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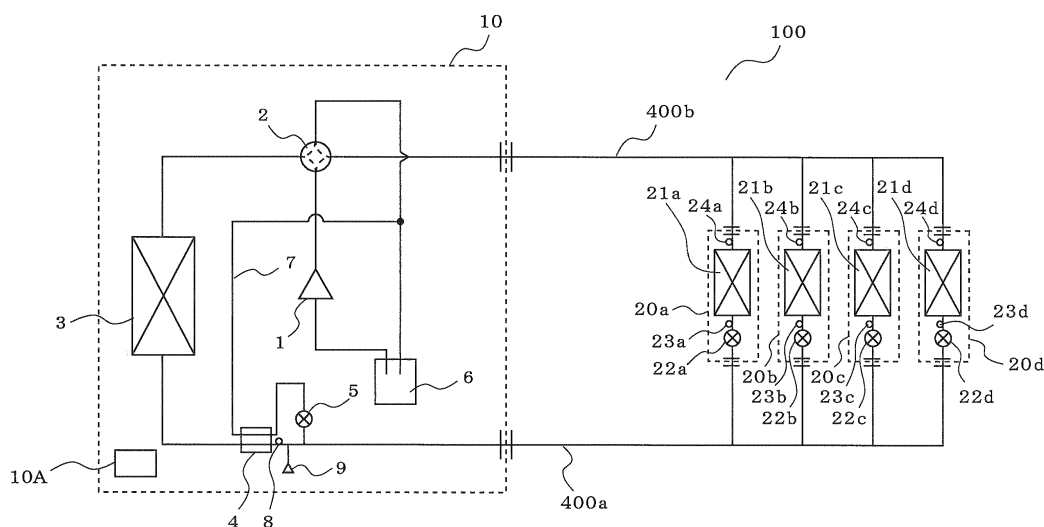
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(54) **AIR CONDITIONER DEVICE**

(57) Obtained is an air-conditioning apparatus capable of having a thin low-pressure gas pipe even when a refrigerant with a low refrigerant density at low pressure is used. An air-conditioning apparatus includes a refrigerant circuit 10 connecting a compressor 1, a heat source side heat exchanger 3, expansion devices 20, and use side heat exchangers 21 with pipes and circulating a re-

frigerant whose density in a saturated refrigerant gas at 0 degrees C is 35 to 65% of the density of an R410A refrigerant, and supercooling means (supercooling heat exchanger 4, expansion device 5, and bypass 7) making a liquid temperature sent from the heat source side heat exchanger 3 to the expansion devices 20 be 5 degrees C or less in a cooling operation.

F I G . 1



Description

Technical Field

5 **[0001]** The present invention relates to an air-conditioning apparatus.

Background Art

10 **[0002]** Conventionally, there is an air-conditioning apparatus that includes supercooling means and that cools a refrigerant sent from a condenser to an expansion device using a bypass-side refrigerant (see, for example, Patent Literature 1). In such an air-conditioning apparatus including supercooling means, a pressure loss in an evaporator and an extension pipe after the expansion device can be reduced, because the amount of a circulating refrigerant sent to the expansion device is reduced.

15 Citation List

Patent Literature

20 **[0003]**

Patent Literature 1: Japanese Unexamined Patent Application Publication No. 6-265232 (Fig. 1, page 6)

Summary of Invention

25 Technical Problem

30 **[0004]** In recent years, from the viewpoint of global warming, there has been a move toward restricting the use of HFC refrigerants having large global warming potential (e.g., R410A, R-404A, R-407C, R-134a), and an air-conditioning apparatus using a refrigerant having small global warming potential (e.g., HFO1234yf, carbon oxide, and the like) has been proposed. HFO1234yf has a refrigerant density significantly lower than that of R410A at low pressure and has a pressure characteristic considerably lower than that of R410A at the same temperature. When an air-conditioning apparatus performs a cooling operation using such a low refrigerant density at low pressure, the influence of the pressure loss on a low-pressure gas pipe is enormous. Accordingly, there is a problem in that the pipe is required to have a large diameter to reduce the pressure loss.

35 **[0005]** In particular, for a large system, such as a multi-air-conditioning system for buildings (10HP), the diameter of a low-pressure gas pipe when R410A is used is on the order of ϕ 22.2 mm, whereas that when a refrigerant with a low refrigerant density at low pressure is used is on the order of ϕ 44.5 mm, which is approximately twice the diameter for R410A. Accordingly, it is very difficult to process, for example, bend such a thick pipe, thus markedly increasing the process cost. In addition, since almost no refrigerant pipe with such a large pipe diameter is used in the market in most cases, the cost is significantly increased. Thus in a case of using a refrigerant with a low refrigerant density, one of the major issues is to reduce the pipe diameter of the low-pressure gas pipe.

40 **[0006]** The air-conditioning apparatus in Patent Literature 1 is effective at reducing the pressure loss, as described above. However, it is not intended to use a refrigerant with a low refrigerant density at low pressure as a working refrigerant, and the advantageous effect of reducing the pressure loss is insufficient. Accordingly, simply applying a refrigerant with a low refrigerant density at low pressure to this air-conditioning apparatus cannot solve the above-described problem of a significantly increased diameter of the low-pressure gas pipe.

45 **[0007]** The present invention is made to solve the above issue, and it is an object of the present invention to obtain an air-conditioning apparatus capable of having a thin low-pressure gas pipe even when a refrigerant with a low refrigerant density at low pressure is used.

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Solution to Problem

55 **[0008]** An air-conditioning apparatus according to the present invention includes a refrigerant circuit connecting a compressor, a heat source side heat exchanger, an expansion device, and a use side heat exchanger with pipes and circulating a refrigerant whose density in a saturated refrigerant gas at 0 degrees C is 35 to 65% of a density of an R410A refrigerant, and supercooling means making a liquid temperature of a high-pressure liquid refrigerant sent from the heat source side heat exchanger to the expansion device be 5 degrees C or less in a cooling operation. Advantageous Effects of Invention

[0009] According to the present invention, since the liquid temperature of the high-pressure liquid refrigerant sent from the heat-source heat exchanger to the expansion device is 5 degrees C or less in a cooling operation, the refrigeration effect can be increased, and the flow rate of the refrigerant can be reduced. Accordingly, the low-pressure pipe can be narrowed.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a schematic circuit configuration diagram that illustrates one example of the circuit configuration of an air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 2] Fig. 2 is a refrigerant circuit diagram that illustrates how a refrigerant flows in cooling operation mode in the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 3] Fig. 3 illustrates an example of the structure of a double-pipe supercooling heat exchanger.

[Fig. 4] Fig. 4 is a graph that illustrates a relationship between the liquid temperature and the flow ratio.

[Fig. 5] Fig. 5 is a graph that illustrates a relationship between the liquid temperature and the pressure loss ratio.

[Fig. 6] Fig. 6 is a graph that illustrates a relationship between the liquid temperature and the pipe diameter ratio.

[Fig. 7] Fig. 7 is a refrigerant circuit diagram that illustrates how the refrigerant flows in heating operation mode in the air-conditioning apparatus according to Embodiment 1 of the present invention.

[Fig. 8] Fig. 8 is a schematic circuit configuration diagram that illustrates one example of the circuit configuration of an air-conditioning apparatus according to Embodiment 2 of the present invention.

[Fig. 9] Fig. 9 is a refrigerant circuit diagram that illustrates how the refrigerant flows in cooling operation mode in the air-conditioning apparatus according to Embodiment 2 of the present invention.

[Fig. 10] Fig. 10 is a circuit diagram of an air-conditioning apparatus according to Embodiment 3 (simultaneous heating and cooling type) of the present invention. Description of Embodiments

[0011] Embodiments of the present invention are described below on the basis of the drawings.

Embodiment 1

[0012] Fig. 1 is a schematic circuit configuration diagram that illustrates one example of the circuit configuration of an air-conditioning apparatus according to Embodiment 1 of the present invention. The detailed circuit configuration of the air-conditioning apparatus is described on the basis of Fig. 1. Fig. 1 illustrates a case where four indoor units 20 are connected, as an example. In the drawings, including Fig. 1, the relationship among the sizes of the components may be different from that in practical use. In Fig. 1 and other drawings described below, the elements having the same reference numerals are the same or equivalent, and the same applies to the entire text of the Specification. The form of each of the components described in the entire text of the Specification is merely an example, and is not limited to the description.

[0013] As illustrated in Fig. 1, an air-conditioning apparatus 100 is configured such that an outdoor unit (heat source unit) 10 and an indoor unit 20a to an indoor unit 20d (hereinafter may be referred to as indoor units 20) are connected by an extension pipe 400a and an extension 400b (hereinafter may be referred to as extension pipes 400). That is, the plurality of indoor units 20 are connected in parallel with respect to the outdoor unit 10 in the air-conditioning apparatus 100. Each of the extension pipes 400 is a refrigerant pipe through which a refrigerant (heat source side refrigerant) passes. In the air-conditioning apparatus 100, HFO1234fy or HFO1234ze is sealed as the refrigerant.

[Outdoor Unit 10]

[0014] The outdoor unit 10 includes a compressor 1, a channel switching device 2 such as a four-way valve, a heat source side heat exchanger 3, a supercooling heat exchanger 4, and an accumulator 6, are connected with pipes to use side heat exchangers 21 and expansion devices 22, which are described below, in each of the indoor units 20, and then constitutes a refrigerant circuit through which a refrigerant circulates. The outdoor unit 10 further includes the supercooling heat exchanger 4 between the heat source side heat exchanger 3 and the expansion device 22. The outdoor unit 10 includes a bypass 7 that branches from between the supercooling heat exchanger 4 and the expansion device 22, and that is connected to the entry side of the accumulator 6 through an expansion device 5 and the low-pressure side of the supercooling heat exchanger 4. The supercooling heat exchanger 4 exchanges heat between a high-pressure side refrigerant between the heat source side heat exchanger 3 and the expansion devices 22 and a low-pressure side refrigerant that is part of the high-pressure side refrigerant and whose pressure is reduced by the expansion device 5, so as to cool the high-pressure side refrigerant.

[0015] The compressor 1 sucks the refrigerant, compresses the refrigerant to be in a high temperature and high pressure state, and conveys it to the refrigerant circuit and may be an inverter compressor with a controllable capacity, for example. The channel switching device 2 switches the flow of the refrigerant in heating operation mode and the flow of the refrigerant in cooling operation mode.

[0016] The heat source side heat exchanger (outdoor side heat exchanger) 3 functions as an evaporator in a heating operation and as a radiator in a cooling operation and exchanges heat between the refrigerant and air supplied from an air-sending device, which is not illustrated, such as a fan. The accumulator 6 is disposed on the suction side of the compressor 1 and accumulates a surplus refrigerant resulting from the difference between the refrigerant in heating operation mode and that in cooling operation mode and a surplus refrigerant responsive to a transient operation change (e.g., a change in the number of active indoor units 20).

[0017] A pressure sensor 8 and a temperature sensor 9 are disposed at the exit (liquid side) of the supercooling heat exchanger 4. The outdoor unit 10 further includes various sensors such as sensors, which is not illustrated, for detecting the suction temperature and the discharge temperature of the compressor 1.

