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**MAEDA et al.**

(54) **THERMAL MANAGEMENT SYSTEM**

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(52) **U.S. Cl.**

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(57) **ABSTRACT**

A thermal management system includes refrigeration cycle equipment and a heating medium circuit. The heating medium circuit includes a high-temperature-side circuit connecting with the heating medium channel of the high-temperature-side water-refrigerant heat exchange portion, a low-temperature-side circuit connecting with a heating medium channel of a low-temperature-side water-refrigerant heat exchange portion, and a heat transfer portion connecting the high-temperature-side circuit and the low-temperature-side circuit. The low-temperature-side circuit includes a first heat exchange portion, a second heat exchange portion, a heating medium bypass channel, and a low-temperature-side circuit switching portion. While the heat transfer portion is transferring heat, the low-temperature-side circuit switching portion switches a circuit configuration of the low-temperature-side circuit to a circuit configuration that circulates the heating medium between the first heat exchange portion and the heating medium bypass channel.

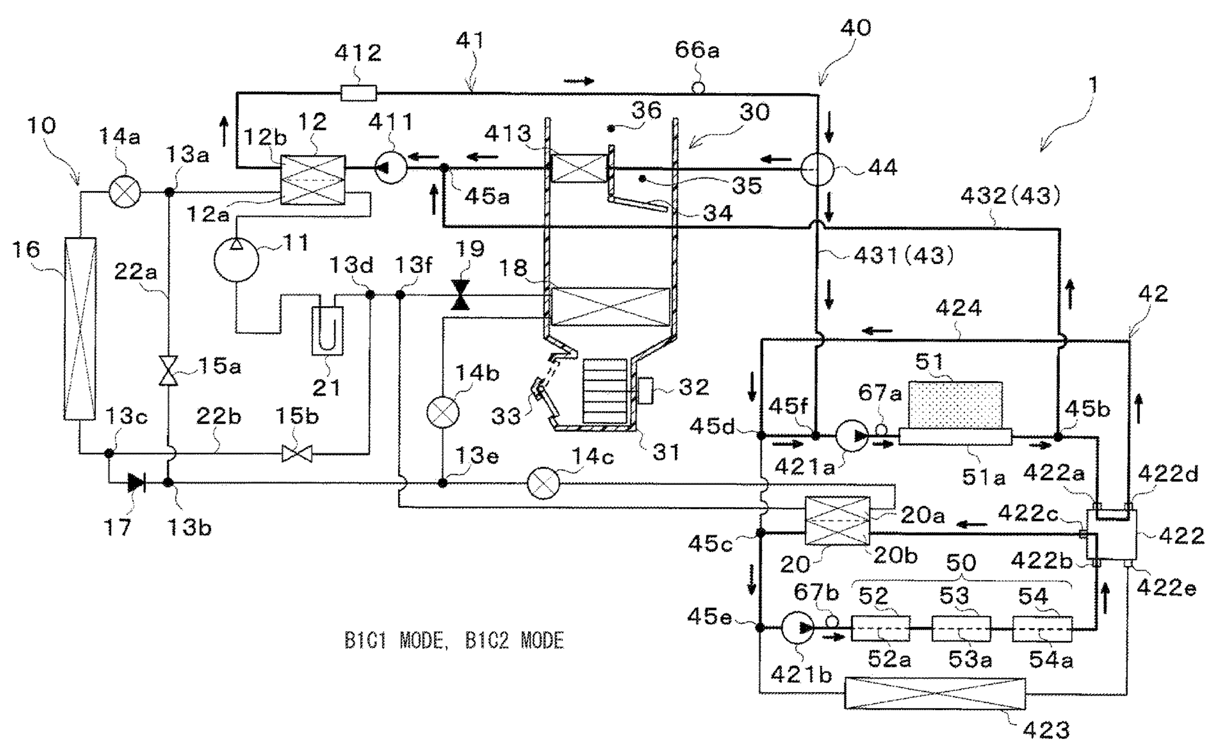

FIG. 1

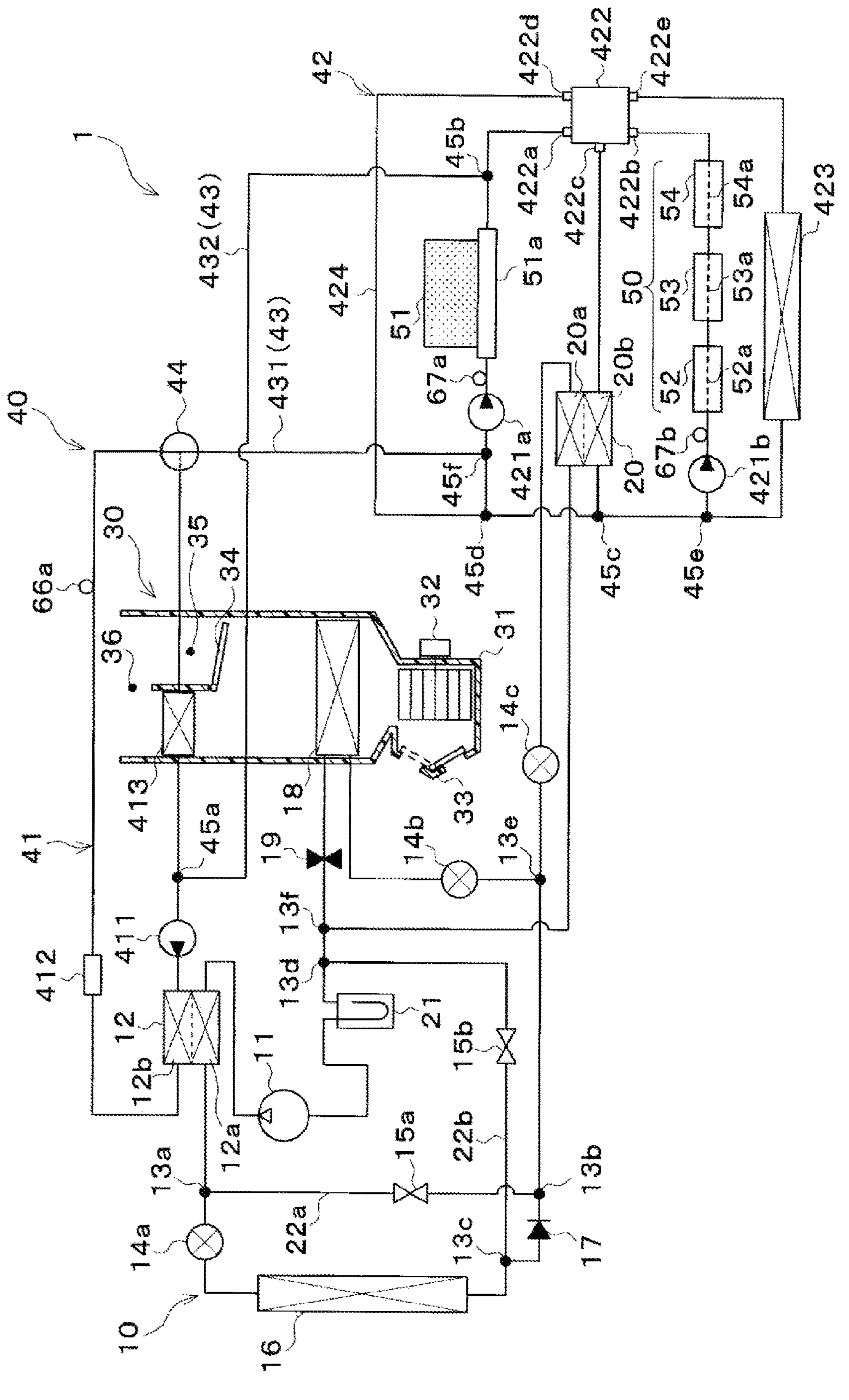
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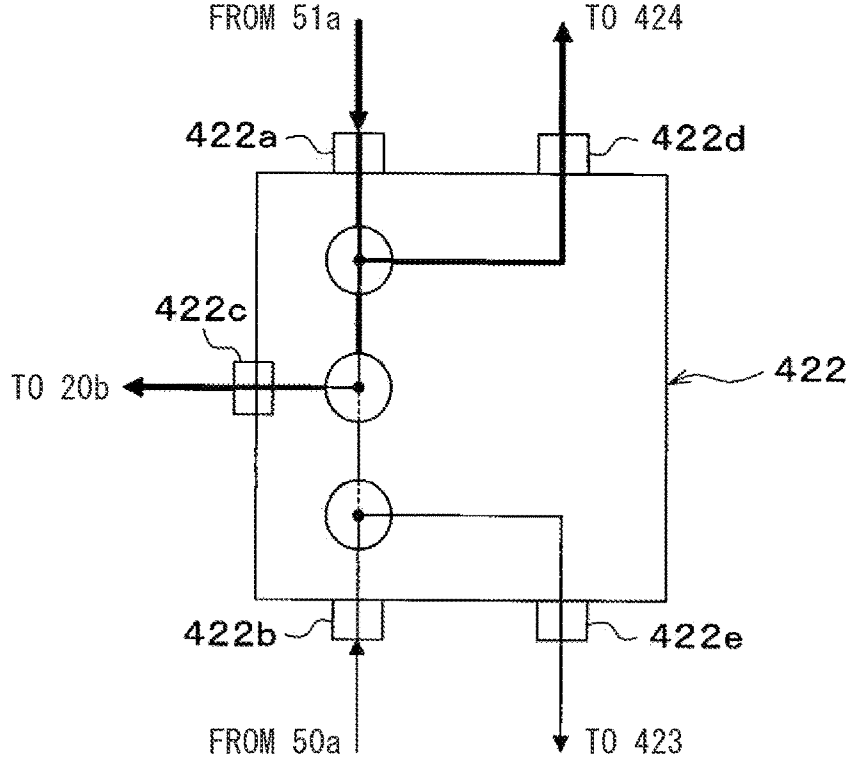
FIG. 2


FROM 51a
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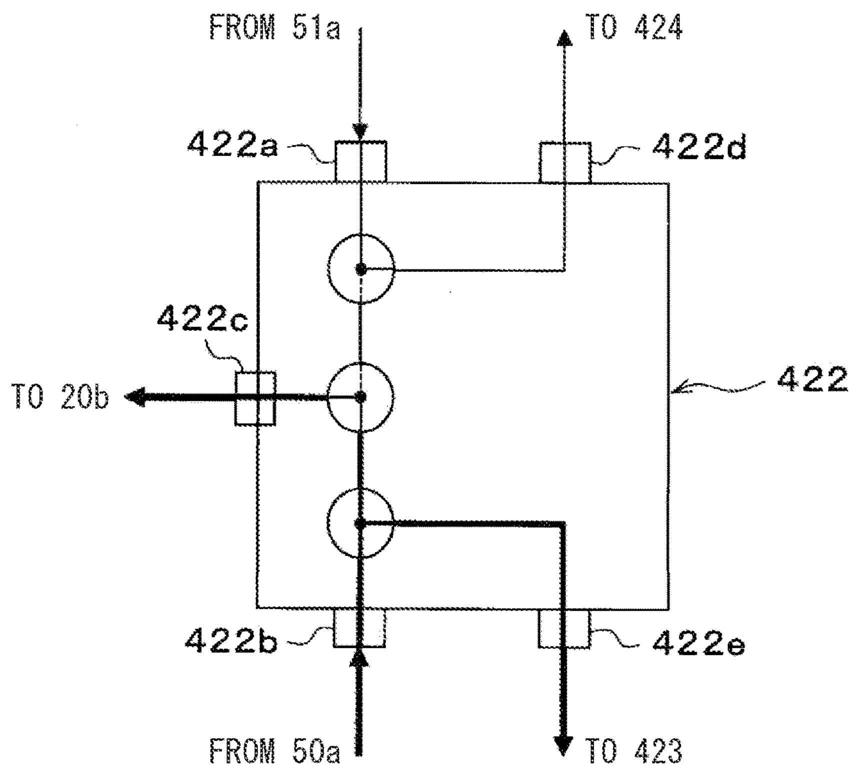
FROM 50a
TO 423

