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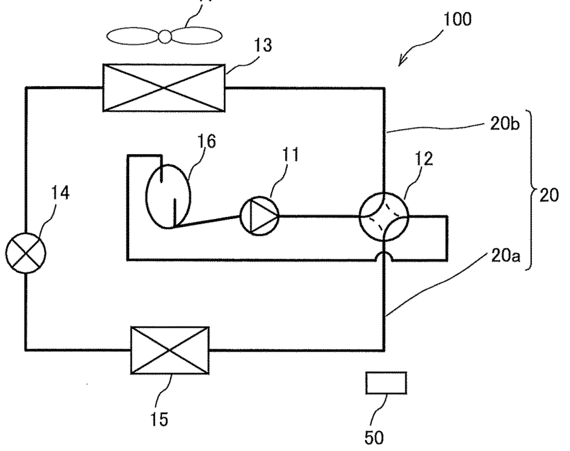
(54) **REFRIGERATION CYCLE DEVICE**

(57) A refrigeration cycle apparatus includes a refrigerant circuit in which a compressor, a refrigerant flow switching device, an air-side heat exchanger, an expansion valve, a water-side heat exchanger, and an accumulator are connected by refrigerant pipes and refrigerant is circulated. G/A is less than or equal to a predetermined threshold χ, where G [L] is a difference in volume between the air-side heat exchanger and the water-side heat exchanger, and A [L] is a volume of the refrigerant circuit.

FIG. 2



EP 4 012 290 A1

Description

Technical Field

[0001] The present disclosure relates to a refrigeration cycle apparatus in which refrigerant circulates in a refrigerant circuit.

Background Art

[0002] In general, in an air-cooled chiller, refrigerant is highly efficiently condensed at a water-side heat exchanger than at an air-side heat exchanger. Thus, the volume of the water-side heat exchanger can be reduced. Furthermore, in a heating operation, the amount of refrigerant that is required for a refrigeration cycle apparatus is smaller than that in a cooling operation. Therefore, in the heating operation in which the water-side heat exchanger operates as a condenser, it is necessary to store surplus refrigerant because a required amount of refrigerant is smaller than that in the cooling operation. In view of the above, a refrigeration cycle apparatus is proposed that can store surplus refrigerant that generates for the above reason (for example, see Patent Literature 1).

[0003] The refrigeration cycle apparatus disclosed in Patent Literature 1 includes a compressor, a refrigerant flow switching device such as a four-way valve, an air-side heat exchanger, a main expansion valve, a water-side heat exchanger, an accumulator, a refrigerant-amount adjustment tank, two sub-expansion valves serving as refrigerant flow control valves, a gas purge circuit, and a heat-source-apparatus control device serving as a controller. Furthermore, the compressor, the refrigerant flow switching device, the air-side heat exchanger, the main expansion valve, the water-side heat exchanger, and the accumulator are sequentially connected by refrigerant pipes to form a main circuit of a refrigerant circuit. In addition, the refrigerant-amount adjustment tank, the sub-expansion valves, and the gas purge circuit form a sub-circuit of the refrigerant circuit.

[0004] The refrigerant-amount adjustment tank included in the refrigeration cycle apparatus is provided in parallel with the main expansion valve, and stores surplus refrigerant that generates because of a difference between an operation state of the cooling operation and that of the heating operation.

Citation List

Patent Literature

[0005] Patent Literature 1: Japanese Patent No. 6479203

Summary of Invention

Technical Problem

[0006] In the refrigeration cycle apparatus disclosed in Patent Literature 1, the refrigerant-amount adjustment tank is housed in a machine chamber. That is, the machine chamber needs to secure a space to house the refrigerant-amount adjustment tank. Inevitably, the apparatus is made larger.

[0007] The present disclosure is applied to solve the above problem, and relates to a refrigeration cycle apparatus that can be made smaller.

Solution to Problem

[0008] A refrigeration cycle apparatus according to an embodiment of the present disclosure includes a refrigerant circuit in which a compressor, a refrigerant flow switching device, an air-side heat exchanger, an expansion valve, a water-side heat exchanger, and an accumulator are connected by refrigerant pipes and refrigerant is circulated. G/A is less than or equal to a predetermined threshold χ, where G [L] is a difference in volume between the air-side heat exchanger and the water-side heat exchanger, and A [L] is a volume of the refrigerant circuit.

Advantageous Effects of Invention

[0009] In the refrigeration cycle apparatus according to the embodiment of the present disclosure, G/A is less than or equal to the predetermined threshold χ. Therefore, the surplus refrigerant that is refrigerant the amount of which corresponds to the difference in volume between the air-side heat exchanger and the water-side heat exchanger can be stored in the refrigerant circuit, that is, the surplus refrigerant can be stored in the compressor, the air-side heat exchanger, the expansion valve, the water-side heat exchanger, the accumulator, and the refrigerant pipes. As a result, a refrigerant tank configured to store the surplus refrigerant does not need to be provided, and it is not necessary to secure a space to house the refrigerant tank in the machine chamber. Accordingly, the refrigeration cycle apparatus can be made smaller.