[0018] The outdoor unit 10 includes a controller 10A. The controller 10A is connected so as to be able to receive detection signals of the various sensors in the outdoor unit 10 and various sensors, which are described below, in the indoor units 20. The controller 10A performs control such as adjusting each opening degree of the expansion device 5 and the expansion device 22, on the basis of detection signals from the various sensors. The controller 10A also carries out an operation of cooling operation mode and heating operation mode by switching made by the channel switching device 2. While Fig. 1 illustrates a configuration in which the controller 10A is included in only the outdoor unit 10, another configuration may also be available in which a sub-control device having part of the functions of the controller 10A is provided with each of the indoor units 20 and the controller 10A and the sub-control device cooperatively process with communicating data each other.

[Indoor Units 20]

[0019] The indoor units 20 include the use side heat exchangers (indoor side heat exchangers) 21 (21 a to 21 d) and the expansion devices 22 (22a to 22d) connected in series, respectively and constitute part of the refrigerant circuit. Each of the use side heat exchangers 21 functions as a radiator in a heating operation or as an evaporator in a cooling operation, exchanges heat between the refrigerant and air supplied from an air-sending device, which is not illustrated, such as a fan, and generates air for heating or air for cooling to supply to an air-conditioned space. The expansion devices 22 have the functions as a pressure reducing valve and an expansion valve, reduce the pressure of the refrigerant, and expand it. The expansion devices 22 may be composed with an element having a variably controllable opening degree such as an electronic expansion valve.

[0020] In Embodiment 1, a case where the four indoor units 20 are connected is illustrated as an example. The indoor units 20 are illustrated as the indoor unit 20a, indoor unit 20b, indoor unit 20c, and indoor unit 20d from the left side in Fig. 1. The use side heat exchangers 21 are also illustrated as the use side heat exchanger 21 a, use side heat exchanger 21 b, use side heat exchanger 21 c, and use side heat exchanger 21d from the left side in Fig. 1 so as to correspond to the indoor unit 20a to indoor unit 20d. Similarly, the expansion devices 22 are also illustrated as the expansion device 22a, expansion device 22b, expansion device 22c, and expansion device 22d from the left side in Fig. 1, respectively. The number of the indoor units 20 connected is not limited to four.

[0021] The indoor units 20 include temperature sensors 23a to 23d and 24a to 24d at the entry and the exit of the refrigerant of the use side heat exchangers 21. A detection signal of each of the temperature sensors 23a to 23d and 24a to 24d is output to the controller 10A. In Embodiment 1, the controller 10A in the outdoor unit controls the indoor units. Each of the indoor units may include a controller, and the controller may control a corresponding one of the indoor units 20a to 20d.

[0022] As described above, the air-conditioning apparatus 100 uses HFO1234yf or HFO1234ze, which is a low-pressure refrigerant, as the refrigerant. Saturated gas densities of these refrigerants at 0 degrees C are provided in Table 1. According to Table 1, the gas density of HFO1234yf is 58% of that of R410A and the gas density of HFO1234ze is 38% of that of R410A. That is, the gas densities at low pressure of these refrigerants are on the order of 35 to 65% of that of R410A refrigerant, which is currently used in many air-conditioning apparatuses. The values are extracted from REFPROP Version 8.0 released from National Institute of Standards and Technology (NIST).

[0023]

[Table 1]

Refrigerant	R410A	HFO1234yf	HFO1234ze
Saturated Gas Density [kg/m ³]	30.575	17.646	11.724

[0024] As described above, if a refrigerant with a low gas density is used, the flow velocity of the HFO1234yf refrigerant is approximately twice that of the R410A refrigerant when the refrigerants simply flow in the pipe with the same flow rate (kg/hr). Since the pressure loss is roughly proportional to the square of the flow velocity, the pressure loss for the HFO1234yf refrigerant is approximately four times that for the R410A refrigerant. As a result, when the pipe having the same pipe diameter as in the case of the R410A refrigerant is used, since the pressure loss for the HFO1234yf refrigerant is four times as much as that in the case of the R410A refrigerant, the performance is significantly decreased. In order to suppress the performance decrement caused by the pressure loss of the HFO1234yf to be equivalent to that of a traditional refrigerant (R410A), a pipe diameter needs to be twice that of the traditional refrigerant. Since HFO1234yf and HFO1234ze have substantially the same density, the pressure loss for HFO1234yf and that for HFO1234ze indicate substantially the same value.

[0025] In a system having a small capacity such as a room air conditioner, even if the pipe diameter is doubled, since the original pipe diameter is small, no problem occurs in terms of processing. However, in a system having a large capacity such as a multi-air-conditioning apparatus for buildings (10HP), as described above in the related art, the pipe diameter would be as large as the order of ϕ 44.5 mm, and adverse effects on ease of construction and the processing cost would be large.

[0026] In Embodiment 1, the temperature of the high-pressure liquid refrigerant sent from the heat source side heat exchanger 3 to the expansion device 22, which functions as a radiator in cooling operation mode, is reduced to 5 degrees C or less. This is a key in Embodiment 1. In Embodiment 1, the condensing temperature is 49 degrees C. When the target temperature of the liquid temperature of the high-pressure liquid refrigerant is 5 degrees C or less, the degree of supercooling is 44 degrees C or more. Thus, setting the liquid temperature of the high-pressure liquid refrigerant to be 5 degrees C or less can increase a refrigeration effect compared to that when the liquid temperature is, for example, 44 degrees C (degree of supercooling is 5 degrees C). As a result, the flow rate of the refrigerant can be reduced, and the size of the pipe can be reduced.

[0027] Operation modes which the air-conditioning apparatus 100 carries out are described below.

[Cooling Operation Mode]

[0028] Fig. 2 is a refrigerant circuit diagram that illustrates how the refrigerant flows in cooling operation mode in the air-conditioning apparatus 100. Fig. 2 illustrates a case where all of the indoor units 20 are driven, as an example. In Fig. 2, the directions in which the refrigerant flows are indicated by the arrows.

[0029] A low-temperature and low-pressure refrigerant is compressed by the compressor 1, and is discharged as the resultant high-temperature and high-pressure gas refrigerant. The high-temperature and high-pressure gas refrigerant that has discharged from the compressor 1 passes through the channel switching device 2 and flows into the heat source side heat exchanger 3.

[0030] The high-temperature and high-pressure gas refrigerant that has flown into the heat source side heat exchanger 3 is liquefied by exchanging heat with air supplied from the air-sending device, which is not illustrated, and flows out of the heat source side heat exchanger 3. The refrigerant in the liquid state that has flown out of the heat source side heat exchanger 3 flows into the high-pressure side of the supercooling heat exchanger 4. A low-pressure two-phase gas-liquid refrigerant that has been part of the refrigerant passing through the supercooling heat exchanger 4 and that has been decompressed by the expansion device 5 in the bypass 7 flows into the low-pressure side of the supercooling heat exchanger 4. Thus the liquid refrigerant in the high-pressure side of the supercooling heat exchanger 4 exchanges heat with the refrigerant in the low-pressure side to be cooled, its liquid temperature is reduced (the degree of supercooling is increased), and the refrigerant flows out of the supercooling heat exchanger 4. The low-pressure two-phase refrigerant in the low-pressure side of the supercooling heat exchanger 4 exchanges heat with the refrigerant in the high-pressure side to become the low-pressure gas refrigerant. The low-pressure gas refrigerant flows out of the supercooling heat exchanger 4 and is directed to the accumulator 6.

[0031] Here, as previously described, in Embodiment 1, the opening degree of the expansion device 5 is adjusted such that the liquid temperature of the high-pressure liquid refrigerant at the exit of the supercooling heat exchanger 4 is reduced to substantially 5 degrees C. This enhances the refrigeration effect, and thus the opening degree of the expansion device 5 is smaller than that when the degree of supercooling is, for example, 5 degrees C. Accordingly, the amount of the refrigerant supplied to the use side heat exchangers 21 is reduced. As a result, the size of the pipe can be reduced. The opening degree of the expansion device 5 is adjusted by the controller 10A on the basis of detection signals of the pressure sensor 8 and temperature sensor 9.

[0032] The supercooling heat exchanger 4 in Embodiment 1 is of the double-pipe type, as illustrated in Fig. 3. The high-pressure liquid refrigerant, which is the high-pressure side refrigerant, flows in the annular space, and the two-phase gas-liquid refrigerant, which is the low-pressure side refrigerant, flows in the inner pipe. This is because, if the two-phase gas-liquid refrigerant flows in the annular space, the liquid refrigerant collects in the bottom portion of the annular space, and the heat exchange performance degrades.

[0033] The supercooling heat exchanger 4 is not limited to the double-pipe type, and it may be a plate-type heat exchanger. If the plate-type heat exchanger is used, the low-pressure two-phase gas-liquid refrigerant flows from the bottom to the top and the high-pressure liquid refrigerant flows from the top to the bottom (countercurrent), which achieves the effective heat exchanger performance.

[0034] The liquid refrigerant flowing out of the supercooling heat exchanger 4 passes through the extension pipe 400a, is directed to the indoor units 20, and flows into each of the indoor unit 20a to indoor unit 20d. The refrigerants that have flowed into the indoor unit 20a to indoor unit 20d are expanded (pressure is reduced) by the expansion device 22a to expansion device 22d, respectively, and become a low-temperature and low-pressure two-phase gas-liquid state. The refrigerants in the two-phase gas-liquid state flow into the use side heat exchanger 21 a to use side heat exchanger 21 d, respectively. The refrigerants in the two-phase gas-liquid state which have flowed into the use side heat exchanger 21 a to use side heat exchanger 21 d exchange heat with air (indoor air) supplied from the air-sending device, which is not illustrated, and thus remove heat from the air, become low-pressure gas refrigerants, and flow out of the use side heat exchanger 21 a to use side heat exchanger 21 d.

[0035] Here, the amount of the refrigerant supplied to the use side heat exchangers 21 is adjusted using information on the temperature from the temperature sensors 23a to 23d and 24a to 24d at the refrigerant entry and exit of the use side heat exchangers 21. Specifically, the controller 10A acquires information from the temperature sensors 23a to 23d and 24a to 24d, and calculates the degree of superheat (temperature of the refrigerant on the exit side - temperature of the refrigerant on the entry side) on the basis of the acquired information. Then the controller 10A determines the opening degrees of the expansion devices 22 such that the degree of superheat is substantially 2 to 5 degrees C, and adjusts the amount of the refrigerant to be supplied to the use side heat exchangers 21.

[0036] The low-pressure gas refrigerants that have flowed out of the use side heat exchanger 21 a to use side heat exchanger 21 d flow out of the indoor unit 20a to indoor unit 20d. Each of the refrigerants passes through the extension pipe 400b, and flows into the outdoor unit 10. The refrigerant that has flowed into the outdoor unit 10 passes through the channel switching device 2, and flows into the accumulator 6. The refrigerant that has flowed into the accumulator 6 is separated into the liquid refrigerant and gas refrigerant, and the gas refrigerant is sucked into the compressor 1 again.

[0037] In such cooling operation mode, the degree of superheat is controlled in each of the indoor units 20 such that the degree of superheat is in a positive range. Thus the refrigerant in a liquid state does not flow into the accumulator 6. However, if any one of the indoor units 20 is in a transient state or stopped, a small amount of the refrigerant in a liquid state (with a quality of substantially 0.95) may flow into the accumulator 6. Some of the liquid refrigerant that has flowed into the accumulator 6 evaporate and are sucked into the compressor 1 or other are sucked into the compressor 1 through an oil return hole, which is not illustrated, disposed in the exit pipe of the accumulator 6.