FIG. 3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FROM 50a
TO 423

FIG. 4

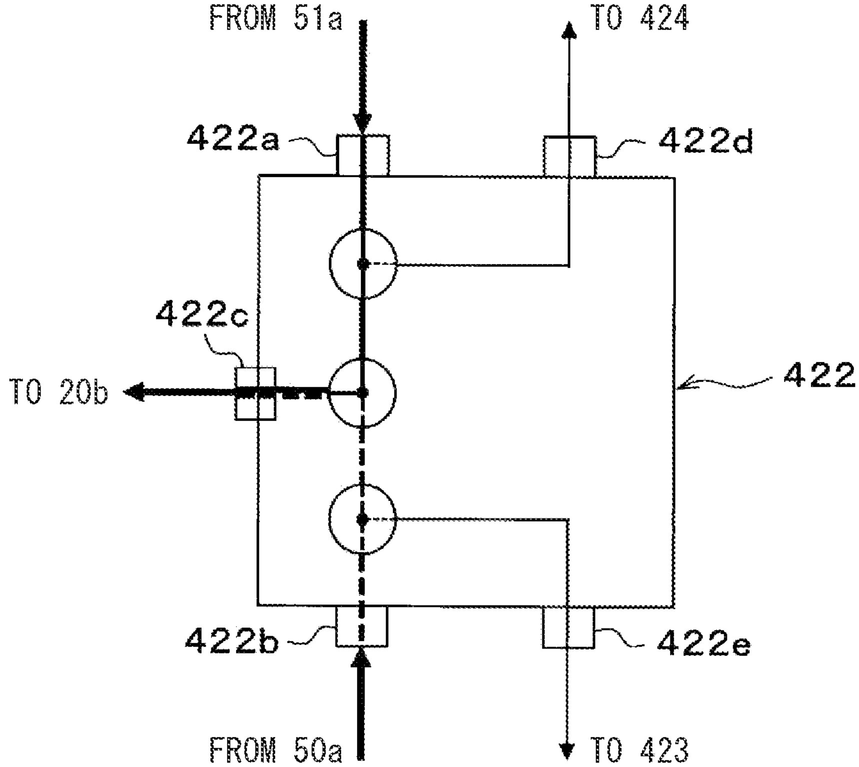
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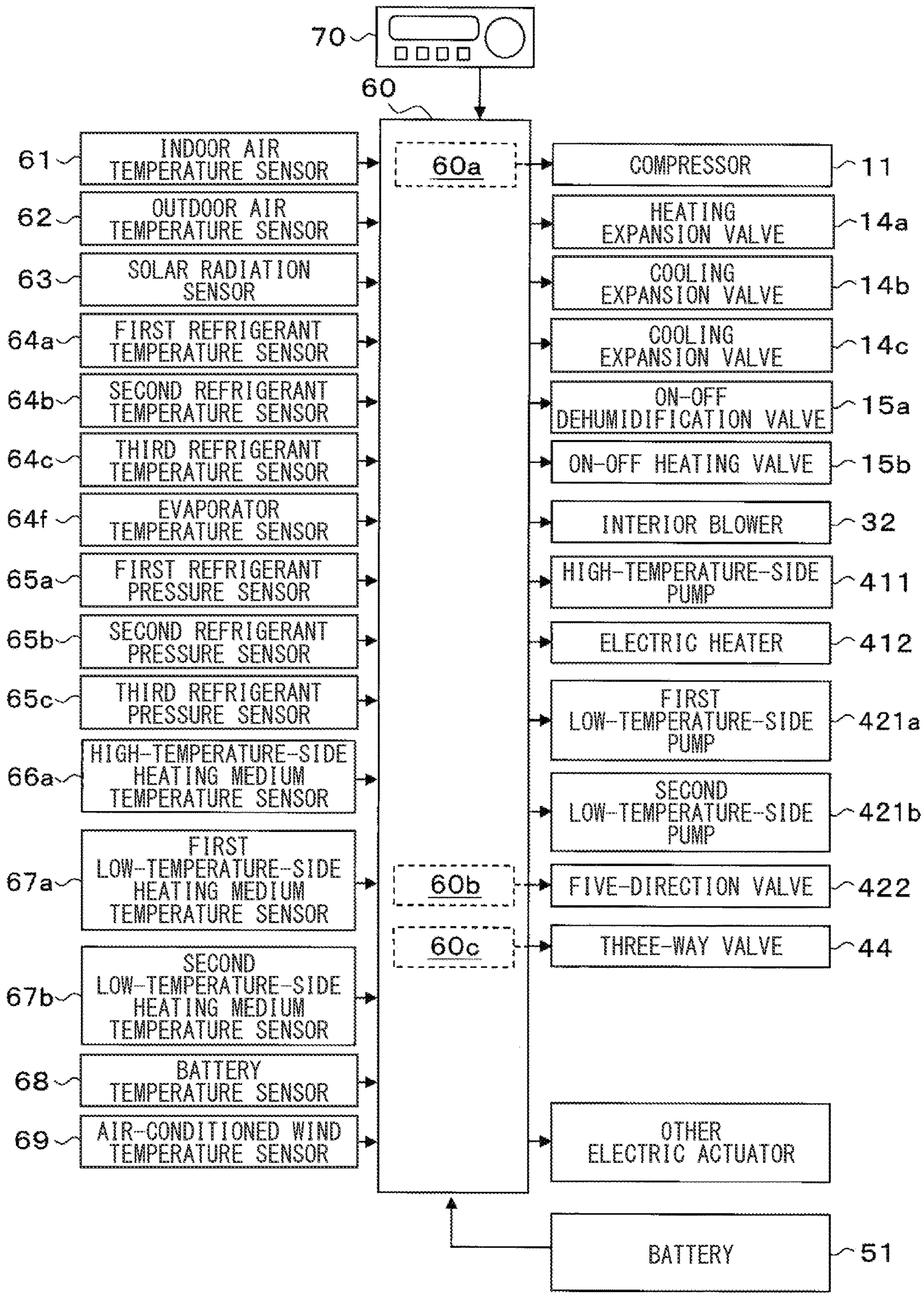
FIG. 5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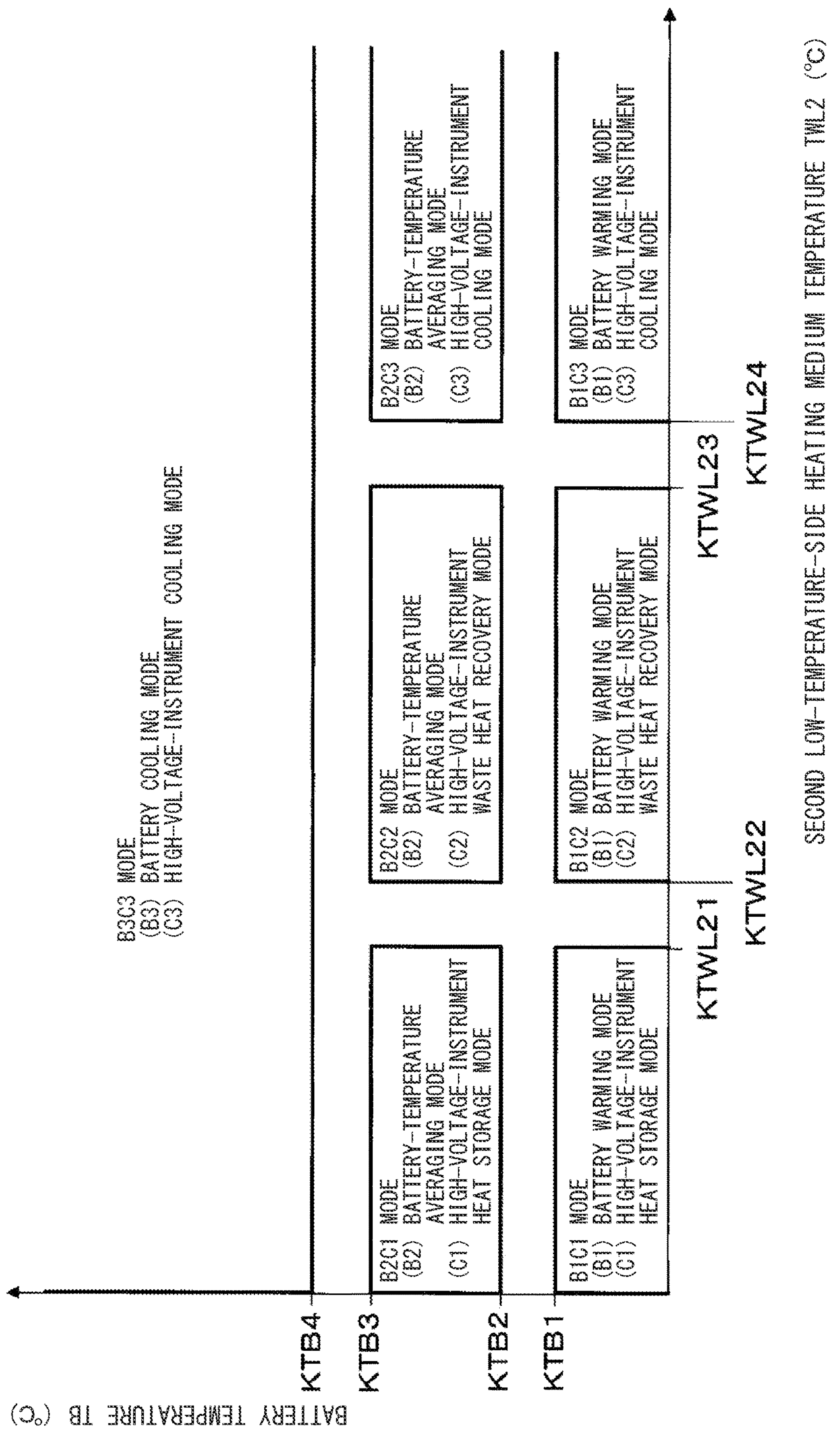
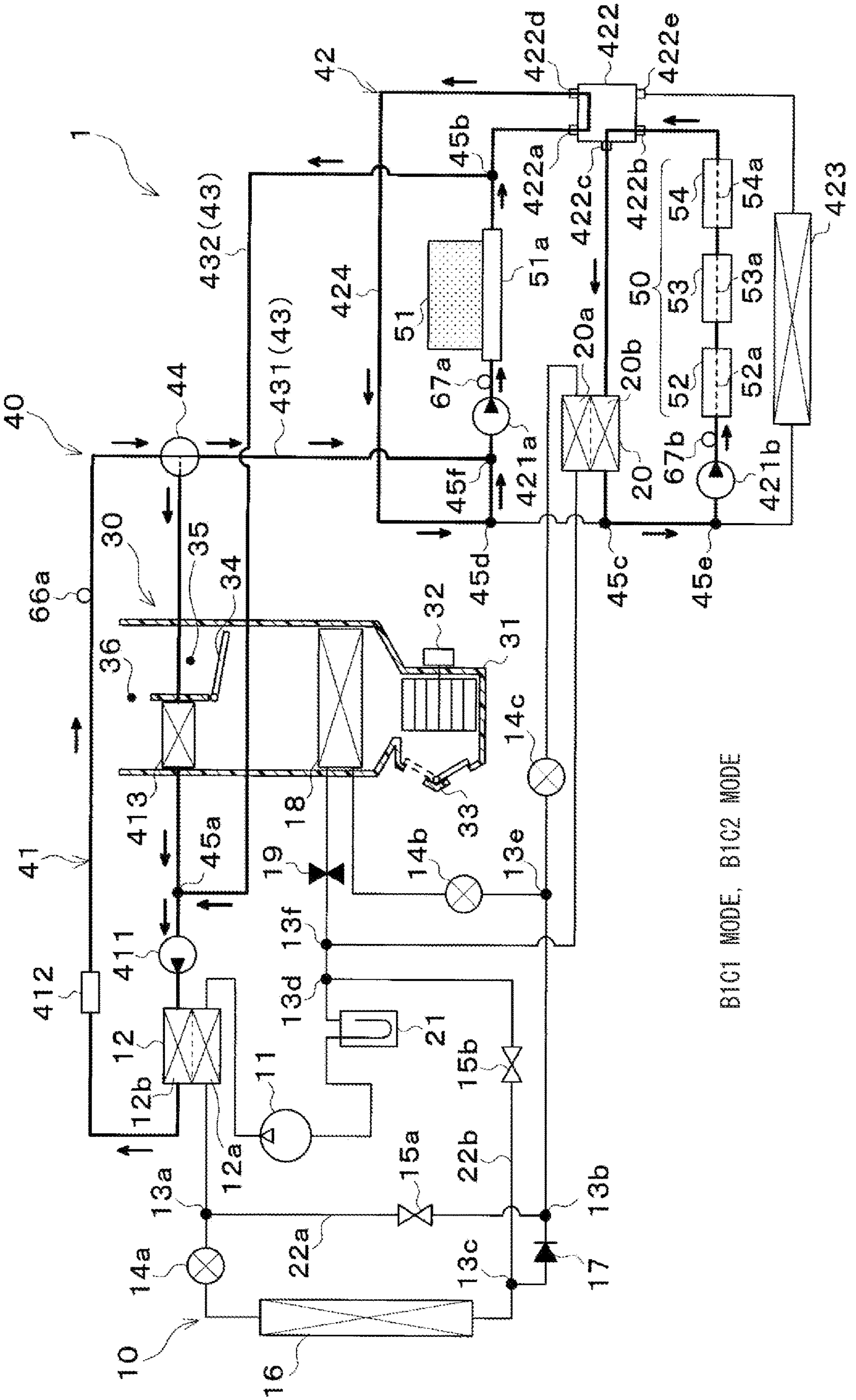
61 INDOOR AIR TEMPERATURE SENSOR
62 OUTDOOR AIR TEMPERATURE SENSOR
63 SOLAR RADIATION SENSOR
64a FIRST REFRIGERANT TEMPERATURE SENSOR
64b SECOND REFRIGERANT TEMPERATURE SENSOR
64c THIRD REFRIGERANT TEMPERATURE SENSOR
64f EVAPORATOR TEMPERATURE SENSOR
65a FIRST REFRIGERANT PRESSURE SENSOR
65b SECOND REFRIGERANT PRESSURE SENSOR
65c THIRD REFRIGERANT PRESSURE SENSOR
66a HIGH-TEMPERATURE-SIDE HEATING MEDIUM TEMPERATURE SENSOR
67a FIRST LOW-TEMPERATURE-SIDE HEATING MEDIUM TEMPERATURE SENSOR
67b SECOND LOW-TEMPERATURE-SIDE HEATING MEDIUM TEMPERATURE SENSOR
68 BATTERY TEMPERATURE SENSOR
69 AIR-CONDITIONED WIND TEMPERATURE SENSOR
COMPRESSOR 11
HEATING EXPANSION VALVE 14a
COOLING EXPANSION VALVE 14b
COOLING EXPANSION VALVE 14c
ON-OFF DEHUMIDIFICATION VALVE 15a
ON-OFF HEATING VALVE 15b
INTERIOR BLOWER 32
HIGH-TEMPERATURE-SIDE PUMP 411
ELECTRIC HEATER 412
FIRST LOW-TEMPERATURE-SIDE PUMP 421a
SECOND LOW-TEMPERATURE-SIDE PUMP 421b
FIVE-DIRECTION VALVE 422
THREE-WAY VALVE 44
OTHER ELECTRIC ACTUATOR
BATTERY 51

