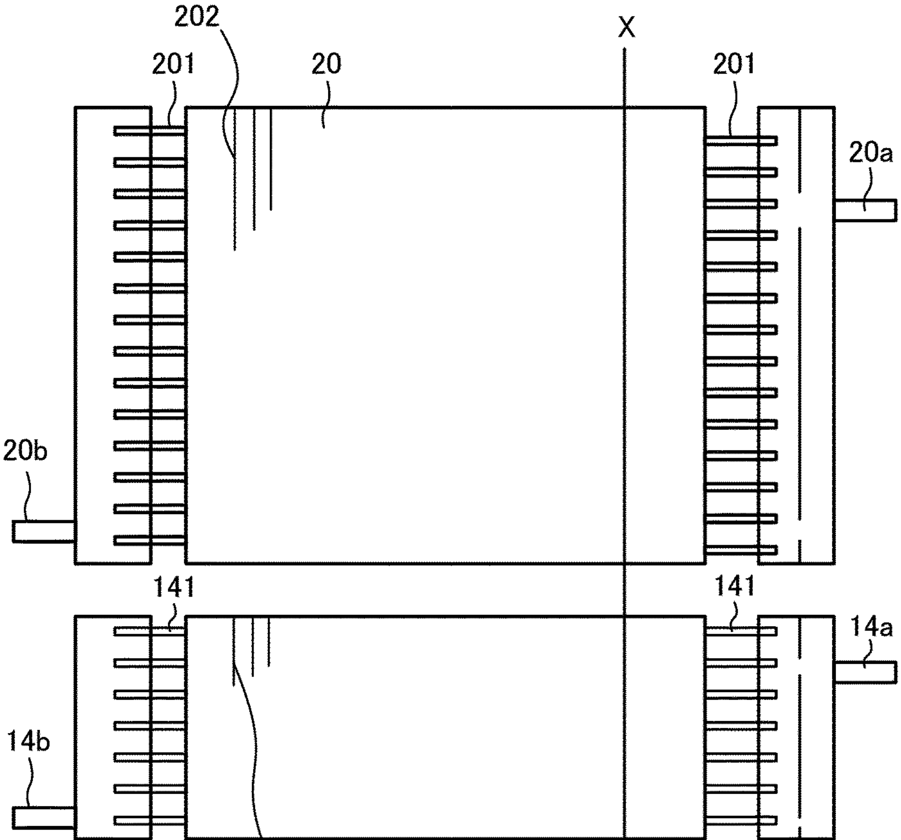


FIG. 5

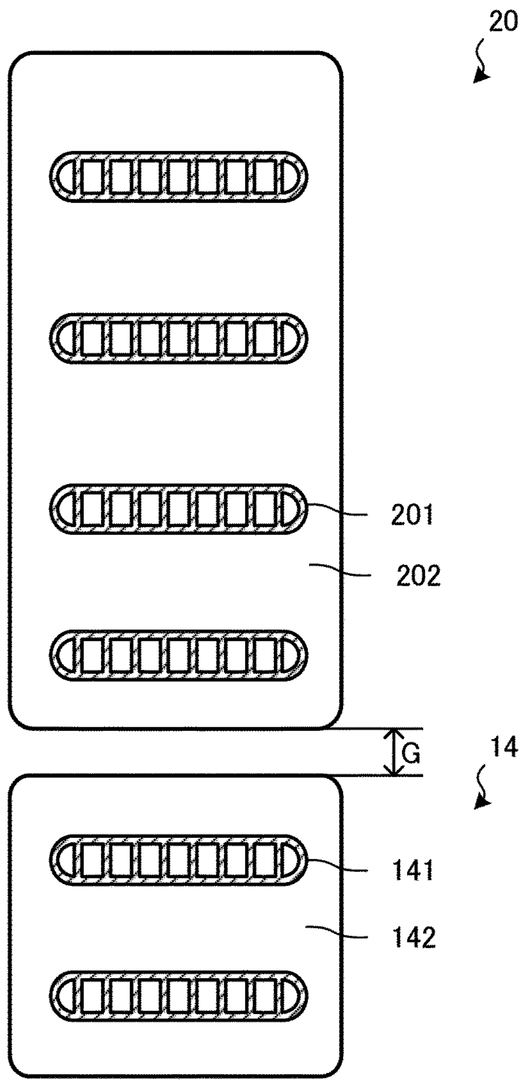


FIG. 6

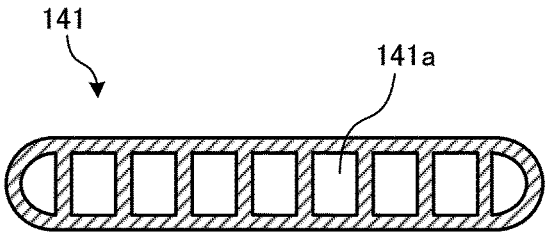
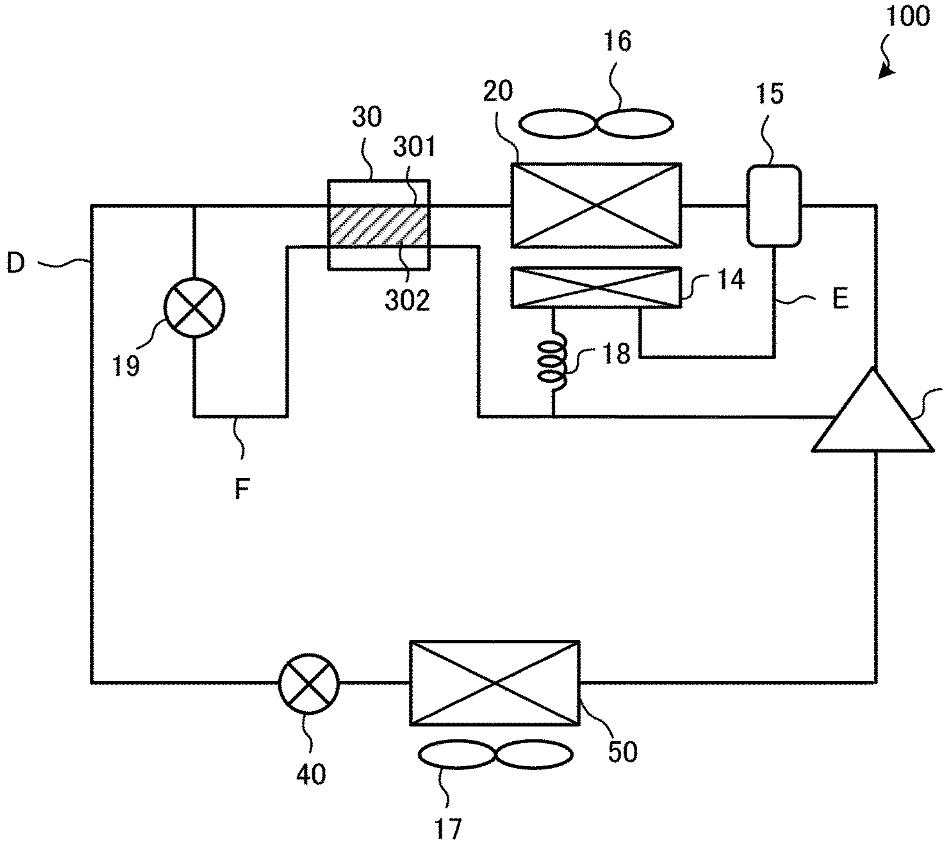


FIG. 7



## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/018149

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. F25B1/10(2006.01)i
FI: F25B1/10G

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. F25B1/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

| | |
|---|---|
| Published examined utility model applications of Japan | 1922-1996 |
| Published unexamined utility model applications of Japan | 1971-2021 |
| Registered utility model specifications of Japan | 1996-2021 |
| Published registered utility model applications of Japan | 1994-2021 |

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X<br>Y | JP 2021-55940 A (DAIKIN IND LTD.) 08 April 2021 (2021-04-08), paragraphs [0027]-[0131], fig. 1-12C | 1-7, 9<br>8, 10-12 |
| Y | JP 2020-16391 A (DAIKIN IND LTD.) 30 January 2020 (2020-01-30), fig. 1, 8A-10B | 8, 10-12 |
| Y | JP 2014-20727 A (MITSUBISHI ELECTRIC CORP.) 03 February 2014 (2014-02-03), fig. 1, 2 | 8, 10-12 |
| Y | JP 2016-3840 A (PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO., LTD.) 12 January 2016 (2016-01-12), fig. 1 | 8, 10-12 |

☐ Further documents are listed in the continuation of Box C.    ☒ See patent family annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 31 May 2021 | 08 June 2021 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Japan Patent Office<br>3-4-3, Kasumigaseki, Chiyoda-ku,<br>Tokyo 100-8915, Japan | Telephone No. |

Form PCT/ISA/210 (second sheet) (January 2015)

**INTERNATIONAL SEARCH REPORT**
Information on patent family members

International application No.
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|---|---|---|
| JP 2021-55940 A | 08 April 2021 | (Family: none) |
| JP 2020-16391 A | 30 January 2020 | EP 3599433 A1<br>fig. 1, 8A-10B |
| JP 2014-20727 A | 03 February 2014 | (Family: none) |
| JP 2016-3840 A | 12 January 2016 | CN 105318591 A<br>fig. 1 |

Form PCT/ISA/210 (patent family annex) (January 2015)

## REFERENCES CITED IN THE DESCRIPTION

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