Brief Description of Drawings

[0010]

[Fig. 1] Fig. 1 is a perspective view illustrating an air-cooled heat pump chiller to which a refrigeration cycle apparatus according to an embodiment of the present disclosure is applied.
[Fig. 2] Fig. 2 is a schematic diagram illustrating an example of the circuit configuration of the refrigeration cycle apparatus according to the embodiment in a cooling operation.
[Fig. 3] Fig. 3 is a schematic diagram illustrating an example of the circuit configuration of the refrigeration cycle apparatus according to the embodiment in a heating operation.
[Fig. 4] Fig. 4 is a diagram indicating volumes of common high-pressure pipes for use in a refrigerant circuit, which correspond to respective sizes of the common high-pressure pipes.
[Fig. 5] Fig. 5 is a diagram indicating volumes of common low-pressure pipes for use in the refrigerant circuit, which corresponds to respective sizes of the common low-pressure pipes.
[Fig. 6] Fig. 6 is a diagram indicating a relationship between the volume of a refrigerant tank in each of existing apparatuses and a difference in volume between an air-side heat exchanger and a water-side heat exchanger in each existing apparatus.
[Fig. 7] Fig. 7 is a diagram indicating a relationship between the volume of the refrigerant tank and the difference in volume difference between the air-side heat exchanger and the water-side heat exchanger.
[Fig. 8] Fig. 8 is a diagram indicating thresholds for respective sizes of the high-pressure pipes and the low-pressure pipes indicated in Figs. 4 and 5.
[Fig. 9] Fig. 9 is a diagram indicating a relationship between the thresholds and the respective sizes of the low-pressure pipes.

Description of Embodiments

[0011] An embodiment of the present disclosure will be described with reference to the drawings. It should be noted that the following description is not limiting. Furthermore, in figures to be referred to below, relationships in size between components may be different from actual ones.

Embodiment

[0012] A refrigeration cycle apparatus 100 according to the embodiment will be described.

[0013] Fig. 1 is a perspective view illustrating an air-cooled heat pump chiller 101 to which the refrigeration cycle apparatus 100 according to the embodiment is applied. Fig. 2 is a schematic diagram illustrating an example of the circuit configuration of the refrigeration cycle apparatus 100 according to the embodiment in a cooling operation. Fig. 3 is a schematic diagram illustrating an example of the circuit configuration of the refrigeration cycle apparatus 100 according to the embodiment in a heating operation.

[0014] The refrigeration cycle apparatus 100 according to the embodiment is applied to, for example, an air-cooled heat pump chiller 101 that is provided as illustrated in Fig. 1 and that cools and heats water to generate cold water and hot water. The refrigeration cycle apparatus 100 may be applied to an air-conditioning apparatus that is provided to cool and heat an indoor space. As illustrated in Fig. 1, a machine chamber 30 that houses a compressor 11, an expansion valve 14, and other components is provided at a lower portion of the air-cooled heat pump chiller 101. Furthermore, an air-side heat exchanger 13 is provided on the machine chamber 30, and an air-side air-sending device is provided on the air-side heat exchanger 13.

[Circuit Configuration of Refrigeration Cycle Apparatus]

[0015] As illustrated in Figs. 2 and 3, the refrigeration cycle apparatus 100 includes the compressor 11, a refrigerant flow switching device 12, the air-side heat exchanger 13, the expansion valve 14, a water-side heat exchanger 15, an accumulator 16, the air-side air-sending device, and a heat-source-apparatus control device 50 serving as a controller.

[0016] Furthermore, the refrigeration cycle apparatus 100 includes a refrigerant circuit in which the compressor 11, the refrigerant flow switching device 12, the air-side heat exchanger 13, the expansion valve 14, the water-side heat exchanger 15, and the accumulator 16 are sequentially connected by refrigerant pipes 20. The refrigerant circuit is filled with refrigerant that circulates in the circuit. The refrigerant pipes include gas pipes and a liquid pipe. The gas pipes are a high-pressure pipe 20a that connects a discharge side of the compressor 11 with the water-side heat exchanger 15 in the heating operation and a low-pressure pipe 20b that connects the air-side heat exchanger 13 with a suction side of the compressor 11 in the heating operation. The liquid pipe connects the water-side heat exchanger 15 with the air-side heat exchanger 13.

[0017] As the refrigerant to be filled in the refrigerant circuit, for example, single-component refrigerant such as R-22 or R-134a, pseudo-azeotropic refrigerant mixture such as R-410A and R-404A, or non-azeotropic refrigerant mixture such as R-407C can be used. Furthermore, refrigerant having a relatively small global warming potential and including a double bond in a chemical formula, such as $CF_3CF{=}CH_2$, a mixture thereof, natural refrigerant such as CO_2 or propane can be used.

[0018] The compressor 11 sucks low-temperature and low-pressure refrigerant, compresses the low-temperature and low-pressure refrigerant to change into high-temperature and high-pressure gas refrigerant, and discharges the high-temperature and high-pressure gas refrigerant. The compressor 11 is, for example, an inverter compressor that can be controlled in volume that is a refrigerant sending amount per unit time, by arbitrarily changing a driving frequency.