FIG. 6



B3C3 MODE
(B3) BATTERY COOLING MODE
(C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE
B2C1 MODE
(B2) BATTERY-TEMPERATURE AVERAGING MODE
(C1) HIGH-VOLTAGE-INSTRUMENT HEAT STORAGE MODE
B2C2 MODE
(B2) BATTERY-TEMPERATURE AVERAGING MODE
(C2) HIGH-VOLTAGE-INSTRUMENT WASTE HEAT RECOVERY MODE
B2C3 MODE
(B2) BATTERY-TEMPERATURE AVERAGING MODE
(C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE
B1C1 MODE
(B1) BATTERY WARMING MODE
(C1) HIGH-VOLTAGE-INSTRUMENT HEAT STORAGE MODE
B1C2 MODE
(B1) BATTERY WARMING MODE
(C2) HIGH-VOLTAGE-INSTRUMENT WASTE HEAT RECOVERY MODE
B1C3 MODE
(B1) BATTERY WARMING MODE
(C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE
KTB4
KTB3
KTB2
KTB1
BATTERY TEMPERATURE TB (°C)
KTWL21
KTWL22
KTWL23
KTWL24
SECOND LOW-TEMPERATURE-SIDE HEATING MEDIUM TEMPERATURE TWL2 (°C)

FIG. 7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432(43)
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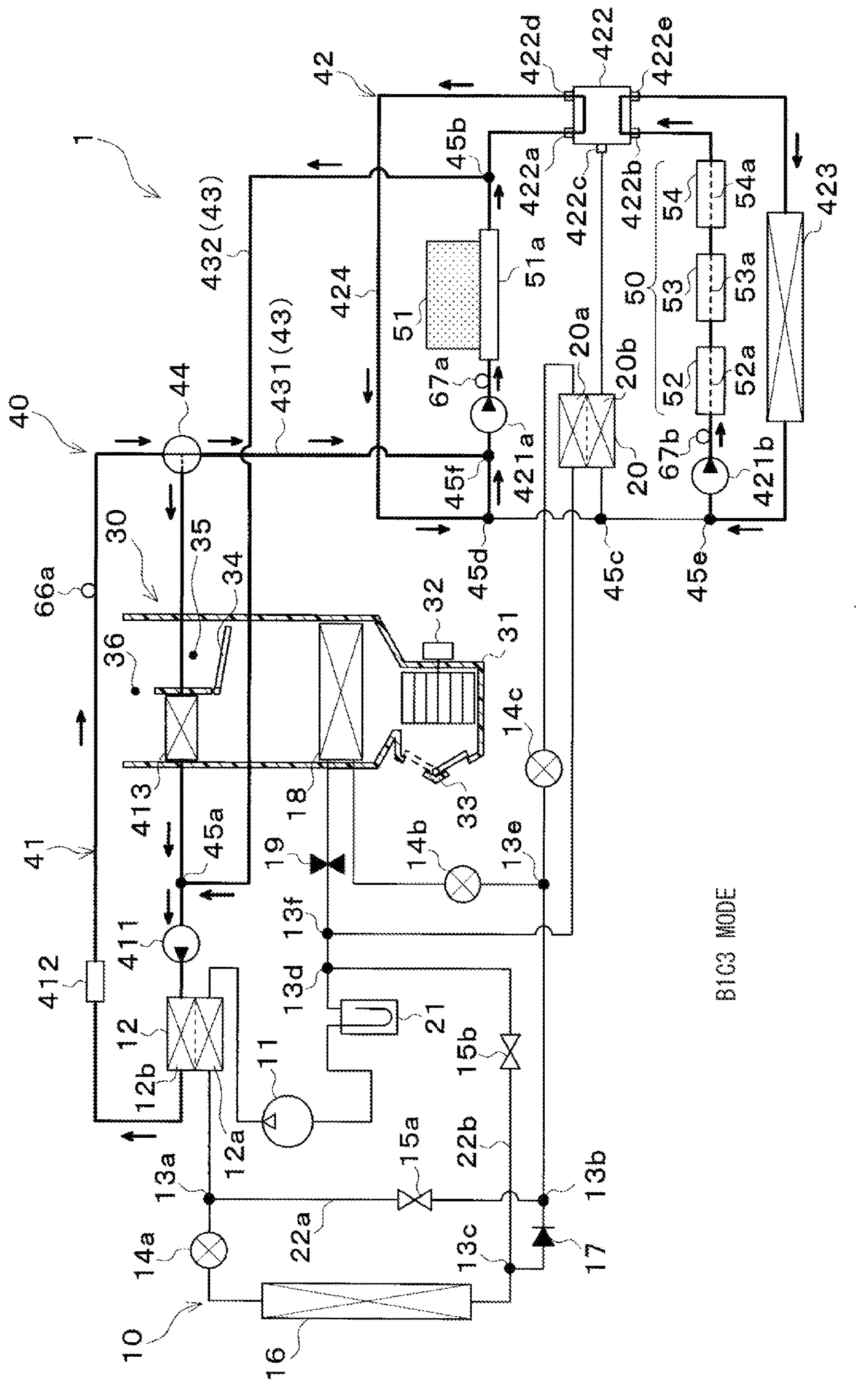
B1C1 MODE, B1C2 MODE