[0038] Next, the advantageous effects provided by reducing the temperature of the high-pressure liquid refrigerant at the exit of the supercooling heat exchanger 4 to substantially 5 degrees C are described. Fig. 4 illustrates a relationship between the liquid temperature at the exit of the supercooling heat exchanger 4 and the reduction ratio of the flow rates of the refrigerant. The flow rate of the refrigerant for the liquid temperature of 44 degrees C (degree of supercooling of 5 degrees C) is taken as one. Other conditions of this trial calculation are that the evaporating temperature is 0 degrees C and the condensing temperature is 49 degrees C.

According to Fig. 4, the flow rate when the liquid temperature at the exit of the supercooling heat exchanger 4 is substantially 5 degrees C is substantially 66% of the flow rate when the liquid temperature is 44 degrees C (degree of supercooling of 5 degrees C), that is, the flow rate of the refrigerant passing through the extension pipes 400a and 400b is reduced by 34% as well.

[0039] Fig. 5 illustrates a relationship between the liquid temperature at the exit of the supercooling heat exchanger and the reduction ratio of the pressure losses of the pipe. The pressure loss for the liquid temperature of 44 degrees C (degree of supercooling of 5 degrees C) is taken as one. According to Fig. 5, the pressure loss when the liquid temperature at the exit of the supercooling heat exchanger 4 is substantially 5 degrees C is substantially 44% of the pressure loss when the liquid temperature is 44 degrees C (degree of supercooling of 5 degrees C), that is, pressure loss in the extension pipes 400a and 400b is reduced by 56% as well.

[0040] Fig. 6 illustrates a relationship between the liquid temperature at the exit of the supercooling heat exchanger and the reduction ratio of the pipe diameters. The pipe diameter for the liquid temperature of 44 degrees C (degree of supercooling of 5 degrees C) is taken as one. According to Fig. 6, the pipe diameter when the liquid temperature at the exit of the supercooling heat exchanger 4 is substantially 5 degrees C is substantially 80% of the pipe diameter when the liquid temperature is 44 degrees C (degree of supercooling of 5 degrees C) and the pipe diameter of the extension pipes 400a and 400b is reduced by 20% as well. That is, the pipe diameter can be reduced by from one to two sizes, and the extension pipes 400a and 400b can be narrowed. The extension pipe 400b, which is a low-pressure pipe through which a gas refrigerant passes, is susceptible to the pressure loss, and it is thicker than the extension pipe 400a. Accordingly, being able to reduce the pipe diameter of the extension pipe 400b by one through two sizes is significantly effective in that the advantageous effects of reducing the cost of pipes, improving ease of construction, and reducing the cost of construction are obtainable.

[Heating Operation Mode]

[0041] Fig. 7 is a refrigerant circuit diagram that illustrates how the refrigerant flows in heating operation mode in the air-conditioning apparatus 100. Fig. 7 illustrates a case where all of the indoor units 20 are driven, as an example. In Fig. 7, the directions in which the refrigerant flows are indicated by the arrows. In heating operation mode, the expansion device 5 is closed.

[0042] A low-temperature and low-pressure refrigerant is compressed by the compressor 1, and the resultant high-temperature and high-pressure gas refrigerant is discharged. The high-temperature and high-pressure gas refrigerant that has discharged from the compressor 1 passes through the channel switching device 2, flows out of the outdoor unit 10, passes through the extension pipe 400b, and flows into each of the indoor unit 20a to indoor unit 20d.

[0043] The high-temperature and high-pressure gas refrigerants that have flowed into the indoor unit 20a to indoor unit 20d each exchange heat with air (indoor air) supplied from the air-sending device, which is not illustrated, in the corresponding use side heat exchanger 21 a to use side heat exchanger 21 d, thus transfer heat to the air, to be liquefied. The refrigerant in the liquid state flows out of each of the use side heat exchanger 21 a to use side heat exchanger 21 d. This high-pressure refrigerant in the liquid state is expanded (pressure is reduced) by each of the expansion device 22a to expansion device 22d, and becomes a low-pressure and low-temperature two-phase gas-liquid state. The refrigerant in the two-phase gas-liquid state flows out of each of the indoor unit 20a to indoor unit 20d.

[0044] The amount of the refrigerant supplied to the use side heat exchangers 21 is adjusted using information from the temperature sensors 23a to 23d at the refrigerant exits of the use side heat exchangers 21 and pressure sensors, which is not illustrated. Specifically, the degree of supercooling (saturated temperature obtained by conversion from a detected pressure of the refrigerant on the exit side - temperature of the refrigerant on the exit side) is calculated on the basis of information from the sensors, the opening degrees of the expansion devices 22 is determined such that the degree of supercooling is substantially 2 to 5 degrees C, and the amount of the refrigerant to be supplied to the heat source side heat exchanger 3 is adjusted.

[0045] The low-temperature and low-pressure refrigerant in the two-phase gas-liquid state that has flowed out of each of the indoor unit 20a to indoor unit 20d passes through the extension pipe 400a, and flows into the outdoor unit 10. The refrigerant passes through the supercooling heat exchanger 4 without being processed and flows into the heat source side heat exchanger 3. The low-temperature and constant-pressure refrigerant in the two-phase gas-liquid state exchanges heat with air supplied from the air-sending device, which is not illustrated, and thus removes heat from the air, and the quality gradually increases. Then it becomes the two-phase gas-liquid refrigerant in a large quality state at the exit of the heat source side heat exchanger 3, and flows out of the heat source side heat exchanger 3. The refrigerant flowing out of the heat source side heat exchanger 3 flows into the accumulator 6 through the channel switching device 2. The refrigerant that has flowed into the accumulator 6 is separated into the liquid refrigerant and gas refrigerant, and the gas refrigerant is sucked into the compressor 1 again.

[0046] In heating operation mode, although the circuit in Embodiment 1 cannot reduce the flow rate of the refrigerant flowing into the extension pipe 400b, since the high-pressure gas refrigerant (high-density refrigerant) flows in the extension pipe 400b, the influence of the pressure loss is small, and the refrigerant is not made to flow in the supercooling heat exchanger 4. If the refrigerant is made to flow in the supercooling heat exchanger 4, the low-pressure pipe in the outdoor unit 10 (the pipe from the exit of the supercooling heat exchanger 4 → the evaporator → the accumulator 6) can also be narrowed. Also in this heating operation mode, the liquid temperature of the high-pressure liquid refrigerant to be sent from the use side heat exchangers 21 to the expansion devices 22 may be made to be 5 degrees C or less, or the degree of supercooling may be made to be 44 degrees C or more.

[0047] As described above, according to Embodiment 1, reducing the high-pressure liquid temperature to substantially 5 degrees C using the supercooling means (supercooling heat exchanger 4, expansion device 5, and bypass 7) in cooling operation mode enables the pipe diameter of the extension pipe (low-pressure gas pipe) 400b to be reduced by one through two sizes. As a result, the cost of pipes and the cost of construction can be reduced, in addition, the energy loss associated with disposal can be reduced, and a contribution to environmental preservation can also be achieved. Since the pressure loss can be reduced, an operation with high energy efficiency can be carried out, and the energy-saving effects are also obtainable.

Embodiment 2

[0048] The supercooling means in Embodiment 1 is composed of the supercooling heat exchanger 4, expansion device 5, and bypass 7. In Embodiment 2, the supercooling means is composed of a refrigerant circuit for use in supercooling.

[0049] Fig. 8 is a schematic diagram of an air-conditioning apparatus according to Embodiment 2 of the present invention. This air-conditioning apparatus 101 includes a refrigerant circuit 101A and a supercooling circuit 101 B. The description of Embodiment 2 focuses on differences from Embodiment 1, and the same reference numerals are used

in the same portions as those in Embodiment 1. Specific examples and variations applied to similar components to those in Embodiment 1 are also applicable to those in Embodiment 2. The same applies to embodiments described below.

[Refrigerant Circuit 101 A]

[0050] The refrigerant circuit 101A includes the compressor 1, the channel switching device 2 such as a four-way valve, the heat source side heat exchanger 3, and the accumulator 6. The refrigerant circuit 101A is connected to the use side heat exchangers 21 and the expansion devices 22 in the respective indoor units 20 with pipes, and these elements constitute a refrigeration cycle through which a refrigerant circulates.

[Supercooling Circuit 101B]

[0051] The supercooling circuit 101 B includes a compressor 31, a condenser 32, an expansion device 33, and a supercooling heat exchanger 34, connects these with pipes to circulate a refrigerant, and constitutes a refrigeration cycle functioning as the supercooling means. The supercooling heat exchanger 34 exchanges heat between a low-pressure side refrigerant circulating through the supercooling circuit 101 B and a high-pressure side refrigerant between the heat source side heat exchanger 3 and the expansion devices 22 in the refrigerant circuit 101 A.

[0052] The devices in the refrigerant circuit 101 A other than the use side heat exchangers 21 and the expansion devices 22, and the supercooling circuit 101 B are placed in the same casing and constitute an outdoor unit 30. A compressor having a capacity smaller than that of the compressor 1 is provided in the compressor 31 in the supercooling circuit 101 B.

[0053] The outdoor unit 30 includes a controller 30A. The controller 30A is connected so as to be able to receive detection signals of various sensors in the outdoor unit 30 and various sensors, which are described below, in each of the indoor units 20. The controller 30A performs control such as adjusting the opening degree of each of the expansion device 33 and the expansion device 22, on the basis of detection signals from the various sensors. The controller 30A also carries out operations in cooling operation mode and in heating operation mode by switching made by the channel switching device 2. Fig. 8 illustrates a configuration in which the controller 30A is included in only the outdoor unit 30. Another configuration may also be used in which a sub-control device having part of the functions of the controller 30A is included in each of the indoor units 20 and cooperative processing is performed by data communication between the controller 30A and the sub-control device.

[0054] Operation modes implemented by the air-conditioning apparatus 101 are described below.

[Cooling Operation Mode]

[0055] Fig. 9 is a refrigerant circuit diagram that illustrates how the refrigerant flows in cooling operation mode in the air-conditioning apparatus according to Embodiment 2 of the present invention. Fig. 9 illustrates a case where all of the indoor units 20 are driven, as an example. In Fig. 9, the directions in which the refrigerant flows are indicated by the arrows.

[0056] First, an operation of the refrigerant circuit 101A is described. A low-temperature and low-pressure refrigerant is compressed by the compressor 1, and the resultant high-temperature and high-pressure gas refrigerant is discharged. The high-temperature and high-pressure gas refrigerant that has discharged from the compressor 1 passes through the channel switching device 2 and flows into the heat source side heat exchanger 3.

[0057] The high-temperature and high-pressure gas refrigerant that has flowed into the heat source side heat exchanger 3 exchanges heat with air supplied from the air-sending device, which is not illustrated, to be liquefied, and flows out of the heat source side heat exchanger 3 into the supercooling heat exchanger 34. The liquid refrigerant that has flowed into the supercooling heat exchanger 34 is cooled by a two-phase gas-liquid refrigerant generated by the supercooling circuit 101 B, with lowering a liquid temperature thereof (degree of supercooling is increased), and the refrigerant flows out of the supercooling heat exchanger 34.

[0058] Here, in Embodiment 2, the temperature of the high-pressure liquid refrigerant at the exit of the supercooling heat exchanger 34 is reduced to substantially 5 degrees C, as in Embodiment 1. The temperature of the high-pressure liquid refrigerant depends on the amount of heat exchanged in the supercooling heat exchanger 34. Accordingly, the temperature of the high-pressure liquid refrigerant at the exit of the supercooling heat exchanger 34 is reduced to substantially 5 degrees C by adjustment of the opening degree of the expansion device 33 in the supercooling circuit 101 B and the rotation speed of the compressor 31 therein. As a result, the same advantageous effects as in Example 1 are obtainable.