[0019] The refrigerant flow switching device 12 switches a flow direction of the refrigerant between a flow direction of the refrigerant in the cooling operation and that in the heating operation. To be more specific, in the cooling operation, the refrigerant flow switching device 12 switches the flow direction of the refrigerant such that the gas refrigerant discharged from the compressor 11 flows into the air-side heat exchanger 13, as illustrated in Fig. 2. In contrast, in the heating operation, the refrigerant flow switching device 12 switches the flow direction of the refrigerant such that the gas refrigerant discharged from the compressor 11 flows tin the water-side heat exchanger 15, as illustrated in Fig. 3. The refrigerant flow switching device 12 is, for example, a four-way valve; however, other valves may be used in combination as the refrigerant flow switching device 12.

[0020] The air-side heat exchanger 13 causes heat exchange to be performed between the refrigerant and air that is supplied by, for example, the air-side air-sending device, such as fan, which is provided close to the air-side heat exchanger 13. More specifically, in the cooling operation, the air-side heat exchanger 13 operates as a condenser that radiates heat of the refrigerant to the air to condense the refrigerant. In addition, in the heating operation, the air-side heat exchanger 13 operates as an evaporator that evaporates the refrigerant to cool outdoor air with heat of evaporation at that time. The air-side heat exchanger 13 is formed by combining a plurality of plate fins and a plurality of refrigerant pipes.

[0021] The expansion valve 14 has a function of reducing the pressure of refrigerant that flows in the refrigerant circuit and expanding of the refrigerant. The expansion valve 14 is, for example, an electronic expansion valve, that is, a valve whose opening degree can be controlled.

[0022] The water-side heat exchanger 15 operates as a condenser or an evaporator, and causes heat exchange to be performed between the refrigerant that flows in the refrigerant circuit and a heat medium such as water.

[0023] The accumulator 16 is provided on the suction side of the compressor 11, which is a low-pressure side of the compressor 11. The accumulator 16 accumulates surplus refrigerant that generates because of a difference between an operation state of the cooling operation and an operation state of the heating operation, and surplus refrigerant that generates because of a transient change of the operation.

[0024] The heat-source-apparatus control device 50 controls the entire refrigeration cycle apparatus 100. The heat-source-apparatus control device 50 is, for example, dedicated hardware or a central processing unit (CPU, also referred to as a central processing device, a processing device, an arithmetic device, a microprocessor, a microcomputer, or a processor) that executes programs stored in a memory.

[0025] In the case where the heat-source-apparatus control device 50 is the dedicated hardware, the heat-source-apparatus control device 50 corresponds to, for example, a single circuit, a composite circuit, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or a combination thereof. Functional units that are implemented by the heat-source-apparatus control device 50 may be individual hardware, or the functional units may be single hardware.

[0026] In the case where the heat-source-apparatus control device 50 is the CPU, the functions that are fulfilled by the heat-source-apparatus control device 50 are fulfilled by software, firmware, or a combination of software and firmware. The software and the firmware are described as programs and are stored in the memory. The CPU reads a program from the memory and executes the read program to fulfill a function of the heat-source-apparatus control device 50 that corresponds to the program. The memory is, for example, a nonvolatile or volatile semiconductor memory such as a RAM, a ROM, a flash memory, an EPROM, or an EEPROM. It should be noted that of the functions of the heat-source-apparatus control device 50, a function or functions may be fulfilled by the dedicated hardware, and another function or other functions may be fulfilled by the software or the firmware.

[0027] The heat-source-apparatus control device 50 receives information indicating the results of detection from various kinds of detection units such as a low-pressure sensor (not illustrated) and an outside air temperature sensor (not illustrated). Furthermore, the heat-source-apparatus control device 50 controls a driving frequency of the compressor

11, a rotation speed (including on/off) of the air-side air-sending device, a switching operation of the refrigerant flow switching device 12, the opening degree of the expansion valve 14, and other operations, on the basis of operation information on the refrigeration cycle apparatus 100 that is indicated by the results of the detection and an instruction concerning the operation that is given by a user.

[0028] In the case where the amount of refrigerant that is required for the refrigerant circuit in the cooling operation is compared with that in the heating operation, the volume of the water-side heat exchanger 15 can be reduced, since the refrigerant is further efficiently condensed in the water-side heat exchanger 15 than in the air-side heat exchanger 13. Therefore, the amount of the refrigerant that is required for the refrigerant circuit in the heating operation is smaller than that in the cooling operation.

[0029] That is, in the heating operation, the amount of the refrigerant that is required for the refrigerant circuit is redundant. Therefore, in an existing apparatus, in order to compensate for the difference in the amount of refrigerant between the cooling operation and the heating operation, a refrigerant tank is provided in parallel with the expansion valve 14, and surplus refrigerant that generates in the heating operation is stored in the refrigerant tank.

[0030] However, since the refrigerant tank is housed in the machine chamber, it is necessary to secure a space for the refrigerant tank in the machine chamber. Inevitably, the existing apparatus is made larger. In view of this point, the refrigeration cycle apparatus 100 according to the embodiment is formed with no refrigerant tank.

[0031] The amount of refrigerant that can be stored between the air-side heat exchanger 13 and the water-side heat exchanger 15 varies between the cooling operation and the heating operation. In the case where all the surplus refrigerant the amount of which corresponds to the above variance in the amount of the refrigerant can be stored in the refrigerant circuit, that is, in the air-side heat exchanger 13, the water-side heat exchanger 15, the accumulator 16, and the refrigerant pipes 20, it is not necessary to provide a refrigerant tank.