FIG. 8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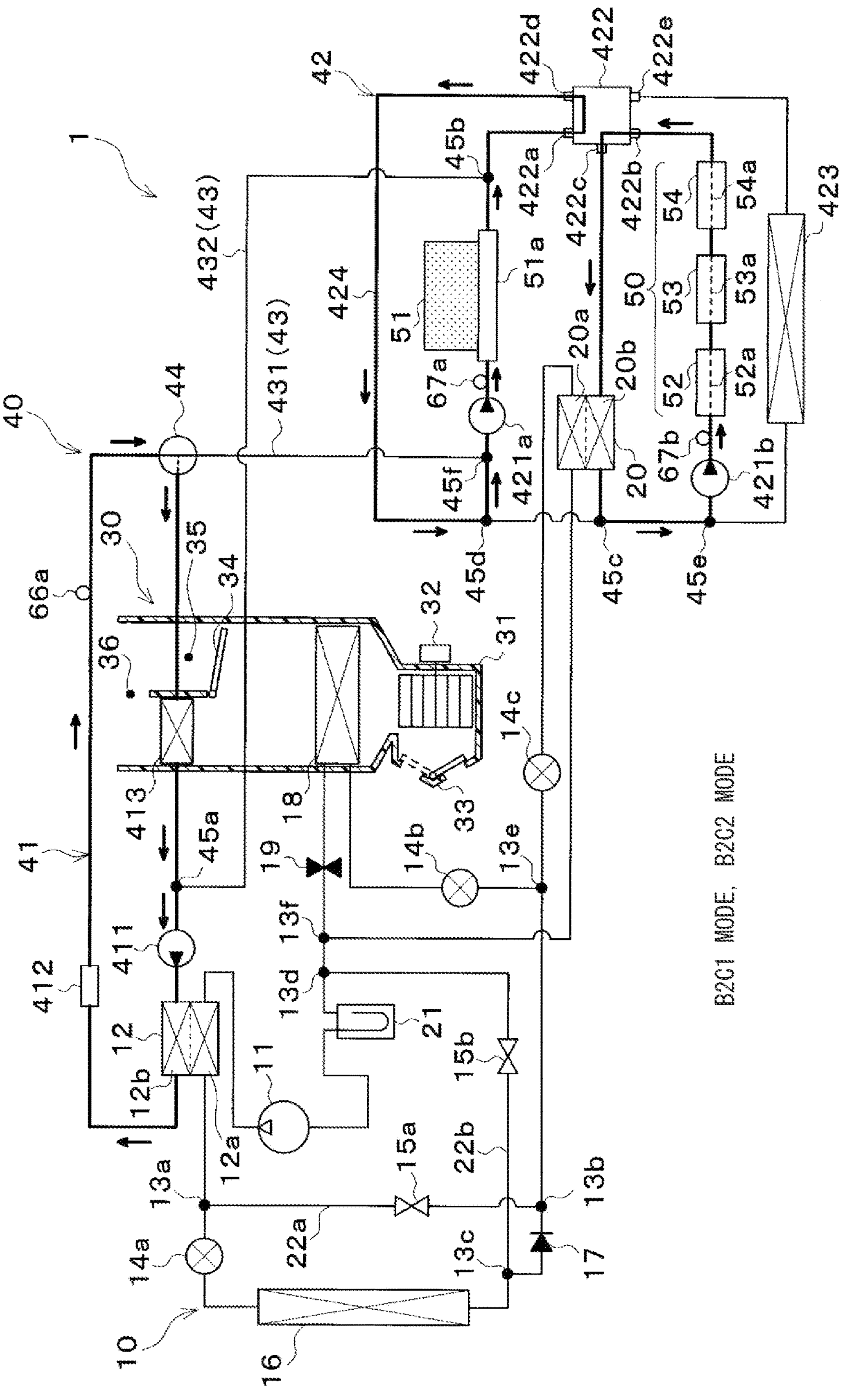
B1C3 MODE

FIG. 9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431(43)
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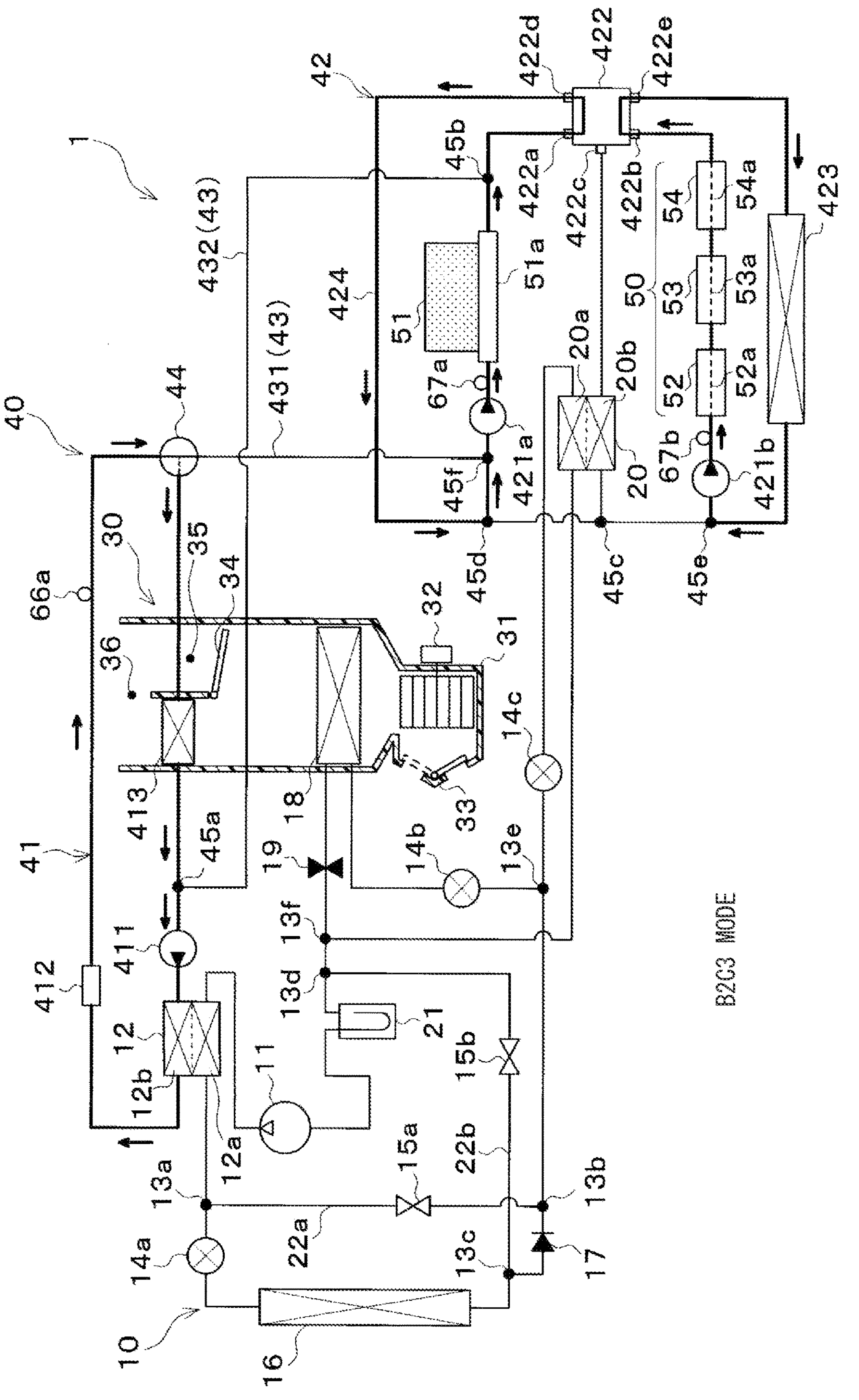
B2C1 MODE, B2C2 MODE

FIG. 10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422d
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422e
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422c
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67a
421a
45f
45d
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421b
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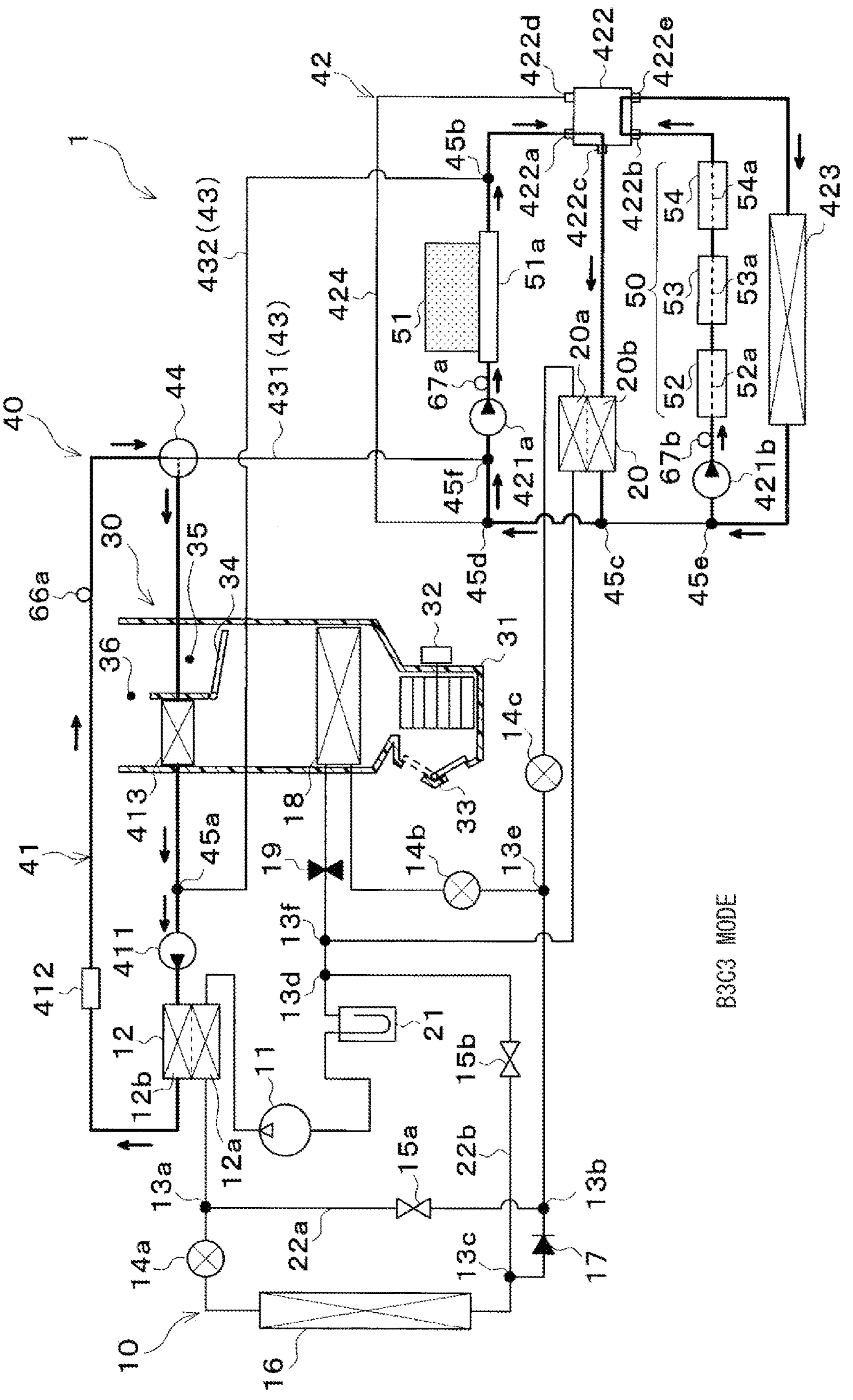
423
B2C3 MODE