[0059] The liquid refrigerant that has flowed out of the supercooling heat exchanger 34 passes through the extension pipe 400a, is directed to the indoor units 20, and flows into the indoor unit 20a to indoor unit 20d. The refrigerants that have flowed into the indoor unit 20a to indoor unit 20d are expanded (pressure is reduced) by the expansion device 22a to expansion device 22d, respectively, and become a low-pressure and low-temperature two-phase gas-liquid state.

The refrigerants in the two-phase gas-liquid state flow into the use side heat exchanger 21 a to use side heat exchanger 21 d, respectively. The refrigerants in the two-phase gas-liquid state which have flowed into the use side heat exchanger 21 a to use side heat exchanger 21 d each exchange heat with air (indoor air) supplied from the air-sending device, which is not illustrated so as to remove heat from the air, become low-pressure gas refrigerants, and flow out of the use

side heat exchanger 21 a to use side heat exchanger 21 d.

[0060] Here, the amount of the refrigerant to be supplied to the use side heat exchangers 21 is adjusted using information on the temperature from the temperature sensors 23a to 23d and 24a to 24d at the refrigerant entry and exit of the use side heat exchangers 21. Specifically, the controller 30A calculates the degree of superheat (temperature of the refrigerant on the exit side - temperature of the refrigerant on the entry side) using information from the temperature sensors 23a to 23d and 24a to 24d. Then the controller 30A determines the opening degrees of the expansion devices 22 such that the degrees of superheat is substantially 2 to 5 degrees C, and adjusts the amount of the refrigerant to be supplied to the use side heat exchangers 21, as in Embodiment 1.

[0061] The low-pressure gas refrigerants that have flowed out of the use side heat exchanger 21 a to use side heat exchanger 21 d flow out of the indoor unit 20a to indoor unit 20d. Each of the refrigerants passes through the extension pipe 400b, and flows into the outdoor unit 10. The refrigerant that has flowed into the outdoor unit 10 passes through the channel switching device 2, and flows into the accumulator 6. The refrigerant that has flowed into the accumulator 6 is separated into the liquid refrigerant and gas refrigerant, and the gas refrigerant is sucked into the compressor 1 again.

[0062] In such cooling operation mode, since the degree of superheat is controlled in each of the indoor units 20, the refrigerant in a liquid state does not flow into the accumulator 6. However, if any one of the indoor units 20 is in a transient state or stopped, a small amount of the refrigerant in a liquid state (with a quality of substantially 0.95) may flow into the accumulator 6. The liquid refrigerant that has flowed into the accumulator 6 may evaporate and be sucked into the compressor 1 or may be sucked into the compressor 1 through an oil return hole (not illustrated) disposed in the exit pipe of the accumulator 6.

[0063] Next, an operation of the supercooling circuit 101 B is described below. The refrigerant is compressed by the compressor 31, and the resultant high-temperature and high-pressure gas refrigerant is discharged. The high-temperature and high-pressure gas refrigerant that has discharged from the compressor 31 flows into the condenser 32. The high-temperature and high-pressure gas refrigerant that has flowed into the condenser 32 exchanges heat with air supplied from the air-sending device, which is not illustrated, to be liquefied and flows out of the condenser 32 into the expansion device 33. The opening degree of the expansion device 33 is adjusted such that the temperature of the high-pressure liquid refrigerant at the exit of the supercooling heat exchanger 34 is reduced to substantially 5 degrees C, as described above. The refrigerant that has flowed into the expansion device 33 is decompressed to be a low-pressure two-phase gas-liquid current, and flows into the supercooling heat exchanger 34. The liquid refrigerant that has flowed into the supercooling heat exchanger 34 exchanges heat with the high-pressure liquid refrigerant generated by the refrigerant circuit 101 A. The two-phase gas-liquid refrigerant having exchanged heat becomes a low-pressure gas refrigerant, and the gas refrigerant flows out of the supercooling heat exchanger 34, and is sucked into the compressor 31 again.

[0064] In Embodiment 2, the temperature of the high-pressure liquid refrigerant flowing out of the supercooling heat exchanger 34 is reduced to substantially 5 degrees C by the supercooling heat exchanger 34, as in Embodiment 1. As a result, the pipe diameter of the extension pipe (low-pressure gas pipe) 400b can be reduced by substantially one through two sizes, and the cost of pipes and the cost of construction can be reduced, as in Embodiment 1.

[0065] In heating operation mode, although the circuit in Embodiment 2 cannot reduce the flow rate of the refrigerant flowing into the extension pipe 400b, since the high-pressure gas refrigerant (high-density refrigerant) flows in the extension pipe 400b, the influence of the pressure loss is small, and the refrigerant is not made to flow in the supercooling heat exchanger 34, as in Embodiment 1. That is, the supercooling circuit 101 B is inactive.

[0066] In Embodiment 2, the refrigerant circuit 101A and supercooling circuit 101 B use the same HFO1234yf or HFO1234ze as the refrigerant. The supercooling circuit 101 B may use another refrigerant having small global warming potential, for example, carbon dioxide or HC refrigerant.

Embodiment 3

[0067] An air-conditioning apparatus according to Embodiment 3 is of the type capable of simultaneously cooling and heating, whose an outdoor unit 40 is applied with the outdoor unit 10 illustrated in Fig. 1 in Embodiment 1 or the outdoor unit 30 illustrated in Fig. 8 in Embodiment 2.

[0068] Fig. 10 is a schematic configuration diagram of the air-conditioning apparatus according to Embodiment 3 of the present invention. Fig. 10 illustrates a case using the outdoor unit 10 out of the outdoor unit 10 and the outdoor unit 30. This air-conditioning apparatus 102 mainly includes the heat source unit (outdoor unit) 40, a heat medium relay unit 60, and indoor units 50. The outdoor unit 40 and the heat medium relay unit 60 are connected to each other by a refrigerant pipe 401 by way of a heat exchanger related to heat medium 61 a and a heat exchanger related to heat medium 61 b

included in the heat medium relay unit 60. The heat medium relay unit 60 and the indoor units 50 are also connected to each other by a pipe 500 by way of the heat exchanger related to heat medium 61 a and the heat exchanger related to heat medium 61 b.

[Outdoor Unit 40]

[0069] The outdoor unit 40 includes the devices and various sensors included in the outdoor unit 10 in Embodiment 1 illustrated in Fig. 1, as described above, and reduces the liquid temperature of the high-pressure liquid refrigerant to substantially 5 degrees C, as in Embodiment 1 and Embodiment 2. The outdoor unit 40 further includes four check valves 41 a to 41 d to limit a refrigerant flow to a single direction. With this circuit, the temperature of the high-pressure liquid refrigerant can be reduced only in a cooling operation.

[0070] The check valve 41 d is disposed in the refrigerant pipe 401 between the heat medium relay unit 60 and the channel switching device 2 and permits a heat source side refrigerant to flow only in a predetermined direction (direction from the heat medium relay unit 60 to outdoor unit 40). The check valve 41 a is disposed in the refrigerant pipe 401 between the heat source side heat exchanger 12 and the heat medium relay unit 60 and permits the heat source side refrigerant to flow only in a predetermined direction (direction from the outdoor unit 40 to heat medium relay unit 60). The check valve 41 b is disposed in a first connection pipe 42a and is used in delivering the heat source side refrigerant discharged from the compressor 1 to the heat medium relay unit 60 in a heating operation. The check valve 41 c is disposed in a second connection pipe 42b and is used in delivering the heat source side refrigerant returning from the heat medium relay unit 60 to the suction side of the compressor 1 in the heating operation.

[0071] The first connection pipe 42a connects the refrigerant pipe 401 between the channel switching device 2 and the check valve 41 d to the refrigerant pipe 401 between the check valve 41 a and the heat medium relay unit 60 in the outdoor unit 40. The second connection pipe 42b connects the refrigerant pipe 401 between the check valve 41 d and the heat medium relay unit 60 to the refrigerant pipe 401 between the heat source side heat exchanger 12 and the check valve 41 a in the outdoor unit 40. Fig. 10 illustrates, as an example, a case where the first connection pipe 42a, second connection pipe 42b, check valve 41 a, check valve 41 b, check valve 41 c, and check valve 41 d are included. The present invention is not limited to this case. These elements are optional.

[0072] The outdoor unit 40 includes a controller 40A. The controller 40A is connected so as to be able to receive detection signals of the various sensors in the outdoor unit 40, the indoor units 50, and the heat medium relay unit 60. The controller 40A performs control such as adjusting the opening degree of each of the expansion device 5 and the expansion device 22 on the basis of detection signals from the various sensors. The controller 10A also carries out operations in cooling operation mode and in heating operation mode by switching made by the channel switching device 2. Fig. 10 illustrates a configuration in which the controller 40A is included in only the outdoor unit 40. Another configuration may also be used in which a sub-control device having part of the functions of the controller 40A is included in each of the indoor units 50 and the heat medium relay unit 60 and cooperative processing is performed by data communication between the controller 30A and the sub-control device. The controller 30A may be included in each unit, or may also be included in the heat medium relay unit 60.

[Indoor Unit 50]

[0073] The indoor units 50 include respective load-side heat exchangers 51 (51 a to 51 d). The load-side heat exchangers 51 are respectively connected to heat medium flow control devices 74 (74a to 74d) and second heat medium channel switching devices 73 (73a to 73d) in the heat medium relay unit 60 with the pipe 500. The load-side heat exchangers 51 each exchange heat between air related to the air-conditioned space supplied from an air-sending device, which is not illustrated, such as a fan and the heat medium, and generates air for heating or air for cooling to be supplied to the indoor space.

[0074] Fig. 10 illustrates a case where the four indoor units 50 are connected to the heat medium relay unit 60, as an example. The indoor unit 50a, the indoor unit 50b, the indoor unit 50c, and the indoor unit 50d are illustrated in that order from the lower side in Fig. 10. The load-side heat exchanger 51 a, the load-side heat exchanger 51 b, the load-side heat exchanger 51 c, and the load-side heat exchanger 51 d are also illustrated in that order from the lower side in Fig. 10 so as to correspond to the indoor unit 50a to indoor unit 50d, respectively. The number of the connected indoor units 50, which is illustrated in Fig. 10 is not limited to four, as in Fig. 1 and Fig. 2.

[Heat Medium Relay Unit 60]

[0075] The heat medium relay unit 60 includes two heat exchangers related to heat medium 61 (61 a, 61 b), two expansion devices 62 (62a, 62b), two opening and closing devices 63 (63a, 63b), two channel switching devices 64 (64a, 64b), two pumps 71 (71 a, 71 b), four first heat medium channel switching devices 72 (72a to 72d), four second

heat medium channel switching devices 73 (73a to 73d), and four heat medium flow control devices 74 (74a to 74d). The heat exchangers related to heat medium 61 correspond to the use side heat exchangers included in the refrigerant circuits in Embodiments 1 and 2 above.