[0032] In order that the surplus refrigerant be stored in the refrigerant pipes 20, it is necessary that the refrigerant in the gas pipe is present as gas refrigerant, not liquid refrigerant, to prevent a failure from occurring at the compressor 11 due to a liquid back. Furthermore, in order for the refrigerant in the gas pipes included in the refrigerant pipes 20 to be present as the gas refrigerant, it is necessary to reduce the pressure in the refrigerant circuit to a predetermined value or less. The volume of the entire refrigerant circuit is related to the pressure in the refrigerant circuit. The pressure in the refrigerant circuit is harder to raise, as the volume of the entire refrigerant circuit is increased.

[0033] Therefore, where G [L] is the difference in volume between the air-side heat exchanger 13 and the water-side heat exchanger 15, A [L] is the volume of the entire refrigerant circuit, when G/A is less than or equal to a predetermined threshold χ, that is, when $G/A \leq \chi$ is satisfied, it is possible to store all the surplus refrigerant as gas refrigerant in the refrigerant circuit, and it is therefore unnecessary to provide a refrigerant tank in the refrigerant circuit. It should be noted that the threshold χ is a threshold at which a refrigerant tank configured to store surplus refrigerant becomes unnecessary, and is a threshold determined for storing all the surplus refrigerant as gas refrigerant in the refrigerant circuit. The volume of the entire refrigerant circuit is the total volume of the compressor 11, the air-side heat exchanger 13, the expansion valve 14, the water-side heat exchanger 15, the accumulator 16, and the refrigerant pipes 20.

[0034] Next, a method of calculating the threshold χ will be described.

[0035] Fig. 4 is a diagram indicating volumes of common high-pressure pipes for use in the refrigerant circuit, which correspond to respective sizes of the common high-pressure pipes. Fig. 5 is a diagram indicating volumes of common low-pressure pipes for use in the refrigerant circuit, which correspond to respective sizes of the common low-pressure pipes. It should be noted that each of the high-pressure pipes is a pipe that connects the discharge side of the compressor with the water-side heat exchanger in the heating operation, and each of the low-pressure pipes is a pipe that connects the air-side heat exchanger with the suction side of the compressor in the heating operation, in a refrigerant circuit configuration similar to the refrigerant circuit configuration of the refrigeration cycle apparatus 100.

[0036] As a calculation condition, the difference in volume between the air-side heat exchanger and the water-side heat exchanger is set to 5 L. The length of each of the refrigerant pipes is set to 1.2 m that corresponds to that of a refrigerant pipe for use in a standard air-cooled heat pump chiller. The volume of the air-side heat exchanger, that of the water-side heat exchanger, and that of the accumulator are set to respective values that are determined depending on the performances of the air-side heat exchanger, the water-side heat exchanger and the accumulator. Furthermore, as indicated in Figs. 4 and 5, the size (outer diameter) of the high-pressure pipe is set to 25.4 mm, 28.6 mm, or 31.75 mm, and the size (outer diameter) of the low-pressure pipe is set to 25.4 mm, 28.6 mm, 31.75 mm, 34.93 mm, 38.1 mm, 41.28 mm, 44.45 mm, or 50.8 mm, based on JIS. The size (outer diameter) of the liquid pipe is set to 12.7 mm that is the size of a liquid pipe that can reduce a refrigerant pressure loss of the liquid refrigerant to a specified value or less.

[0037] It will be descried why the difference in volume between the air-side heat exchanger and the water-side heat exchanger is set to 5 L, as the calculation condition.

[0038] Fig. 6 is a diagram indicating a relationship between the volume of a refrigerant tank in each of existing apparatuses and the difference in volume between an air-side heat exchanger and a water-side heat exchanger in each existing apparatus. It should be noted that "air heat exchanger" described in Fig. 6 is an abbreviation of the air-side heat exchanger, "water heat exchanger" described in Fig. 6 is an abbreviation of the water-side heat exchanger, and the same is true of the following description.

[0039] In an existing apparatus A, the volume of an air-side heat exchanger is 19.6 L, the volume of a water-side heat exchanger is 5.4 L, and the difference in volume between the air-side heat exchanger and the water-side heat exchanger is 14.2 L. In this structure, in the existing apparatus A, a refrigerant tank having a volume of 8.5 L is mounted. In an existing apparatus B, the volume of an air-side heat exchanger is 13.9 L, the volume of a water-side heat exchanger is 5.4 L, and the difference in volume between the air-side heat exchanger and the water-side heat exchanger is 8.5 L. In this structure, in the existing apparatus B, a refrigerant tank having a volume of 4 L is mounted.

[0040] Fig. 7 is a diagram indicating a relationship between the volume of the refrigerant tank and the difference in volume between the air-side heat exchanger and the water-side heat exchanger. An equation y of a straight line indicated in Fig. 7 is obtained from the above structures of the existing apparatus A and the existing apparatus B.