FIG. 11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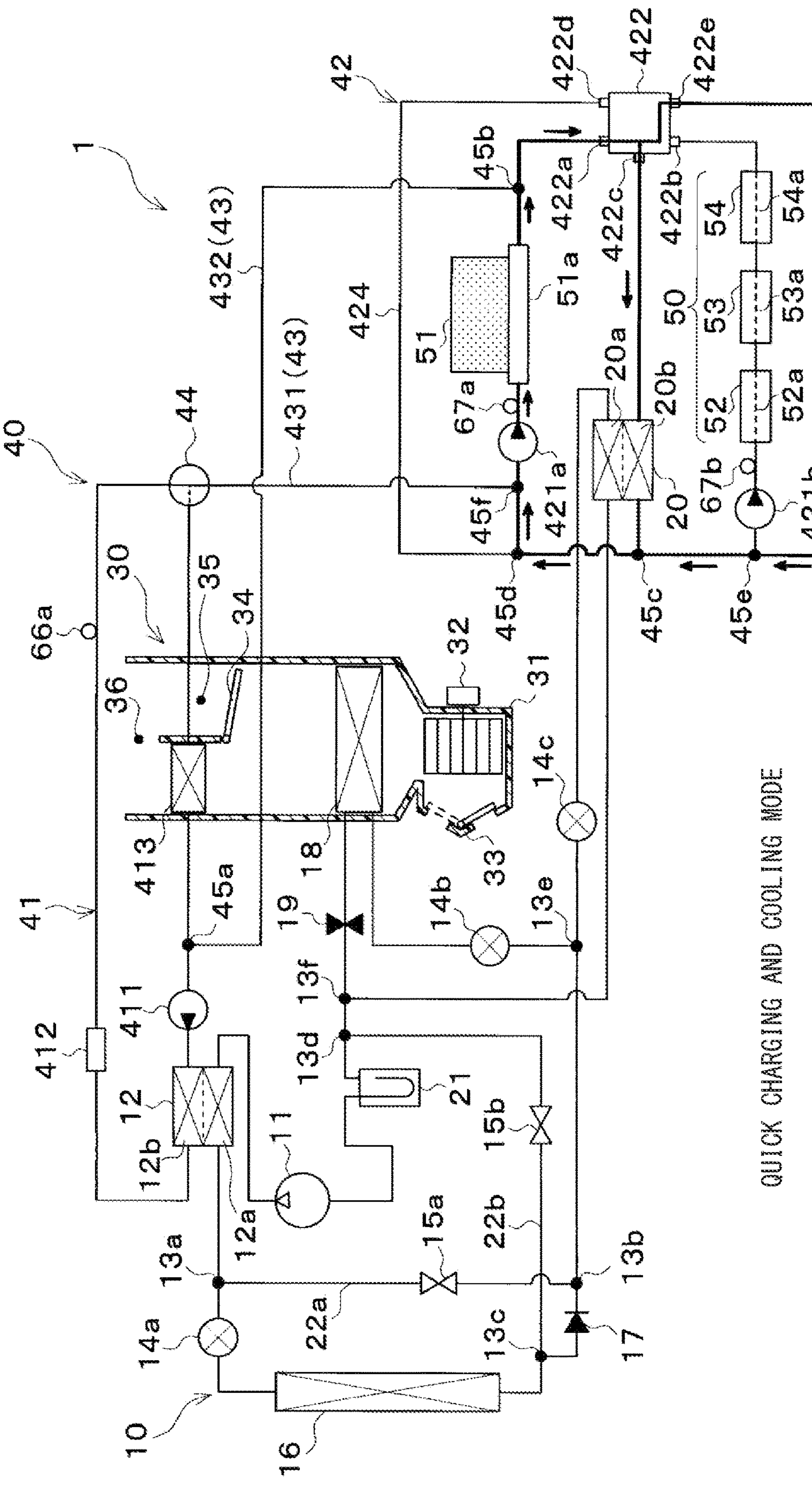
431(43)
432(43)
B3C3 MODE

FIG. 12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431(43)
432(43)
QUICK CHARGING AND COOLING MODE

FIG. 13

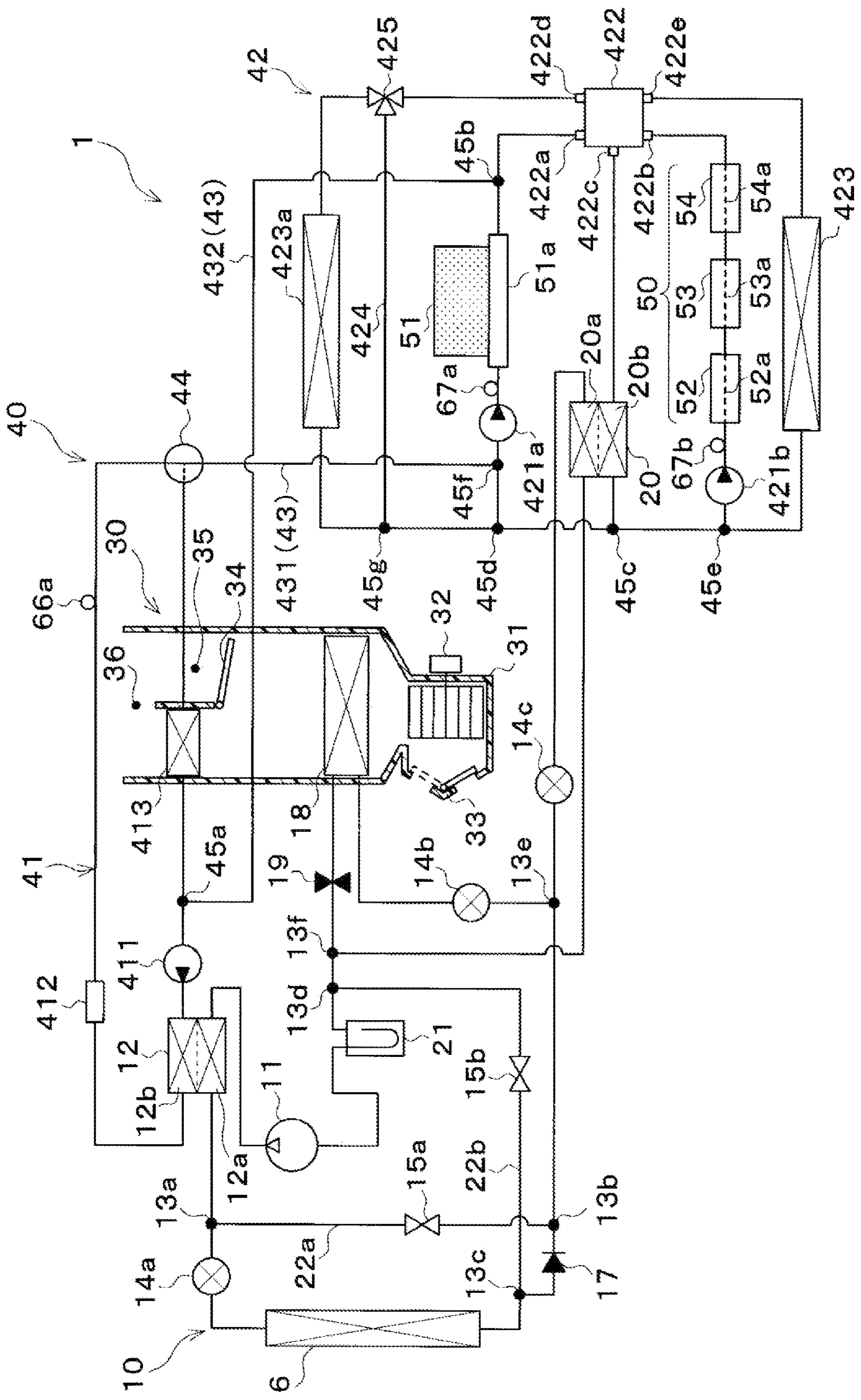
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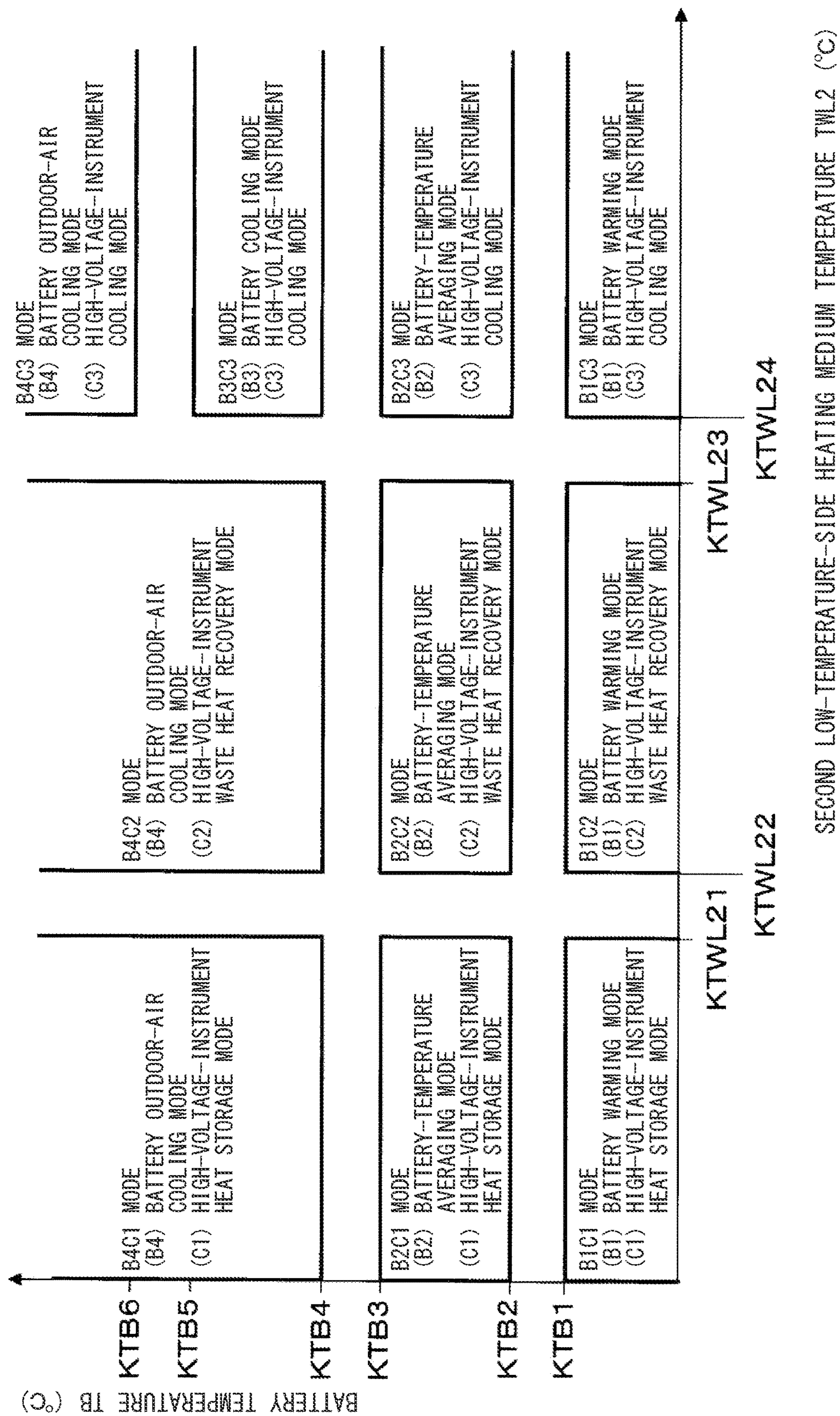
FIG. 14