[0076] The two heat exchangers related to heat medium 61 (heat exchanger related to heat medium 61 a, heat exchanger related to heat medium 61 b) function as a condenser (radiator) or an evaporator, exchange heat between the heat source side refrigerant and the heat medium, and transfer a cooling energy or a heating energy generated by the outdoor unit 40 and stored in the heat source side refrigerant to the heat medium. The heat exchanger related to heat medium 61 a is disposed between the expansion device 62a and the channel switching device 64a in a refrigerant circuit A and is used in heating the heat medium in cooling and heating mixed operation mode. The heat exchanger related to heat medium 61 b is disposed in the expansion device 62b and the channel switching device 64b in the refrigerant circuit A and is used in cooling the heat medium in cooling and heating mixed operation mode. Here, the two heat exchangers related to heat medium 61 are disposed, but one heat exchanger related to heat medium 61 may be used, or three or more heat exchangers related to heat medium 61 may also be used.

[0077] The two expansion devices 62 (expansion device 62a, expansion device 62b) have the functions as a pressure reducing valve and an expansion valve, and decompresses and expands the heat source side refrigerant. The expansion device 62a is disposed upstream of the heat exchanger related to heat medium 61 a in the stream of the heat source side refrigerant in a cooling operation. The expansion device 62b is disposed upstream of the heat exchanger related to heat medium 61 b in the stream of the heat source side refrigerant in the cooling operation. Each of the two expansion devices 62 may be a device with a variably controllable opening degree, such as an electronic expansion valve.

[0078] Each of the two opening and closing devices 63 (opening and closing device 63a, opening and closing device 63b) may be a two-way valve and the like to open and close the refrigerant pipe 401. The opening and closing device 63a is disposed on the entry side for the heat source side refrigerant in the refrigerant pipe 401. The opening and closing device 63b is disposed in a pipe that connects the entry side and the exit side of the refrigerant pipe 401 for the heat source side refrigerant. The two channel switching devices 64 (channel switching device 64a, channel switching device 64b) may be a four-way valve and the like to switch the flows of the heat source side refrigerant in accordance with the operation mode. The channel switching device 64a is disposed downstream of the heat exchanger related to heat medium 61 a in the stream of the heat source side refrigerant in a cooling operation. The channel switching device 64b is disposed downstream of the heat exchanger related to heat medium 61 b in the stream of the heat source side refrigerant in a cooling only operation.

[0079] Each of the two pumps 71 (pump 71 a, pump 71 b) that is a heat medium sending device circulates the heat medium passing through the pipe 500. The pump 71 a is disposed in the pipe 500 between the heat exchanger related to heat medium 61 a and the second heat medium channel switching devices 73. The pump 71b is disposed in the pipe 500 between the heat exchanger related to heat medium 61 b and the second heat medium channel switching devices 73. Each of the two pumps 71 may be configured such as a capacity controllable pump.

[0080] Each of the four first heat medium channel switching devices 72 (first heat medium channel switching device 72a to first heat medium channel switching device 72d) may be a three-way valve and the like to switch the channel of the heat medium. The number of the first heat medium channel switching devices 72 corresponds to the number of the indoor units 50 (here, four). Of the three ways of each of the first heat medium channel switching devices 72, one is connected to the heat exchanger related to heat medium 61a, another is connected to the heat exchanger related to heat medium 61 b, and the other is connected to the heat medium flow control device 74. The first heat medium channel switching device 72 is disposed on the exit side of the heat medium passage of the load-side heat exchanger 51. The first heat medium channel switching device 72a, the first heat medium channel switching device 72b, the first heat medium channel switching device 72c, and the first heat medium channel switching device 72d are illustrated in that order from the lower side in Fig. 10 so as to correspond to the indoor units 50.

[0081] Each of the four second heat medium channel switching devices 73 (second heat medium channel switching device 73a to second heat medium channel switching device 73d) may be a three-way valve and the like to switch the channel of the heat medium. The number of the second heat medium channel switching devices 73 corresponds to the number of the indoor units 50 (here, four). Of the three ways of each of the second heat medium channel switching devices 73, one is connected to the heat exchanger related to heat medium 61 a, another is connected to the heat exchanger related to heat medium 61 b, and the other is connected to the load-side heat exchanger 51. The second heat medium channel switching devices 73 are disposed on the entry sides of the heat medium passages of the load-side heat exchangers 51. The second heat medium channel switching device 73a, the second heat medium channel switching device 73b, the second heat medium channel switching device 73c, and the second heat medium channel switching device 73d are illustrated in that order from the lower side in Fig. 10 so as to correspond to the indoor units 50.

[0082] Each of the four heat medium flow control devices 74 (heat medium flow control device 74a to heat medium flow control device 74d) may be a two-way valve with a controllable opening area and the like to control the flow rate in the pipe 500. The number of the heat medium flow control devices 74 corresponds to the number of the indoor units 50 (here, four). One way of each of the heat medium flow control devices 74 is connected to the load-side heat exchanger

51, and the other way is connected to the first heat medium channel switching device 72. The heat medium flow control devices 74 are disposed on the exit side of the heat medium passage of the load-side heat exchangers 51. The heat medium flow control device 74a, the heat medium flow control device 74b, the heat medium flow control device 74c, and the heat medium flow control device 74d are illustrated in that order from the lower side in Fig. 10 so as to correspond to the indoor units 50. The heat medium flow control devices 74 may be disposed on the entry side of the respective heat medium passages of the load-side heat exchangers 51.

[0083] The heat medium relay unit 60 includes various detection devices (two first temperature sensors 81, four second temperature sensors 82, four third temperature sensors 83, and a pressure sensor 84). Detection signals related to detection by these detection devices are sent to the controller 40A, for example, and are used in controlling the driving frequency of the compressor 1, the rotation speed of the air-sending device (not illustrated), the switching by the channel switching device 2, the driving frequency of the pump 71, the switching by the channel switching device 64, and the switching of the heat medium channel.

[0084] The two first temperature sensors 81 (first temperature sensor 81 a, first temperature sensor 81 b) detect the temperatures of the heat medium flowing out of the heat exchangers related to heat medium 61, that is, the temperatures of the heat medium at the exit of the heat exchangers related to heat medium 61, and may be a thermistor, for example. The first temperature sensor 81 a is disposed in the pipe 500 at the entry side of the pump 71 a. The first temperature sensor 81 b is disposed in the pipe 500 at the entry side of the pump 71 b.

[0085] The four second temperature sensors 82 (second temperature sensor 82a to second temperature sensor 82d) are disposed between the first heat medium channel switching devices 72 and the heat medium flow control devices 74, detects the temperature of the heat medium flowing out of the load-side heat exchangers 51, and may be a thermistor. The number of the second temperature sensors 82 corresponds to the number of the indoor units 50 (here, four). The second temperature sensor 82a, the second temperature sensor 82b, the second temperature sensor 82c, and the second temperature sensor 82d are illustrated in that order from the lower side in Fig. 10 so as to correspond to the indoor units 50.

[0086] The four third temperature sensors 83 (third temperature sensor 83a to third temperature sensor 83d) are disposed on the entry sides and the exit sides of the heat exchangers related to heat medium 61 for the heat source side refrigerant, detect the temperatures of the heat source side refrigerant flowing into the heat exchangers related to heat medium 61 and the temperatures of the heat source side refrigerant flowing out of the heat exchangers related to heat medium 61, and may be a thermistor. The third temperature sensor 83a is disposed between the heat exchanger related to heat medium 61a and the channel switching device 64a. The third temperature sensor 83b is disposed between the heat exchanger related to heat medium 61 a and the expansion device 62a. The third temperature sensor 83c is disposed between the heat exchanger related to heat medium 61 b and the channel switching device 64b. The third temperature sensor 83d is disposed between the heat exchanger related to heat medium 61 b and the expansion device 62b.

[0087] The pressure sensor 84 is disposed between the heat exchanger related to heat medium 61 b and the expansion device 62b, similar to the position of the third temperature sensor 83d, and detects the pressure of the heat source side refrigerant flowing between the heat exchanger related to heat medium 61 b and the expansion device 62b.

[0088] The pipe 500 passing the heat medium includes a section connected to the heat exchanger related to heat medium 61 a and a section connected to the heat exchanger related to heat medium 61 b. The pipe 500 is split into the number corresponding to the indoor units 50 connected to the heat medium relay unit 60 (here, each section is split into four). The pipe 500 is connected at the first heat medium channel switching device 72 and the second heat medium channel switching device 73. Whether the heat medium from the heat exchanger related to heat medium 61 a is to flow into the load-side heat exchangers 51 or the heat medium from the heat exchanger related to heat medium 61 b is to flow into the load-side heat exchangers 51 is determined by controlling the first heat medium channel switching devices 72 and the second heat medium channel switching devices 73.

[0089] For the air-conditioning apparatus 102, the compressor 1, the channel switching device 2, the heat source side heat exchanger 3, the opening and closing devices 63, the channel switching devices 64, the refrigerant passages of the heat exchangers related to heat medium 61, the expansion devices 62, and the accumulator 6 are connected with the refrigerant pipe 401 to constitute the refrigerant circuit A. The heat medium passages of the heat exchangers related to heat medium 61, the pumps 71, the first heat medium channel switching devices 72, the heat medium flow control devices 74, the load-side heat exchangers 51, and the second heat medium channel switching devices 73 are connected with the pipe 500 to constitute a heat medium circuit B. That is, the plurality of load-side heat exchangers 51 are connected in parallel to each of the heat exchangers related to heat medium 61, and the heat medium circuit B operates with a plurality of lines.

[0090] Accordingly, in the air-conditioning apparatus 102, the outdoor unit 40 and the heat medium relay unit 60 are connected to each other through the heat exchanger related to heat medium 61 a and the heat exchanger related to heat medium 61 b in the heat medium relay unit 60, and the heat medium relay unit 60 and the indoor units 50 are also connected to each other through the heat exchanger related to heat medium 61 a and the heat exchanger related to

heat medium 61 b. That is, in the air-conditioning apparatus 102, the heat source side refrigerant circulating in the refrigerant circuit A and the heat medium circulating in the heat medium circuit B exchange heat with each other in the heat exchanger related to heat medium 61 a and the heat exchanger related to heat medium 61 b.

[0091] The air-conditioning apparatus 102 can perform a cooling operation or heating operation in each of the indoor units 50 on the basis of an instruction from that indoor unit 50. That is, the air-conditioning apparatus 102 can perform the same operation in all of the indoor units 50, and can also perform different operations in the indoor units 50.

[0092] The air-conditioning apparatus 102 can carry out the cooling only operation mode, at which all of the driving indoor units 50 perform a cooling operation, the heating only operation mode, at which all of the driving indoor units 50 perform a heating operation, the cooling main operation mode, at which the cooling load is larger, and the heating main operation mode, at which the heating load is larger.

[0093] As described above, according to Embodiment 3, in the air-conditioning apparatus of the type capable of simultaneously performing cooling and heating, the pipe diameter of the low-pressure pipe can be reduced by from one through two sizes, as in Embodiment 1 and Embodiment 2. As a result, the cost of pipes and the cost of construction can be reduced, in addition, the energy loss associated with disposal can be reduced, and a contribution to environmental preservation can also be achieved. Since the pressure loss can be reduced, an operation with high energy efficiency can be carried out, and the energy-saving effects are also obtainable.

[0094] The heat medium relay unit 60 may have a configuration in which it is separated into a parent heat medium relay unit including a gas-liquid separator and an expansion device and a child heat medium relay unit.