[0041] As indicated in Fig. 7, it can be seen from the equation y of the straight line obtained from the existing apparatuses A and B that in the case where the difference in volume between the air-side heat exchanger and the water-side heat exchanger is less than or equal to 3.43 L, the necessary volume of the refrigerant tank is zero, that is, the refrigerant tank is unnecessary. Therefore, in consideration of individual variability, it is determined that in the case where the difference in volume between the air-side heat exchanger and the water-side heat exchanger is less than or equal to 4 L, the refrigerant tank is unnecessary. Furthermore, the liquid refrigerant can be stored in the refrigerant pipe that extends from the water-side heat exchanger to the expansion valve. In this case, when the expansion valve is provided close to the air-side heat exchanger, the length of the refrigerant pipe from the water-side heat exchanger to the expansion valve is increased, and the volume of refrigerant that can be accumulated is increased. When the expansion valve is provided close to the air-side heat exchanger, and for example, the size (outer diameter) of the liquid pipe is set to 12.7 mm, the volume of the refrigerant pipe from the water-side heat exchanger to the expansion valve is approximately 1 L. Therefore, this value is added to the difference in volume between the air-side heat exchanger and the water-side heat exchanger, thereby obtaining 5 L. Accordingly, as the calculation condition, the difference in volume between the air-side heat exchanger and the water is 5 L.

[0042] Fig. 8 is a diagram indicating thresholds for sizes of the high-pressure pipes and the low-pressure pipes that are indicated regarding their volumes in Figs. 4 and 5. Fig. 9 is a diagram indicating a relationship between the thresholds and the sizes of the low-pressure pipes. It should be noted that in Fig. 9, the vertical axis indicates the threshold, and the horizontal axis indicates the size of the low-pressure pipe.

[0043] When the threshold χ is calculated based on the above calculation condition, the threshold χ varies as indicated in Fig. 8.

[0044] Furthermore, where the size (outer diameter) of the low-pressure pipe is a variable D mm, the threshold χ for each of the sizes (outer diameters) of the high-pressure pipes is expressed by the following equation as indicated in Fig. 9.

[0045] [High-Pressure Pipe: 25.4 mm (1 inch)]

$$x = 0.0000001479D^3 - 0.0000245654D^2 + 0.0000786935D + 0.2018219300$$

[0046] [High-Pressure Pipe: 28.6 mm (1-1/8 inches)]

$$x = 0.0000001432D^3 - 0.0000239347D^2 + 0.0000774572D + 0.1991706771$$

[0047] [High-Pressure Pipe: 31.75 mm (1-1/4 inches)]

$$x = 0.0000001376D^3 - 0.0000231712D^2 + 0.0000758817D + 0.1959228337$$

[0048] Therefore, when G/A is less than or equal to the above-described threshold χ, it is possible to store all the surplus refrigerant as gas refrigerant in the refrigerant circuit, and it is therefore unnecessary to provide a refrigerant tank in the refrigerant circuit.

[0049] As described above, the refrigeration cycle apparatus 100 according to the embodiment includes the refrigerant circuit in which the compressor 11, the refrigerant flow switching device 12, the air-side heat exchanger 13, the expansion valve 14, the water-side heat exchanger 15, and the accumulator 16 are connected by the refrigerant pipes 20 and the refrigerant is circulated. Where G [L] is the difference in volume between the air-side heat exchanger 13 and the water-side heat exchanger 15, and A [L] is the volume of the entire refrigerant circuit, G/A is less than or equal to the predetermined threshold χ.

[0050] In the refrigeration cycle apparatus 100 according to the embodiment, G/A is less than or equal to the predetermined threshold χ. Therefore, the surplus refrigerant that is refrigerant the amount of which corresponds to the difference in volume between the air-side heat exchanger 13 and the water-side heat exchanger 15 can be stored in the refrigerant circuit, that is, the surplus refrigerant can be stored in the compressor 11, the air-side heat exchanger 13, the expansion valve 14, the water-side heat exchanger 15, the accumulator 16, and the refrigerant pipes 20. As a result, a refrigerant storage tank does not need to be provided. Accordingly, it is not necessary to secure, in the machine chamber a space for a refrigerant-amount adjustment tank, and the refrigerant cycle apparatus can thus be made smaller.

[0051] Further, since a refrigerant storage tank is unnecessary, it is not necessary to provide a refrigerant-amount adjustment tank in the machine chamber, and it is therefore possible to improve the maintainability of the refrigerant cycle apparatus. Reference Signs List

[0052] 11: compressor, 12: refrigerant flow switching device, 13: air-side heat exchanger, 14: expansion valve, 15: water-side heat exchanger, 16: accumulator, 17: air-side air-sending device, 20: refrigerant pipe, 20a: high-pressure pipe, 20b: low-pressure pipe, 30: machine chamber, 50: heat-source-apparatus control device, 100: refrigeration cycle apparatus, 101: air-cooled heat pump chiller

Claims

1. A refrigeration cycle apparatus comprising a refrigerant circuit in which a compressor, a refrigerant flow switching device, an air-side heat exchanger, an expansion valve, a water-side heat exchanger, and an accumulator are connected by refrigerant pipes and refrigerant is circulated,
wherein G/A is less than or equal to a predetermined threshold χ, where G [L] is a difference in volume between the air-side heat exchanger and the water-side heat exchanger, and A [L] is a volume of the refrigerant circuit.