BATTERY TEMPERATURE TB (°C)
KTB6
KTB5
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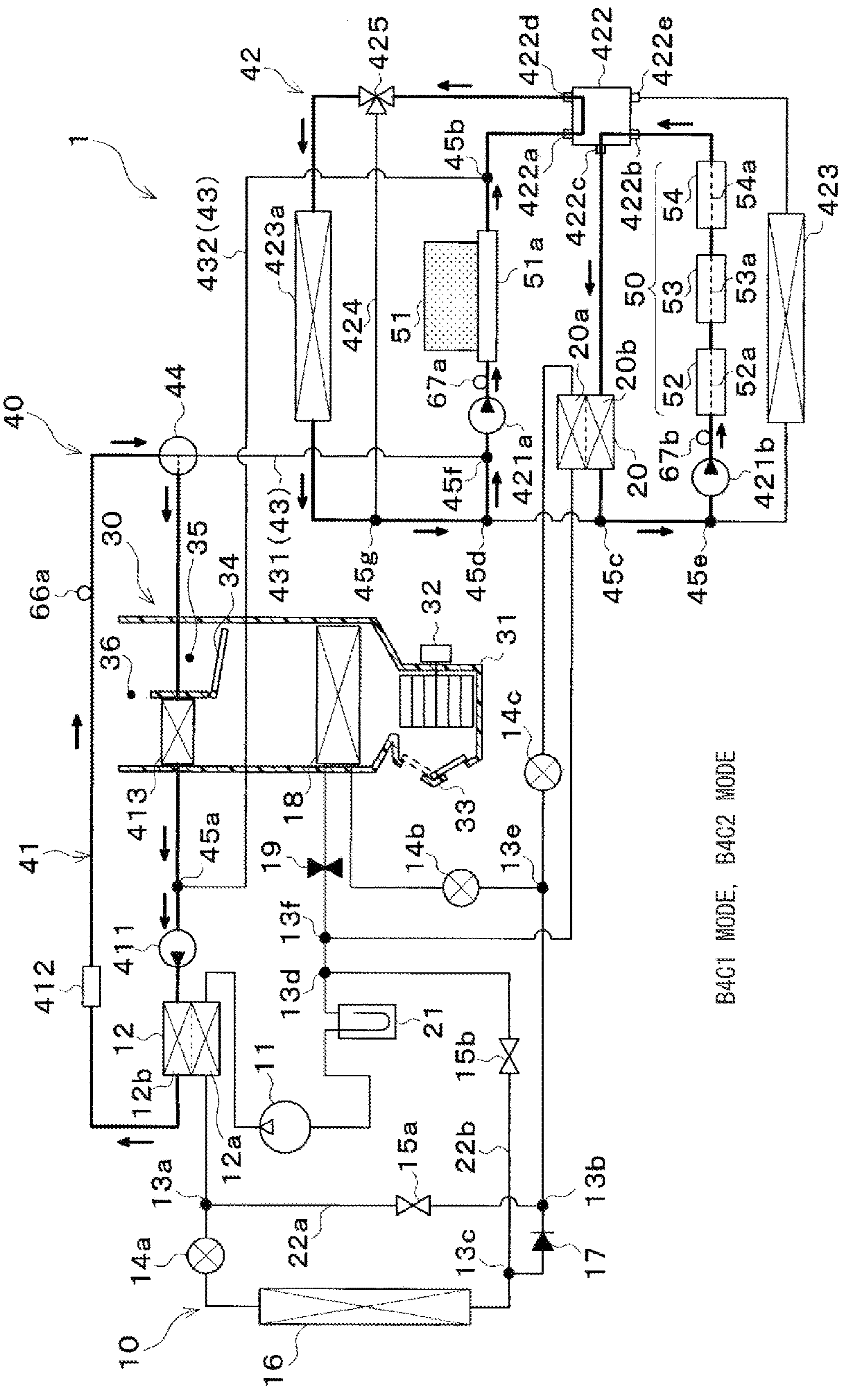
KTB3
KTB2
KTB1
SECOND LOW-TEMPERATURE-SIDE HEATING MEDIUM TEMPERATURE TWL2 (°C)
KTWL21
KTWL22
KTWL23
KTWL24
B4C1 MODE (B4) BATTERY OUTDOOR-AIR COOLING MODE (C1) HIGH-VOLTAGE-INSTRUMENT HEAT STORAGE MODE
B4C2 MODE (B4) BATTERY OUTDOOR-AIR COOLING MODE (C2) HIGH-VOLTAGE-INSTRUMENT WASTE HEAT RECOVERY MODE
B4C3 MODE (B4) BATTERY OUTDOOR-AIR COOLING MODE (C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE
B3C3 MODE (B3) BATTERY COOLING MODE (C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE
B2C1 MODE (B2) BATTERY-TEMPERATURE AVERAGING MODE (C1) HIGH-VOLTAGE-INSTRUMENT HEAT STORAGE MODE
B2C2 MODE (B2) BATTERY-TEMPERATURE AVERAGING MODE (C2) HIGH-VOLTAGE-INSTRUMENT WASTE HEAT RECOVERY MODE
B2C3 MODE (B2) BATTERY-TEMPERATURE AVERAGING MODE (C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE
B1C1 MODE (B1) BATTERY WARMING MODE (C1) HIGH-VOLTAGE-INSTRUMENT HEAT STORAGE MODE
B1C2 MODE (B1) BATTERY WARMING MODE (C2) HIGH-VOLTAGE-INSTRUMENT WASTE HEAT RECOVERY MODE
B1C3 MODE (B1) BATTERY WARMING MODE (C3) HIGH-VOLTAGE-INSTRUMENT COOLING MODE

FIG. 15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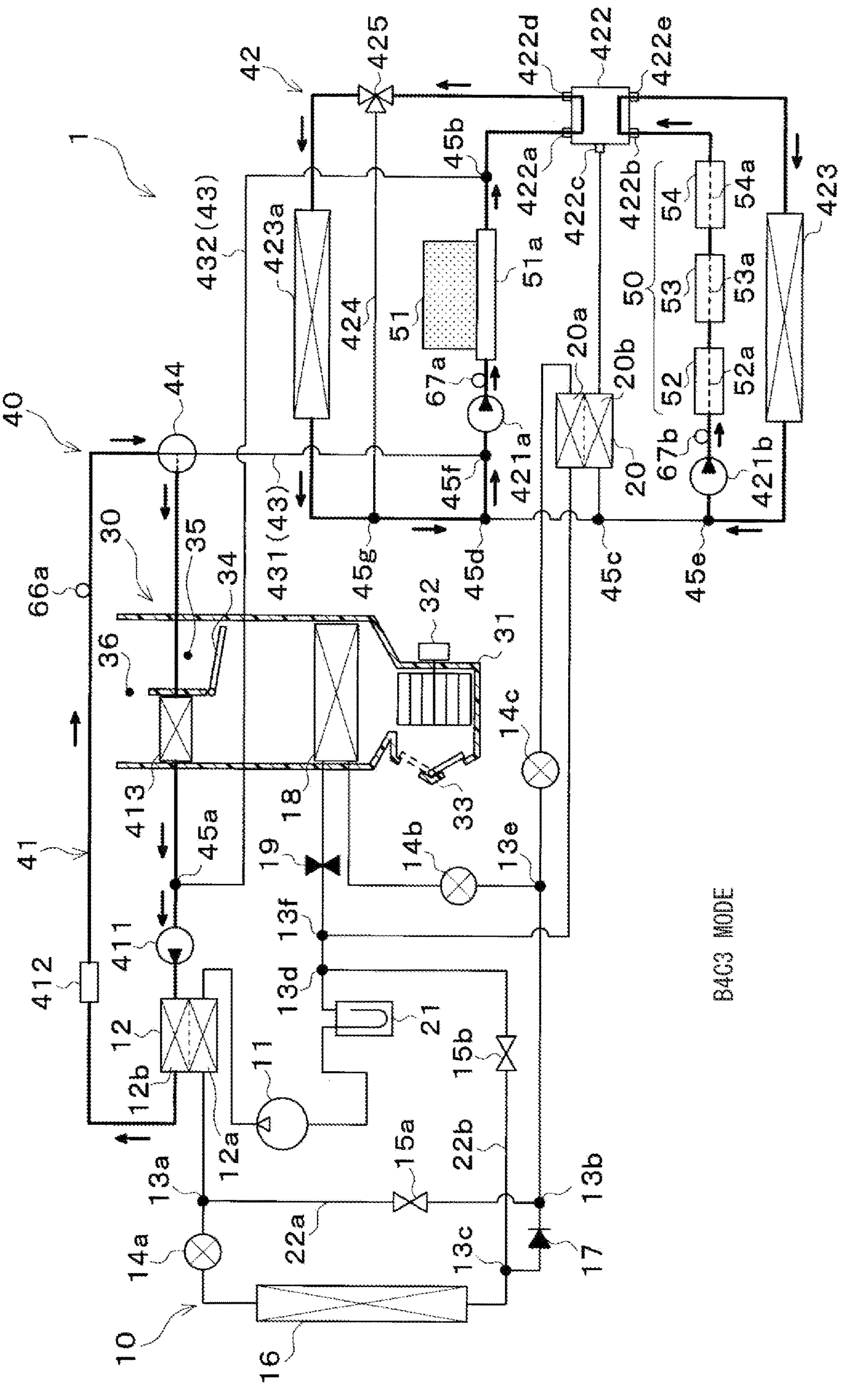
B4C1 MODE, B4C2 MODE