Reference Signs List

[0095] 1 compressor, 2 channel switching device, 3 heat source side heat exchanger, 4 supercooling heat exchanger, 5 expansion device, 6 accumulator, 7 bypass, 7 indoor space, 8 pressure sensor, 9 temperature sensor, 10 outdoor unit, 10A controller, 20 (20a to 20d) indoor unit, 21 (21a to 21d) use side heat exchanger, 22 (22a to 22d) expansion device, 23a to 23d temperature sensor, 24a to 24d temperature sensor, 30 outdoor unit, 30A controller, 31 compressor, 32 condenser, 33 expansion device, 34 supercooling heat exchanger, 40 outdoor unit, 40A controller, 41a to 41d check valve, 42a first connection pipe, 42b second connection pipe, 50 (50a to 50d) indoor unit, 51 (51a to 51d) load-side heat exchanger, 60 heat medium relay unit, 61 (61a, 61b) heat exchanger related to heat medium, 62 (62a, 62b) expansion device, 63 (63a, 63b) opening and closing device, 64 (64a, 64b) channel switching device, 71 (71 a, 71 b) pump, 72 (72a to 72d) first heat medium channel switching device, 73 (73a to 73d) second heat medium channel switching device, 74 (74a to 74d) heat medium flow control device, 81 (81 a, 81 b) first temperature sensor, 82 (82a to 84d) second temperature sensor, 83 (83a to 83d) third temperature sensor, 84 pressure sensor, 100 air-conditioning apparatus, 101 air-conditioning apparatus, 101A refrigerant circuit, 101 B supercooling circuit, 102 air-conditioning apparatus, 400 (400a, 400b) extension pipe, 401 refrigerant pipe, 500 pipe, A refrigerant circuit, B heat medium circuit.

Claims

1. An air-conditioning apparatus comprising:

a refrigerant circuit connecting a compressor, a heat source side heat exchanger, an expansion device, and a use side heat exchanger with pipes and circulating a refrigerant whose density in a saturated refrigerant gas at 0 degrees C is 35 to 65% of a density of an R410A refrigerant; and

supercooling means making a liquid temperature of a high-pressure liquid refrigerant sent from the heat source side heat exchanger to the expansion device be 5 degrees C or less in a cooling operation.

2. The air-conditioning apparatus of claim 1, wherein the supercooling means makes a degree of supercooling of the high-pressure liquid refrigerant be 44 degrees C or more.

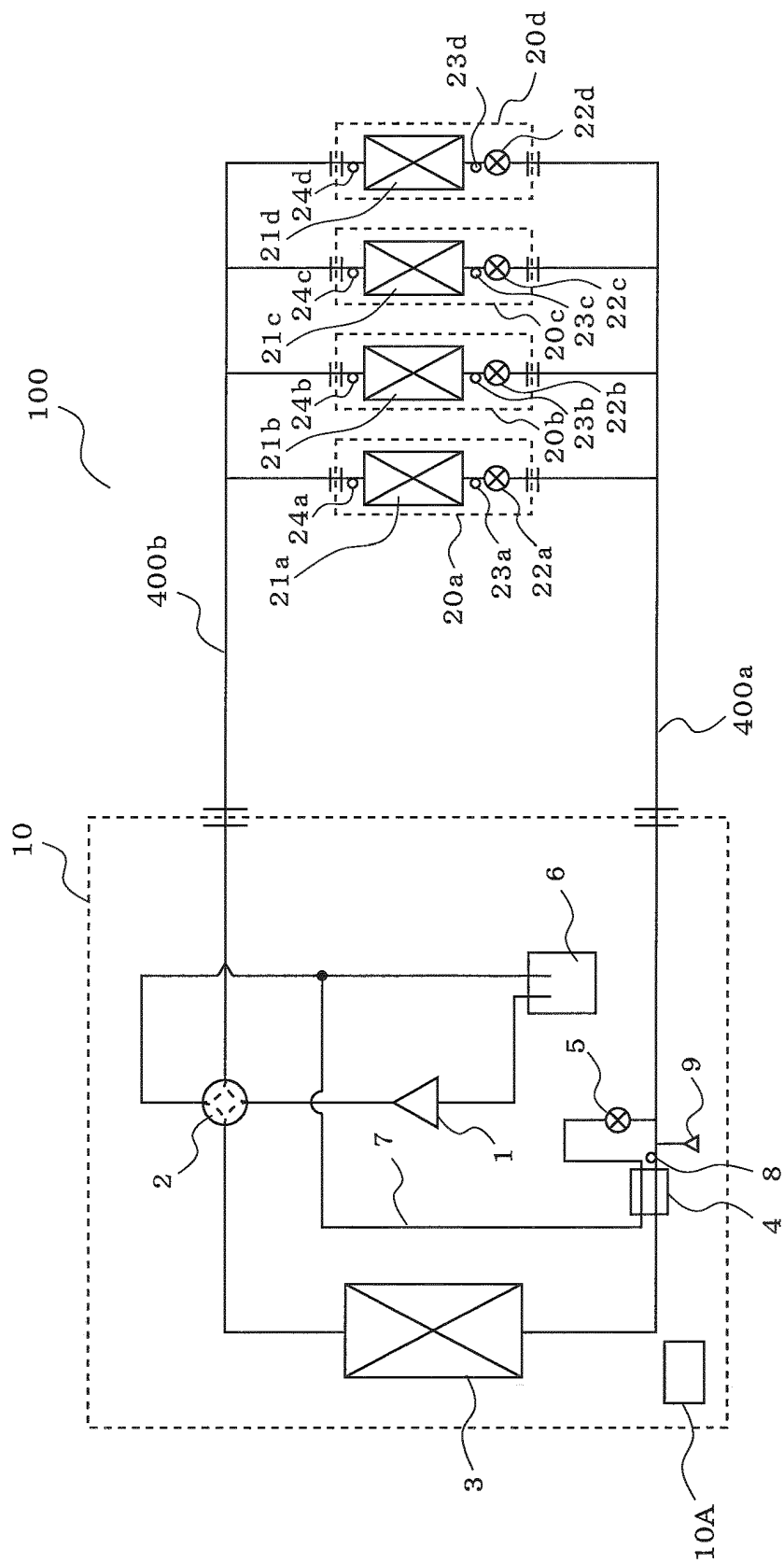
3. The air-conditioning apparatus of claim 1 or claim 2, wherein, in a heating operation, a liquid temperature of a high-pressure liquid refrigerant sent from the use side heat exchanger to the expansion device is 5 degrees C or less or a degree of supercooling thereof is 44 degrees C or more.

4. The air-conditioning apparatus of any one of claim 1 to claim 3, wherein the supercooling means includes a supercooling heat exchanger that exchanges heat between a high-pressure side refrigerant between the heat source side heat exchanger and the expansion device and a low-pressure side refrigerant that is a part of the high-pressure side refrigerant whose pressure has been reduced, so as to cool the high-pressure side refrigerant.

5. The air-conditioning apparatus of any one of claim 1 to claim 3, wherein the supercooling means includes a supercooling circuit connecting a compressor, a condenser, an expansion device, and a supercooling heat exchanger with pipes and circulating the refrigerant, and the supercooling heat exchanger exchanges heat between a low-pressure side refrigerant circulating in the supercooling circuit and the high-pressure side refrigerant between the heat source side heat exchanger and the expansion device in the refrigerant circuit.
6. The air-conditioning apparatus of claim 4 or claim 5, wherein the supercooling heat exchanger is a double-pipe heat exchanger including an annular space and an inner pipe, passing the high-pressure side refrigerant through the annular space, and passing the low-pressure side refrigerant through the inner pipe.
7. The air-conditioning apparatus of claim 4 or claim 5, wherein the supercooling heat exchanger is a plate heat exchanger in which the high-pressure side refrigerant flows from top to bottom and the low-pressure side refrigerant flows from bottom to top.
8. The air-conditioning apparatus of any one of claim 1 to claim 7, wherein HF01234yf or HF01234ze is used as the refrigerant.
9. The air-conditioning apparatus of any one of claim 1 to claim 8, wherein the refrigerant circuit includes a plurality of heat exchangers related to heat medium as the use side heat exchanger, the plurality of heat exchangers related to heat medium exchanging heat between the refrigerant and a heat medium different from the refrigerant so as to get the heat media with respective different temperatures by the heat exchanges, and the air-conditioning apparatus further comprises a heat medium circuit configured to connect:

- a plurality of pumps circulating the heat media related to the heat exchanges in the plurality of heat exchangers related to heat medium;
- a load-side heat exchanger exchanging heat between the heat medium and air related to an air-conditioned space; and
- a heat medium channel switching device switching passage of the heat medium related to passing through each of the plurality of heat exchangers related to heat medium to the load-side heat exchanger, with pipes.