2. The refrigeration cycle apparatus of claim 1, wherein

   the refrigerant pipes include a high-pressure pipe that connects a discharge side of the compressor with the water-side heat exchanger in a heating operation and a low-pressure pipe that connects the air-side heat exchanger with a suction side of the compressor in the heating operation, and
   where an outer diameter of the high-pressure pipe is 25.4 mm, and an outer diameter of the low-pressure pipe is D mm, the threshold χ is expressed by the following equation:

$$x = 0.0000001479D^3 - 0.00000245654D^2 + 0.0000786935D + 0.2018219300.$$

3. The refrigeration cycle apparatus of claim 1, wherein

   the refrigerant pipes include a high-pressure pipe that connects a discharge side of the compressor with the water-side heat exchanger in a heating operation and a low-pressure pipe that connects the air-side heat exchanger with a suction side of the compressor in the heating operation, and
   where an outer diameter of the high-pressure pipe is 28.6 mm, and an outer diameter of the low-pressure pipe is D mm, the threshold χ is expressed by the following equation:

$$x = 0.0000001432D^3 - 0.00000239347D^2 + 0.0000774572D + 0.1991706771.$$

4. The refrigeration cycle apparatus of claim 1, wherein

   the refrigerant pipes include a high-pressure pipe that connects a discharge side of the compressor with the water-side heat exchanger in a heating operation and a low-pressure pipe that connects the air-side heat exchanger with a suction side of the compressor in the heating operation, and
   where an outer diameter of the high-pressure pipe is 31.75 mm, and an outer diameter of the low-pressure pipe is D mm, the threshold χ is expressed by the following equation:

$$x = 0.0000001376D^3 - 0.00000231712D^2 + 0.0000758817D + 0.1959228337.$$

FIG. 1

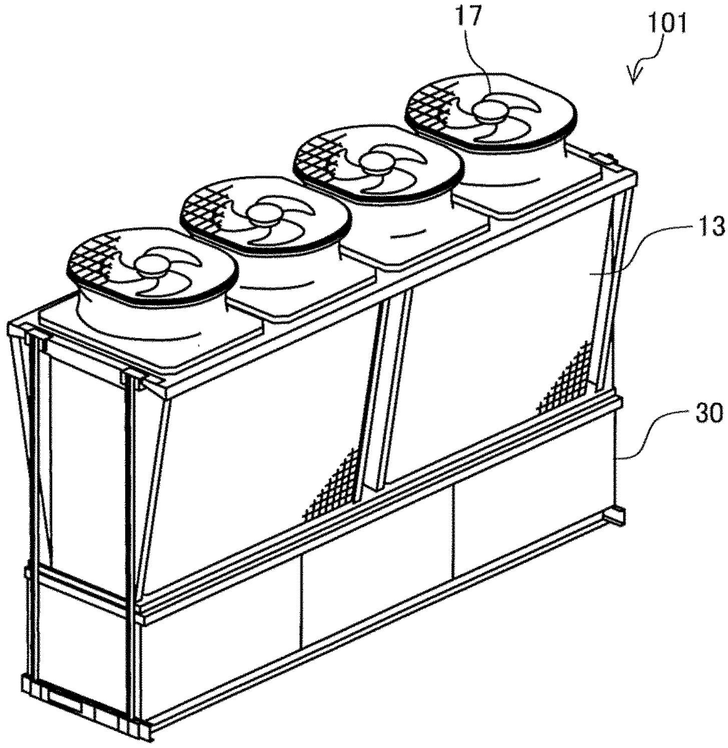


FIG. 2

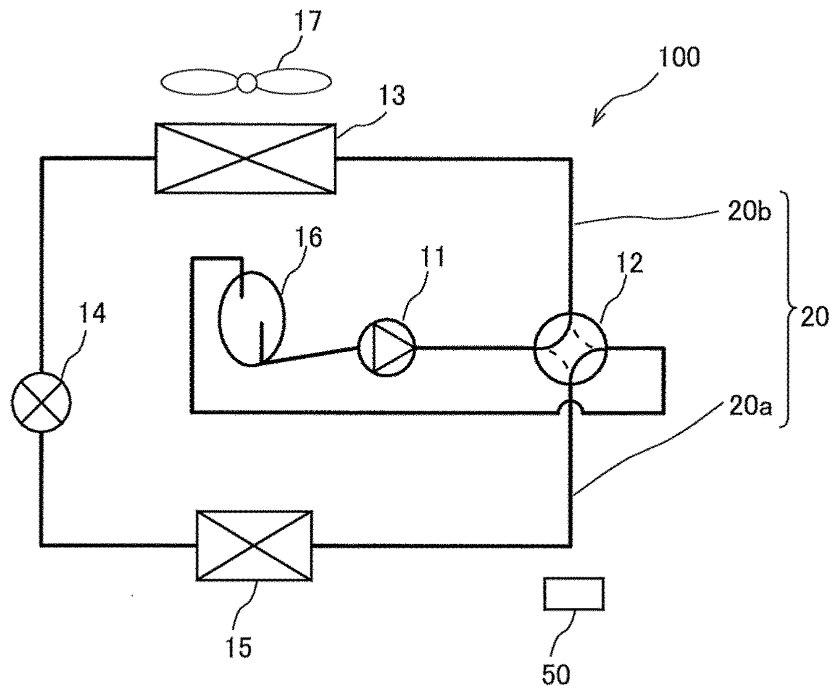


FIG. 3

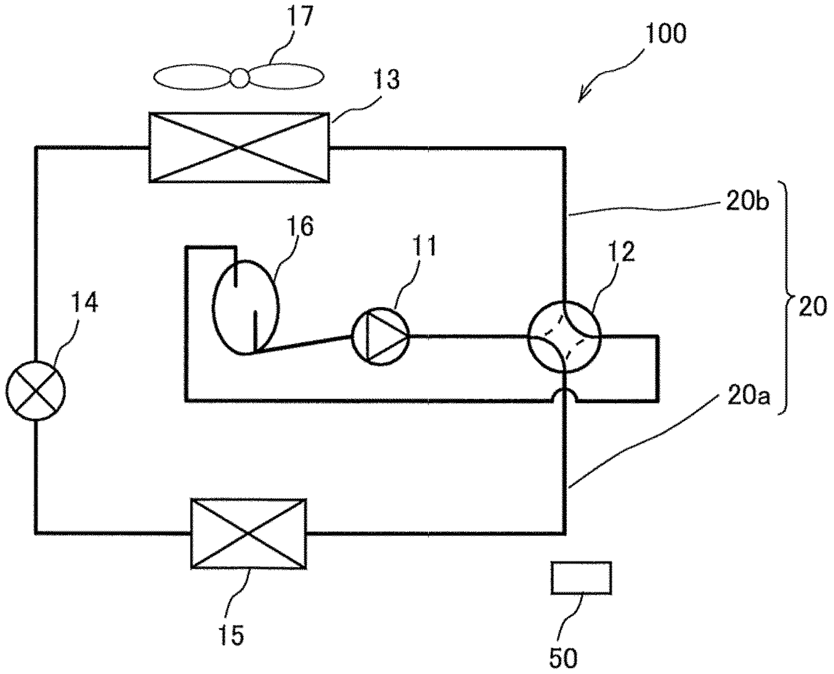


FIG. 4

HIGH-PRESSURE PIPE REFRIGERANT VOLUME			
PIPE SIZE (B)	1	1-1/8	1-1/4
PIPE SIZE (mm)	25.4	28.6	31.75

FIG. 5

LOW-PRESSURE PIPE REFRIGERANT VOLUME								
PIPE SIZE (B)	1	1-1/8	1-1/4	1-3/8	1-1/2	1-5/8	1-3/4	2
PIPE SIZE (mm)	25.4	28.6	31.75	34.93	38.1	41.28	44.45	50.8

FIG. 6

REFRIGERANT VOLUMES OF EXISTING APPARATUS AND EXISTING APPARATUS B

	VOLUME			VOLUME DIFFERENCE (L)
	AIR-SIDE HEAT EXCHANGER	WATER-SIDE HEAT EXCHANGER	REFRIG-ERANT TANK	AIR-SIDE HEAT EXCHANGER - WATER-SIDE HEAT EXCHANGER
EXISTING APPARATUS A	19.6	5.4	8.5	14.2
EXISTING APPARATUS B	13.9	5.4	4	8.5

FIG. 7

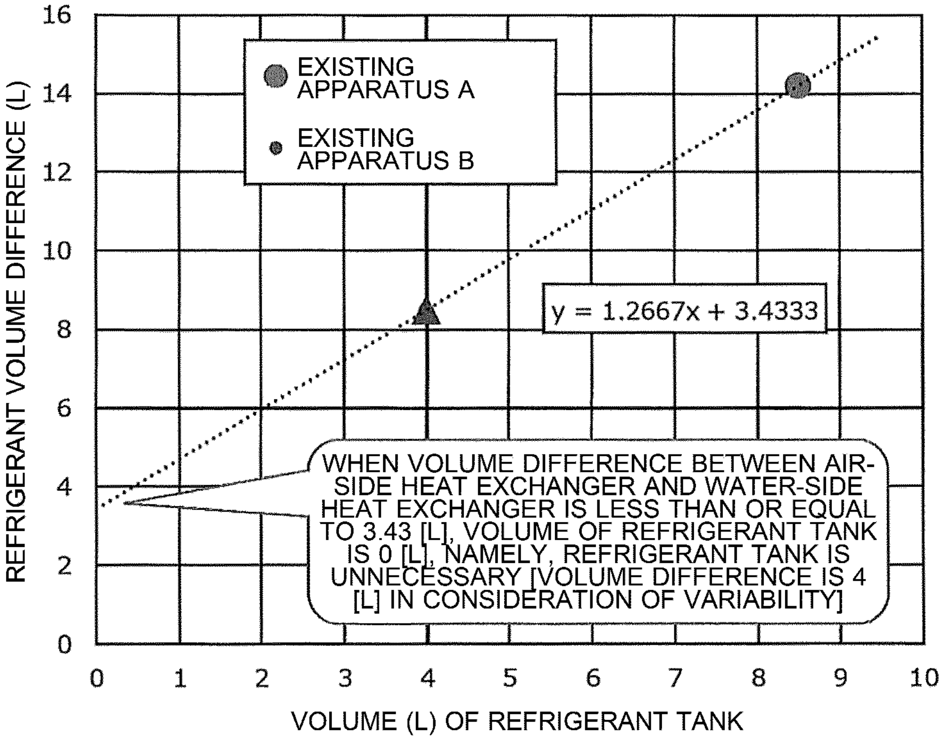
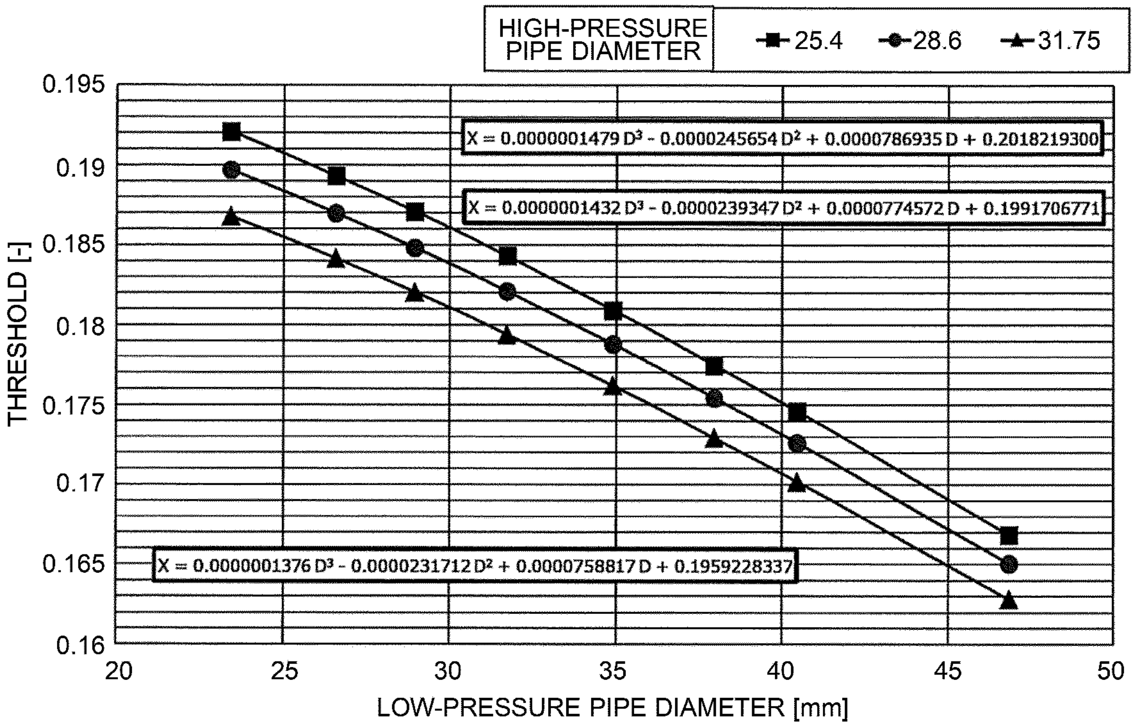