FIG. 16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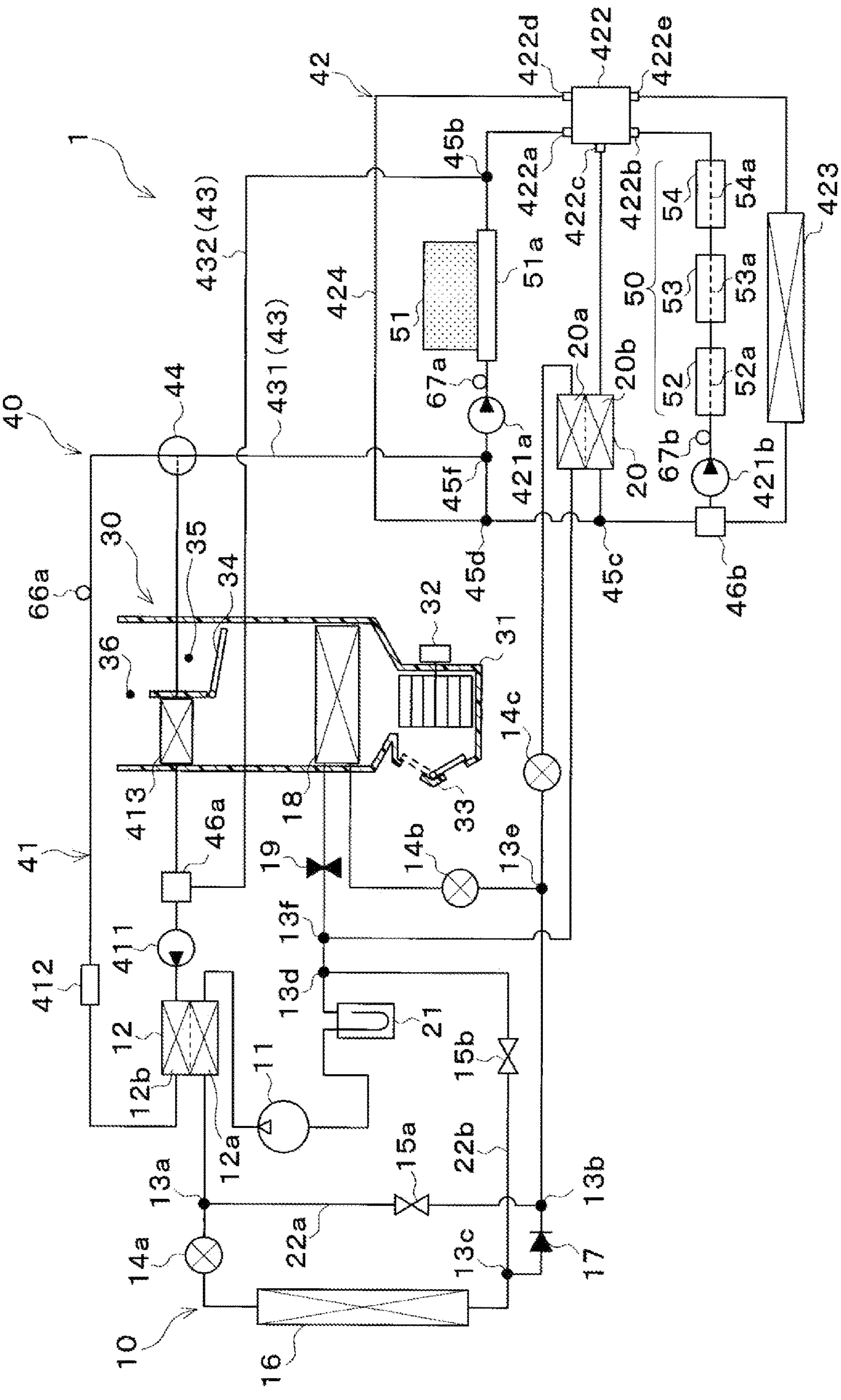
B4C3 MODE

FIG. 17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# THERMAL MANAGEMENT SYSTEM

## CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is a continuation application of International Patent Application No. PCT/JP2021/045094 filed on Dec. 8, 2021, which designated the U.S. and claims the benefit of priority from Japanese Patent Application No. 2021-009652 filed on Jan. 25, 2021. The entire disclosures of all of the above applications are incorporated herein by reference.

## TECHNICAL FIELD

[0002] The present disclosure relates to a thermal management system.

## BACKGROUND

[0003] Conventionally, a vehicle has been equipped with a thermal management system that manages thermal conditions in the vehicle.

## SUMMARY

[0004] According to an aspect of the present disclosure, a thermal management system includes a refrigeration cycle equipment and a heating medium circuit.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** is an overall schematic configuration diagram illustrating the thermal management system according to a first embodiment;

[0006] FIG. **2** is an explanatory diagram illustrating an operation mode of a five-way valve according to the first embodiment;

[0007] FIG. **3** is an explanatory diagram illustrating another operation mode of the five-way valve according to the first embodiment;

[0008] FIG. **4** is an explanatory diagram illustrating yet another operation mode of the five-way valve according to the first embodiment;

[0009] FIG. **5** is a block diagram illustrating an electric control portion of the thermal management system according to the first embodiment;

[0010] FIG. **6** is a control characteristics diagram illustrating switching among operation modes for temperature adjustment in the thermal management system according to the first embodiment;

[0011] FIG. **7** is an overall schematic configuration diagram illustrating the flow of a heating medium in B1C1 mode, for example, according to the first embodiment;

[0012] FIG. **8** is an overall schematic configuration diagram illustrating the flow of a heating medium in B1C3 mode according to the first embodiment;

[0013] FIG. **9** is an overall schematic configuration diagram illustrating the flow of a heating medium in B2C1 mode, for example, according to the first embodiment;

[0014] FIG. **10** is an overall schematic configuration diagram illustrating the flow of a heating medium in B2C3 mode according to the first embodiment;

[0015] FIG. **11** is an overall schematic configuration diagram illustrating the flow of a heating medium in B3C3 mode according to the first embodiment;

[0016] FIG. **12** is an overall schematic configuration diagram illustrating the flow of a heating medium in quick charging and cooling mode according to the first embodiment;

[0017] FIG. **13** is an overall schematic configuration diagram illustrating the thermal management system according to a second embodiment;

[0018] FIG. **14** is a control characteristics diagram illustrating switching among operation modes for temperature adjustment in the thermal management system according to the second embodiment;

[0019] FIG. **15** is an overall schematic configuration diagram illustrating the flow of a heating medium in B4C1 mode, for example, according to the second embodiment;

[0020] FIG. **16** is an overall schematic configuration diagram illustrating the flow of a heating medium in B4C3 mode, for according to the first embodiment;

[0021] FIG. **17** is an overall schematic configuration diagram illustrating the thermal management system according to a third embodiment.

## DETAILED DESCRIPTION

[0022] Hereinafter, examples of the present disclosure will be described.

[0023] According to an example of the present disclosure, a thermal management system for a vehicle performs air-conditioning of vehicle compartments and regulates temperatures of multiple temperature adjustment targets. Temperature adjustment targets in the thermal management system, for example, include a battery to supply power to in-vehicle units and the in-vehicle devices such as inverters and motor generators that generate heat during operation.

[0024] The thermal management system, for example, includes vapor-compression refrigeration cycle equipment and a heating medium circuit. The refrigeration cycle equipment regulates the temperature of the air supplied to a passenger compartment and the temperature of a heating medium. The heating medium circuit circulates a heating medium that is temperature-regulated by the refrigeration cycle equipment. The heating medium circuit connects with a cooling water channel for the battery and a cooling water channel for the in-vehicle unit.

[0025] The thermal management system, for example, cools the battery and the onboard unit. When the passenger compartment is heated, a chiller of the refrigeration cycle equipment performs heat exchange between the heating medium, flowing out of the cooling water channel for the battery and the cooling water channel for the onboard unit, and a low-pressure refrigerant for the refrigeration cycle equipment. The heating medium cooled by the chiller is forced to flow again into the cooling water channel for the battery and the cooling water channel for the onboard unit, thereby cooling the battery and the onboard unit.

[0026] The refrigeration cycle equipment uses the chiller to compress the low-pressure refrigerant that absorbs waste heat from the battery and the in-vehicle unit. A high-pressure refrigerant, compressed by the compressor, is used as a heat source to heat the blown air. The thermal management system cools the battery and the onboard unit and simultaneously recovers waste heat from the battery and the onboard unit and uses the waste heat as a heat source for heating in operation mode to heat the vehicle compartment.

[0027] According to an example, the circuit configuration of the heating medium circuit allows the temperature of the heating medium, flowing into the cooling water channel for the battery, to be equal to the temperature of the heating medium flowing into the cooling water channel for the in-vehicle unit. Therefore, the thermal management system can regulate the battery and the in-vehicle unit to the same temperature but hardly regulates the battery and the in-vehicle unit to different temperatures.

**[0028]** Generally, however, there is a difference between the proper temperature zone capable of appropriately operating the battery and the proper temperature zone capable of appropriately operating the in-vehicle unit. Therefore, there may be an operating condition of warming up the battery and concurrently cooling the other in-vehicle units.

**[0029]** Assumably, the thermal management system according to an example cannot warm up the battery and concurrently cool the other in-vehicle units. In other words, the thermal management system may not be effectively used as a heat source for heating, for example, in such a manner as warming up the battery and concurrently recovering the heat generated from the other onboard units.

**[0030]** According to an example of the present disclosure, a refrigeration cycle equipment includes a high-temperature-side water-refrigerant heat exchange portion and a low-temperature-side water-refrigerant heat exchange portion. The high-temperature-side water-refrigerant heat exchange portion is configured to perform heat exchange between high-pressure refrigerant and heating medium. The low-temperature-side water-refrigerant heat exchange portion is configured to perform heat exchange between low-pressure refrigerant and the heating medium.

**[0031]** The heating medium circuit circulates the heating medium. The heating medium circuit includes a high-temperature-side circuit, a low-temperature-side circuit, and a heat transfer portion. The high-temperature-side circuit connects with the heating medium channel of the high-temperature-side water-refrigerant heat exchange portion. The low-temperature-side circuit connects with the heating medium channel of the low-temperature-side water-refrigerant heat exchange portion. The heat transfer portion transfers heat between the heating medium flowing through the high-temperature-side circuit and the heating medium flowing through the low-temperature-side circuit.

**[0032]** The low-temperature-side circuit includes a first heat exchange portion, a second heat exchange portion, a heating medium bypass channel, and a low-temperature-side circuit switching portion. The first heat exchange portion performs heat exchange between the first temperature adjustment target and the heating medium. The second heat exchange portion performs heat exchange between the second temperature adjustment target and the heating medium. The heating medium bypass channel allows the heating medium, flowing out of the first heat exchange portion or the second heat exchange portion, to bypass the low-temperature-side water-refrigerant heat exchange portion and returns the heating medium toward a heating medium inlet of the first heat exchange portion or the second heat exchange portion. The low-temperature-side circuit switching portion switches the circuit configuration of the low-temperature-side circuit.

**[0033]** The heat transfer portion transfers the heat of the heating medium flowing out of the high-temperature-side water-refrigerant heat exchange portion to the heating medium flowing into the first heat exchange portion.

**[0034]** While the heat transfer portion is transferring heat, the low-temperature-side circuit switching portion switches the circuit configuration of the low-temperature-side circuit to a circuit configuration that circulates the heating medium between the first heat exchange portion and the heating medium bypass channel.

**[0035]** The heat transfer portion can transfer the heat of the heating medium, heated in the high-temperature-side water-refrigerant heat exchange portion of the high-temperature-side circuit, to the heating medium flowing into the first heat exchange portion of the low-temperature-side circuit. Therefore, the first temperature adjustment target can be heated.

**[0036]** When the heat transfer portion is transferring heat, the temperature of the heating medium flowing into the low-temperature-side water-refrigerant heat exchange portion is not affected by the temperature of the heating medium that circulates between the first heat exchange portion and the heating medium bypass channel.

**[0037]** The low-temperature-side water-refrigerant heat exchange portion performs heat exchange, as needed, between the heating medium flowing out of the second heat exchange portion and the low-pressure refrigerant, thereby enabling the low-pressure refrigerant to absorb the heat of the second temperature adjustment target. It is possible to cool the heating medium flowing into the second heat exchange portion and cool the second temperature adjustment target.

**[0038]** In the refrigeration cycle equipment, the high-temperature-side water-refrigerant heat exchange portion can heat the heating medium flowing through the high-temperature-side circuit by using a heat source, that is, the waste heat recovered by the low-pressure refrigerant in the low-temperature-side water-refrigerant heat exchange portion.