FIG. 1



2
G.
I
F

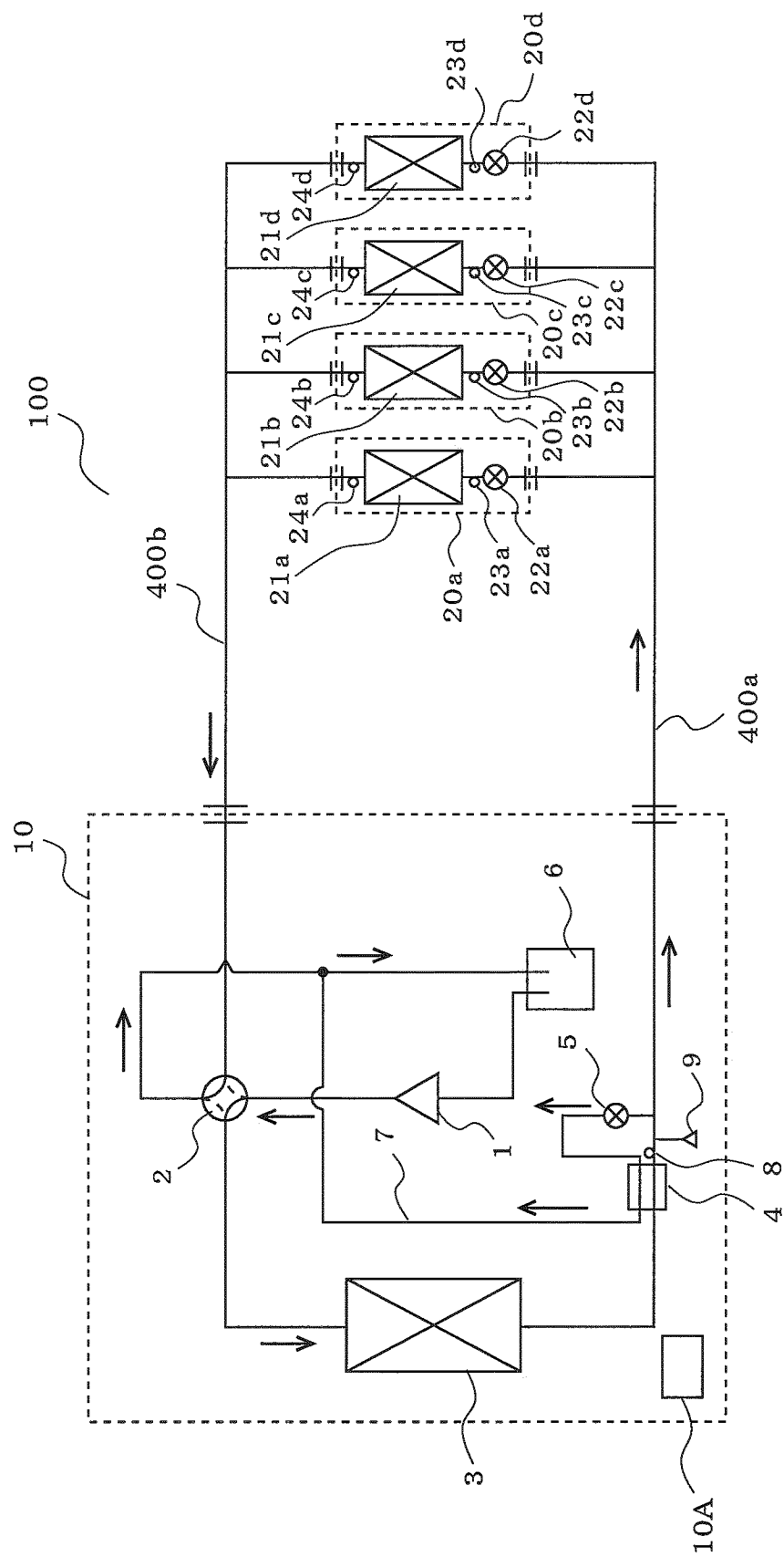


FIG. 3

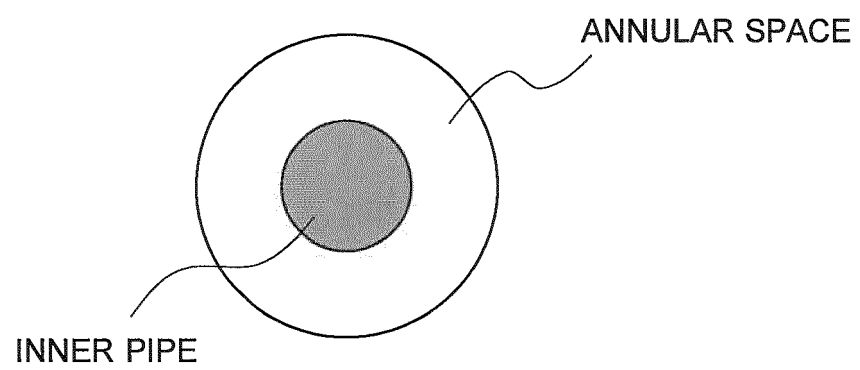


FIG. 4

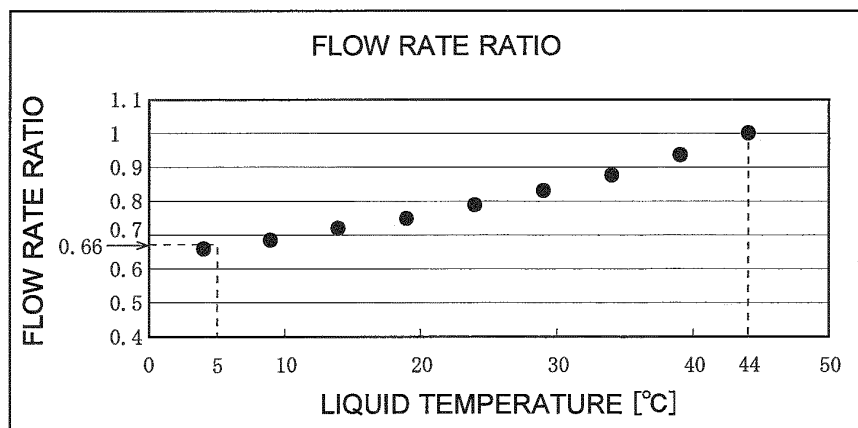


FIG. 5

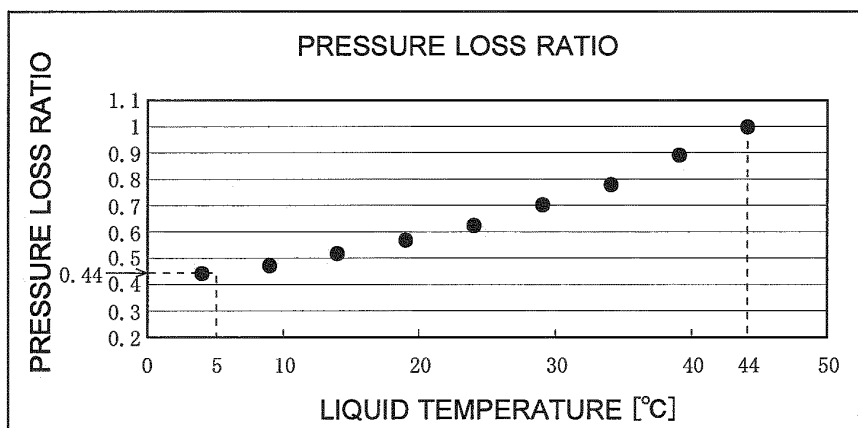


FIG. 6

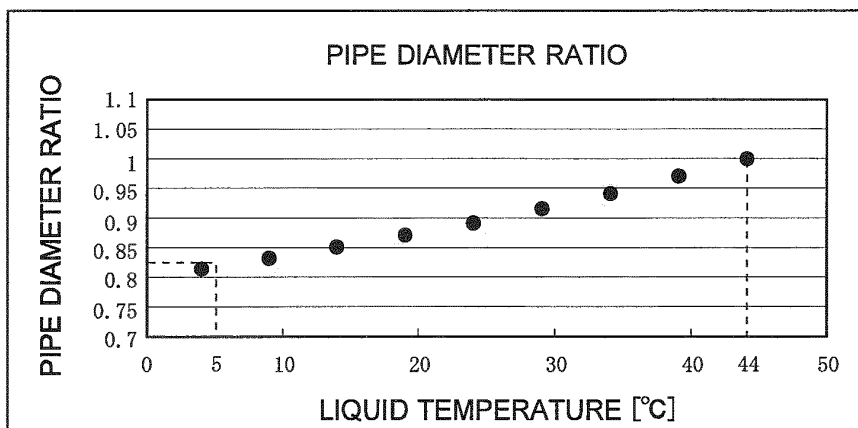
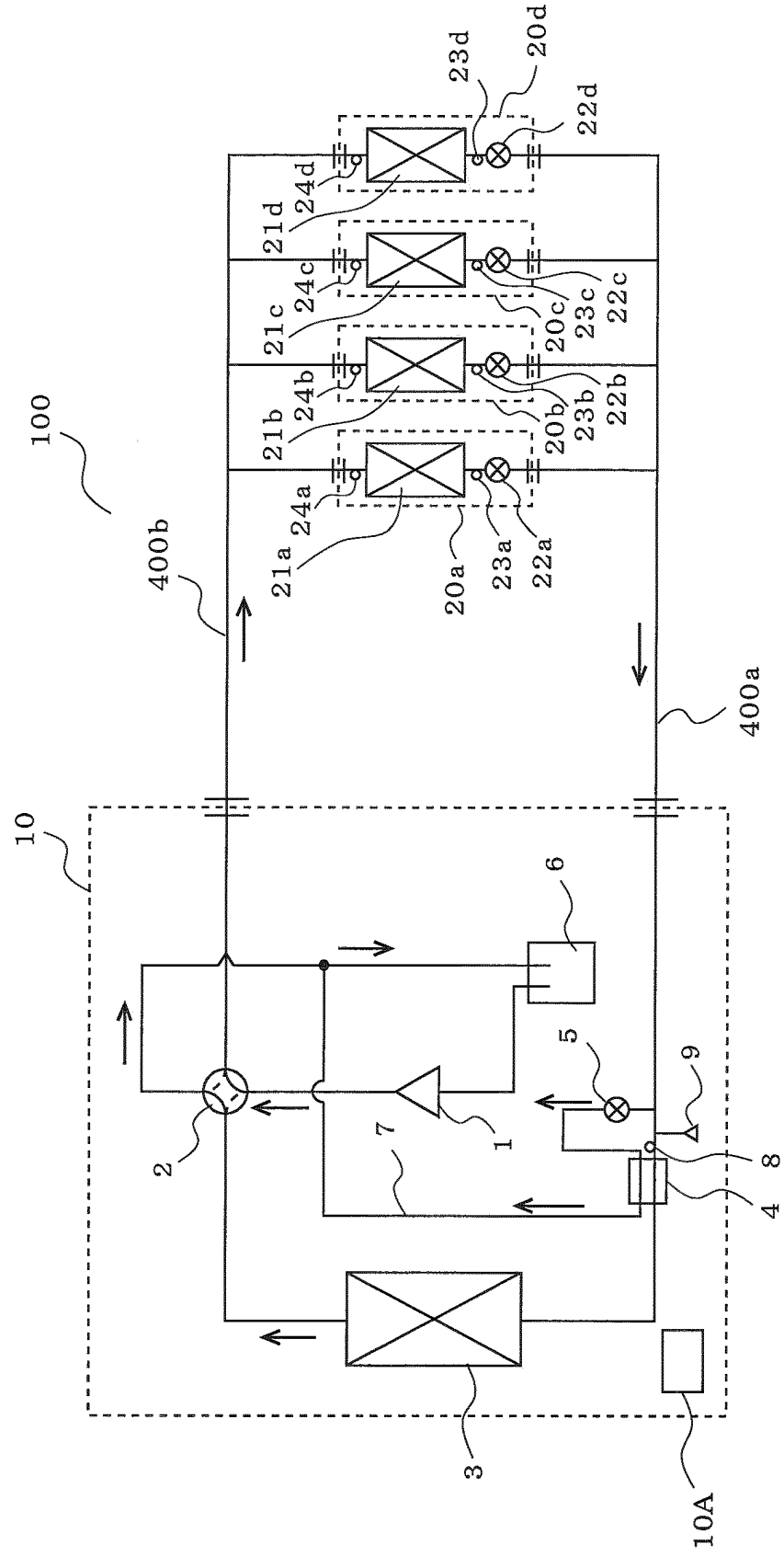
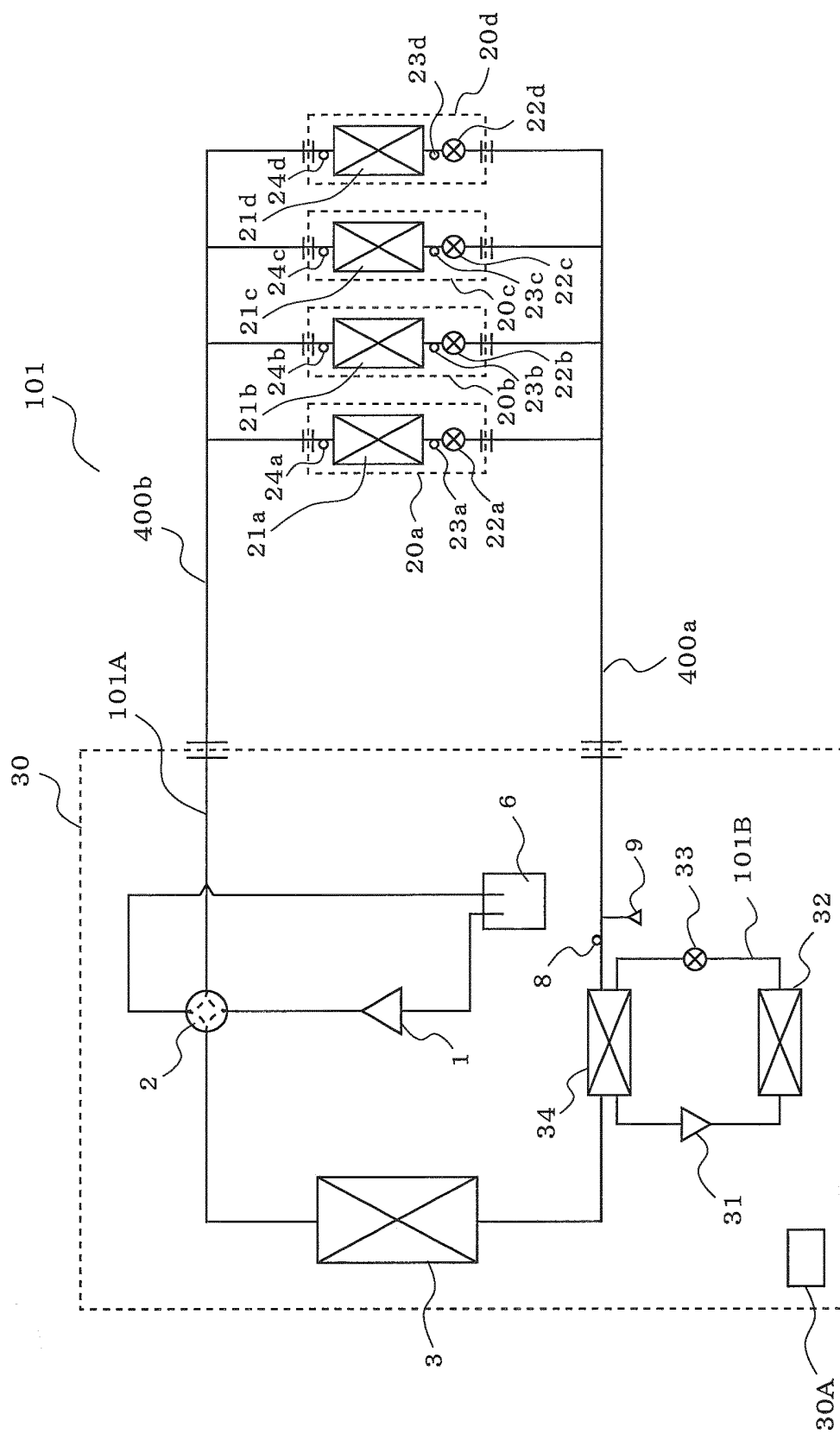