FIG. 8

STRUCTURE WITHOUT REFRIGERANT TANK (VOLUME DIFFERENCE BETWEEN AIR-SIDE HEAT EXCHANGER AND WATER-SIDE HEAT EXCHANGER: 5L)

VOLUME OF ENTIRE CIRCUIT		HIGH-PRESSURE PIPE		
		1	1-1/8	1-1/4
LOW-PRESSURE PIPE		25.4	28.6	31.75
1	25.4	0.192	0.190	0.187
1-1/8	28.6	0.189	0.187	0.184
1-1/4	31.75	0.187	0.185	0.182
1-3/8	34.93	0.184	0.182	0.179
1-1/2	38.1	0.181	0.179	0.176
1-5/8	41.28	0.177	0.175	0.173
1-3/4	44.45	0.175	0.173	0.170
2	50.8	0.167	0.165	0.163

FIG. 9



HIGH-PRESSURE PIPE DIAMETER
25.4
28.6
31.75
X = 0.0000001479 D³ - 0.0000245654 D² + 0.0000786935 D + 0.2018219300
X = 0.0000001432 D³ - 0.0000239347 D² + 0.0000774572 D + 0.1991706771
X = 0.0000001376 D³ - 0.0000231712 D² + 0.0000758817 D + 0.1959228337
THRESHOLD [-]
0.195
0.19
0.185
0.18
0.175
0.17
0.165
0.16
20
25
30
35
40
45
50
LOW-PRESSURE PIPE DIAMETER [mm]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2019/031084

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl. F25B1/00(2006.01)i, F25B41/00(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)
Int. Cl. F25B1/00, F25B41/00

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 1971-2019
Registered utility model specifications of Japan 1996-2019
Published registered utility model applications of Japan 1994-2019

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 Y	WO 2010/128551 A1 (MITSUBISHI ELECTRIC CORP.) 11 November 2010, paragraphs [0012], [0039], fig. 2 & US 2012/0043056 A1, fig. 2, paragraphs [0022], [0055] & EP 2428741 A1 & CN 102422091 A	1 1-4
Y	JP 2011-27314 A (MITSUBISHI ELECTRIC CORP.) 10 February 2011, paragraphs [0036]-[0038] (Family: none)	1-4
Y	WO 2011/121634 A1 (MITSUBISHI ELECTRIC CORP.) 06 October 2011, paragraphs [0031]-[0033] & US 2013/0000339 A1, paragraphs [0057]-[0059] & EP 2554926 A1 & CN 102844631 A	1-4

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

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"O" document referring to an oral disclosure, use, exhibition or other means
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02.09.2019	10.09.2019

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2019/031084

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2001-174088 A (SANYO ELECTRIC CO., LTD.) 29 June 2001, paragraphs [0013]-[0021], fig. 1 (Family: none)	1-4

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 6479203 B **[0005]**