FIG. 7



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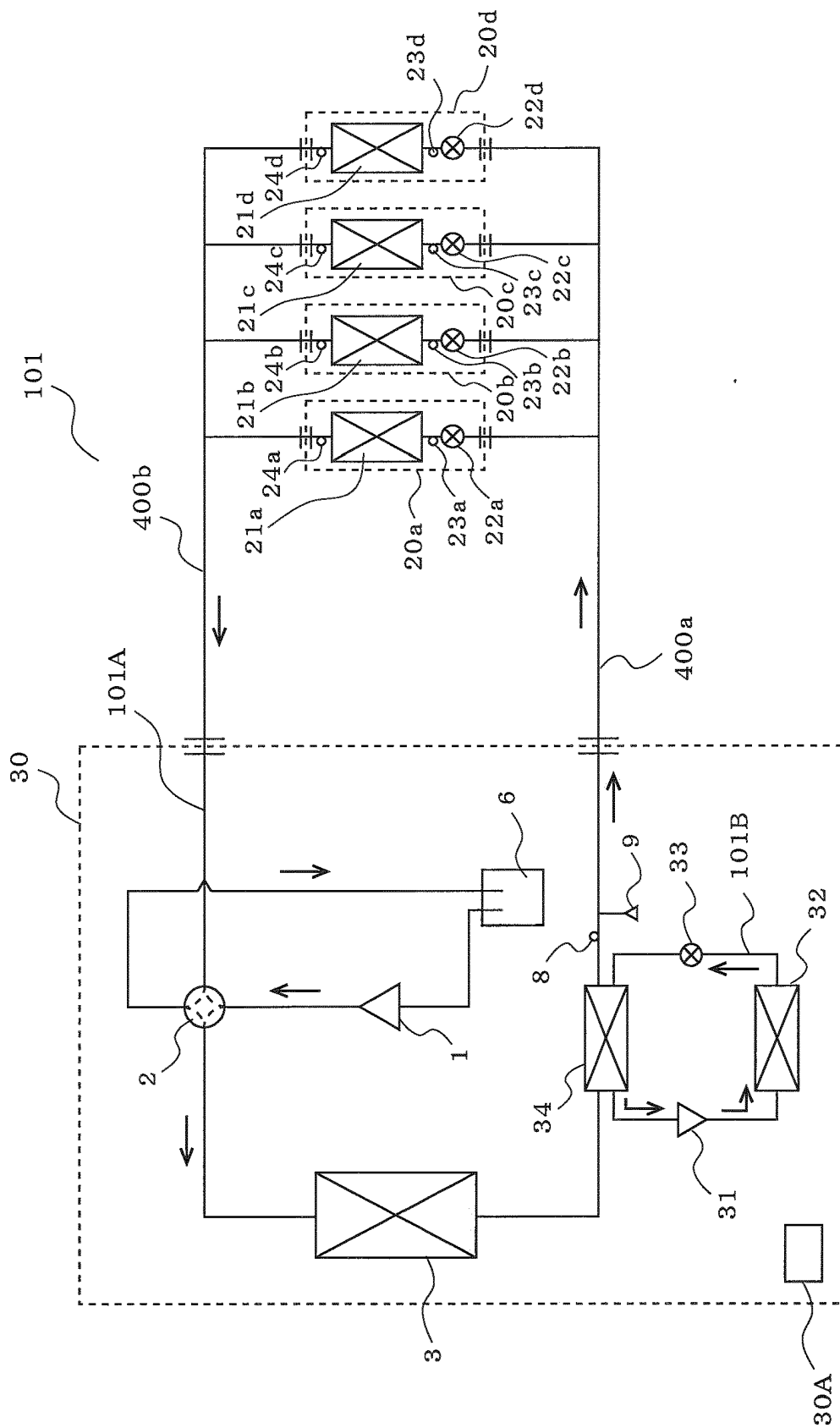
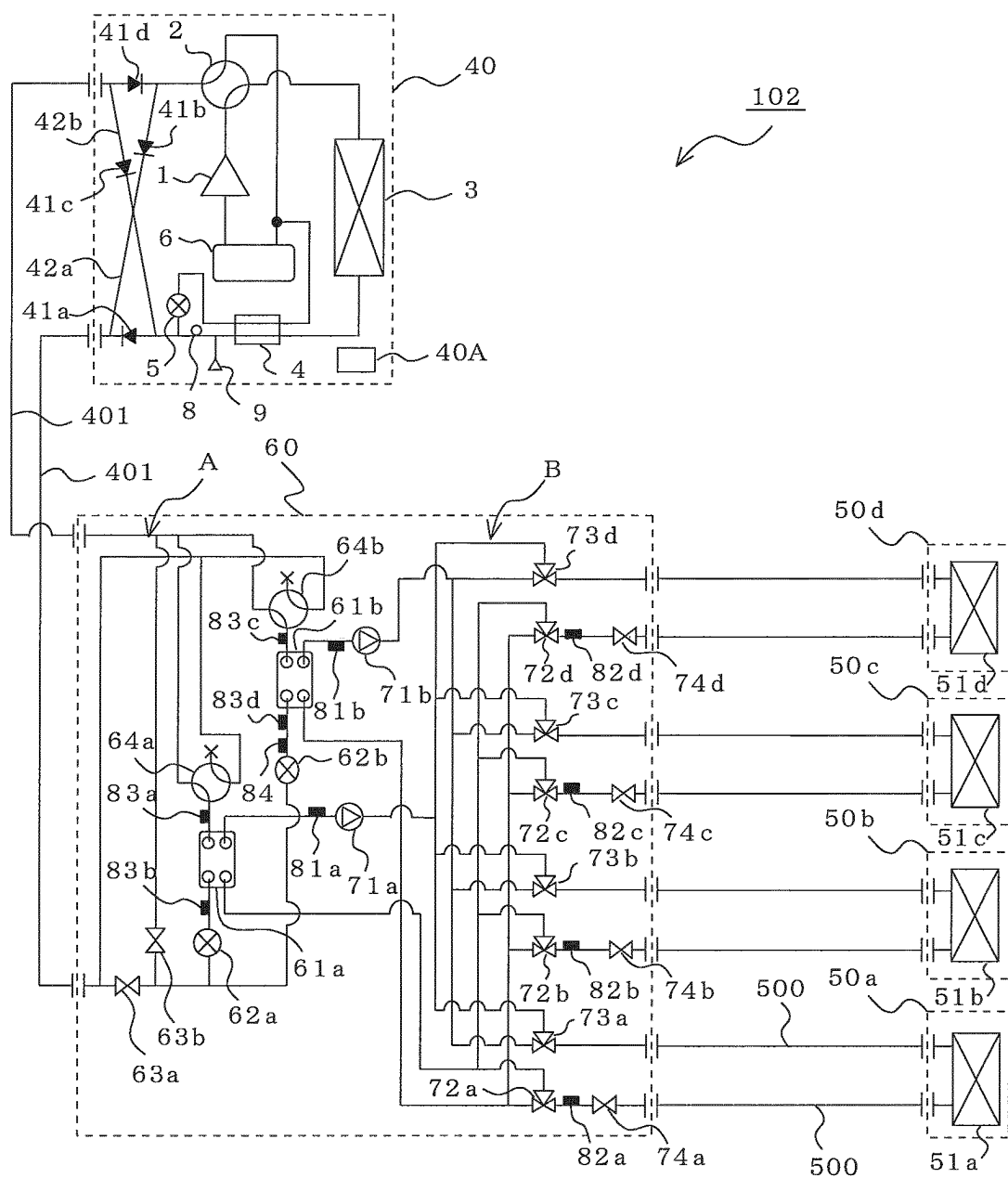


FIG. 10



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/000406

A. CLASSIFICATION OF SUBJECT MATTER

F25B1/00 (2006.01) i

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)

F25B1/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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.
Y	JP 2003-75026 A (Daikin Industries, Ltd.), 12 March 2003 (12.03.2003), claims; paragraphs [0001] to [0036] (Family: none)	1-9
Y	WO 2010/143521 A1 (Mitsubishi Electric Corp.), 16 December 2010 (16.12.2010), paragraphs [0001] to [0121]; claims; fig. 1 to 22 (Family: none)	1-9
Y	JP 2009-276002 A (Daikin Industries, Ltd.), 26 November 2009 (26.11.2009), claims; paragraphs [0001] to [0095]; fig. 1 to 7 & WO 2009/139187 A1	1-9

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

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Date of the actual completion of the international search
28 February, 2011 (28.02.11)Date of mailing of the international search report
08 March, 2011 (08.03.11)Name and mailing address of the ISA/
Japanese Patent Office

Authorized officer

Facsimile No.

Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/000406

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2009-293887 A (Daikin Industries, Ltd.), 17 December 2009 (17.12.2009), claims; paragraphs [0001] to [0104]; fig. 1 to 4 (Family: none)	1-9
Y	JP 2005-114253 A (Mitsubishi Electric Corp.), 28 April 2005 (28.04.2005), claims; paragraphs [0001] to [0039]; fig. 1 to 6 (Family: none)	5-9
Y	JP 2009-299911 A (Hitachi Appliances, Inc.), 24 December 2009 (24.12.2009), paragraphs [0006] to [0008], [0046] (Family: none)	6-9
Y	WO 2010/050002 A1 (Mitsubishi Electric Corp.), 06 May 2010 (06.05.2010), paragraphs [0001] to [0071]; claims; fig. 1 to 10 (Family: none)	9
A	JP 6-265232 A (Mitsubishi Electric Corp.), 20 September 1994 (20.09.1994), entire text; all drawings (Family: none)	1-9

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6265232 A [0003]