**[0039]** The thermal management system according to one aspect of the present disclosure can heat the first temperature adjustment target, meanwhile recover the heat from the second temperature adjustment target, if necessary, and use the recovered heat as a heat source to heat the heating medium that flows through the high-temperature-side circuit. It is possible to fully effectively use the heat generated by the temperature adjustment target.

**[0040]** The description below explains embodiments for carrying out the present disclosure by reference to the drawings. The same reference numerals are given to parts in each embodiment similar to those described in the preceding embodiment and a redundant description may be omitted for simplicity. If only part of a configuration in each embodiment is described, other parts in the configuration may conform to those described in the preceding embodiment. Each embodiment may contain parts that are explicitly described to be capable of combination. In addition, the embodiments can be partially combined, if available, even if the partial combination is not explicitly described to be possible.

First Embodiment

**[0041]** The description below explains the first embodiment of a thermal management system **1** according to the present disclosure by reference to FIGS. **1** to **12**. The thermal management system **1** according to the present embodiment is applied to an electric vehicle. An electric vehicle represents a vehicle that acquires a driving force for running from an electric motor. In the electric vehicle, the thermal management system **1** air-conditions the vehicle compartment as a target space for air conditioning and adjusts the temperature of the in-vehicle unit as a temperature adjustment target.

**[0042]** In the thermal management system **1**, in-vehicle units as temperature adjustment targets specifically include a battery **51**, an inverter **52**, a motor generator **53**, and a controller **54** for the advanced driver assistance system (ADAS).

**[0043]** The battery **51** represents a secondary battery that stores electric power to be supplied to an electric in-vehicle unit such as the inverter **52**. The battery **51** represents an assembled battery formed by electrically connecting multiple packed battery cells in series or parallel. The battery cell according to the present embodiment is a lithium ion battery.

**[0044]** The battery **51** generates heat during operation (charging and discharging). The battery **51** has such traits as easily decreasing outputs at a low temperature and progressively deteriorating at a high temperature. Therefore, the temperature of the battery **51** needs to be maintained within an appropriate temperature zone (higher than or equal to 15° C. and lower than or equal to 55° C. according to the present embodiment). The thermal management system **1** assumes the battery **51** to be the first temperature adjustment target.

**[0045]** The inverter **52** is a power converter that converts frequencies of power supplied from the battery **51** to the motor generator **53** and converts the AC power generated by the motor generator **53** into DC power and outputs the DC power to the battery **51**. The motor generator **53** functions as an electric motor supplied with electric power to output a driving force for traveling and functions as a power-generating unit to generate regenerative power when a vehicle is decelerating or traveling downhill. The advanced driver assistance system supports the driver's driving operations.

**[0046]** The inverter **52**, the motor generator **53**, and the controller **54** for ADAS all generate heat during operation. The inverter **52**, the motor generator **53**, and the controller **54** for ADAS may easily degrade the electric circuits at high temperatures. Therefore, it is necessary to keep the temperature lower than the standard heat-resisting temperature (130° C. according to the present embodiment) capable of protecting the electric circuits.

**[0047]** The thermal management system **1** assumes the inverter **52**, the motor generator **53**, and the ADAS controller **54** to be second temperature adjustment targets. Where appropriate, the following description may use a high-voltage instrument **50** as a generic term for the inverter **52**, the motor generator **53**, and the ADAS controller **54** as the second temperature adjustment targets.

**[0048]** The thermal management system **1** according to the present embodiment does not ensure complete coincidence between an appropriate temperature zone for the first temperature adjustment target capable of properly operating the first temperature adjustment target and an appropriate temperature zone for the second temperature adjustment target capable of properly operating the second temperature adjustment target. That is, the appropriate temperature zone for the first temperature adjustment target differs from the appropriate temperature zone for the second temperature adjustment target.

**[0049]** As illustrated in the overall configuration diagram in FIG. **1**, the thermal management system **1** includes a refrigeration cycle equipment **10**, an interior air-conditioning unit **30**, and a heating medium circuit **40**, for example.

**[0050]** The description below explains the refrigeration cycle equipment **10**. The refrigeration cycle equipment **10** cools or heats the air supplied into the vehicle compartment and the heating medium circulating through the heating medium circuit **40**, for air conditioning in the vehicle compartment and temperature adjustment of the onboard units. Furthermore, the refrigeration cycle equipment **10** is configured to be able to switch between refrigerant circuits according to various operation modes (described later), for air conditioning in the vehicle compartment and temperature adjustment of the onboard units.

**[0051]** The refrigeration cycle equipment **10** uses HFO refrigerant (such as R1234yf) as a refrigerant. The refrigeration cycle equipment **10** provides a vapor-compression subcritical refrigeration cycle at which the pressure of the refrigerant discharged from a compressor **11** does not exceed the critical pressure of the refrigerant. The refrigerant contains refrigerant oil to lubricate the compressor **11**. The refrigerator oil is available as PAG oil that is compatible with liquid-phase refrigerants. The refrigerating machine oil partially circulates through the cycle along with the refrigerant.

**[0052]** The compressor **11** draws, compresses, and discharges the refrigerant in the refrigeration cycle equipment **10**. The compressor **11** is placed in a drive unit chamber toward the front of the vehicle compartment. The driving device room forms a space to place at least part of the instruments (such as the motor generator **53**) used to generate driving force for vehicle travel.

**[0053]** The compressor **11** is an electric compressor that uses an electric motor to drive a fixed-capacity compression mechanism whose discharge capacity is fixed. The compressor **11** is controlled in terms of rotation speeds (or refrigerant discharge capability) by control signals output from a controller **60** for system control (described later).

**[0054]** The outlet of the compressor **11** connects with the inlet side of the refrigerant channel of a water-refrigerant heat exchanger **12**. The water-refrigerant heat exchanger **12** includes a refrigerant channel **12***a* and a heating medium channel **12***b*. The refrigerant channel **12***a* circulates the high-pressure refrigerant discharged from the compressor **11**. The heating medium channel **12***b* circulates the heating medium at the high-temperature-side circuit **41** of the heating medium circuit **40**.

**[0055]** The water-refrigerant heat exchanger **12** is a high-temperature-side water-refrigerant heat exchange portion that provides heat exchange between the high-pressure refrigerant flowing through the refrigerant channel **12***a* and the heating medium flowing through the heating medium channel **12***b*. The water-refrigerant heat exchanger **12** allows the heat of the high-pressure refrigerant to radiate to the heating medium to heat the heating medium.

**[0056]** The inlet side of the first refrigerant joint portion **13***a* is connected to the outlet of the refrigerant channel **12***a* of the water-refrigerant heat exchanger **12**. The first refrigerant joint portion **13***a* is a three-way joint having three inlets/outlets communicating with each other. The first refrigerant joint portion **13***a* may use a joint member that is formed by joining multiple pipes or is formed by providing a metal or resin block with multiple refrigerant channels.

**[0057]** As described later, the refrigeration cycle equipment **10** includes second through sixth refrigerant joint portions **13***b* through **13***f*. The basic configuration of the second through sixth refrigerant joint portions **13***b* through **13***f* is similar to that of the first refrigerant joint portion **13***a*.

**[0058]** One outlet of the first refrigerant joint portion **13***a* connects with the inlet side of a heating expansion valve **14***a*. The other outlet port of the first refrigerant joint portion **13***a* connects with one inlet side of the second refrigerant joint portion **13***b* via a dehumidification channel **22***a*.

**[0059]** The dehumidification channel **22***a* forms a channel through which the refrigerant flows during a parallel dehumidification heating mode (described later). The dehumidification channel **22***a* includes an on-off dehumidification valve **15***a*. The on-off dehumidification valve **15***a* is a solenoid valve that opens and closes the dehumidification channel **22***a*. Operations of the on-off dehumidification valve **15***a* are controlled by a control voltage output from the controller **60**.

**[0060]** As described later, the refrigeration cycle equipment **10** includes an on-off heating valve **15***b* The basic configuration of the on-off heating valve **15***b* is similar to that of the on-off dehumidification valve **15***a*. The on-off dehumidification valve **15***a* and the on-off heating valve **15***b* can switch the refrigerant circuit of the refrigeration cycle equipment **10** by opening and closing the refrigerant channel. Therefore, the on-off dehumidification valve **15***a* and the on-off heating valve **15***b* provide refrigerant circuit switching portions that switch the refrigerant circuits.

**[0061]** The heating expansion valve **14***a* is a heating decompression portion that decompresses the high-pressure refrigerant flowing out of the refrigerant channel **12***a* of the water-refrigerant heat exchanger **12** and adjusts the flow rate (mass flow rate) of the refrigerant flowing downstream in a heating mode (described later), for example.

**[0062]** The heating expansion valve **14***a* is an electric variable throttle mechanism including a valve body portion to vary throttle openings and an electric actuator (such as a stepping motor) to displace the valve body portion. Operations of the heating expansion valve **14***a* are controlled by control pulses output from the controller **60**.

**[0063]** The heating expansion valve **14***a* has a full opening function to function simply as a refrigerant channel by fully opening the valve while scarcely providing any refrigerant decompression action and flow rate adjustment action. In addition, the heating expansion valve **14***a* has a full closing function to close the refrigerant channel by fully closing the valve.

**[0064]** As described later, the refrigeration cycle equipment **10** includes a cooling expansion valve **14***b* and a cooling expansion valve **14***c*. The basic configuration of the cooling expansion valve **14***b* and the cooling expansion valve **14***c* is similar to that of the heating expansion valve **14***a*.

**[0065]** The heating expansion valve **14***a*, the cooling expansion valve **14***b*, and the cooling expansion valve **14***c* can switch the refrigerant circuits of the refrigeration cycle equipment **10** based on the above-described full closing function. Therefore, the heating expansion valve **14***a*, the cooling expansion valve **14***b*, and the cooling expansion valve **14***c* also function as the refrigerant circuit switching portions.

**[0066]** The heating expansion valve **14***a*, the cooling expansion valve **14***b*, and the cooling expansion valve **14***c* may be formed by combining an on-off valve and a variable throttle mechanism devoid of the full closing function. In this case, the on-off valve provides the refrigerant circuit switching portion.

**[0067]** The outlet of the heating expansion valve **14***a* connects with the refrigerant inlet side of the outdoor heat exchanger **16**. The outdoor heat exchanger **16** is an outdoor heat exchange portion that provides heat exchange between the refrigerant flowing from the heating expansion valve **14***a* and the outside air supplied by a cooling fan (not shown). The outdoor heat exchanger **16** is placed toward the front inside the drive unit chamber. The outdoor heat exchanger **16** can be exposed to the outdoor air when the vehicle is traveling.

**[0068]** The refrigerant outlet of the outdoor heat exchanger **16** connects with the inlet side of a third refrigerant joint portion **13***c*. One outlet port of the third refrigerant joint portion **13***c* connects with one inlet side of a fourth refrigerant joint portion **13***d* via a heating channel **22***b*. The heating channel **22***b* forms a channel allowing the refrigerant to flow in a heating mode (described later), for example. The heating channel **22***b* includes the on-off heating valve **15***b* to open and close the heating channel **22***b*.

**[0069]** The other outlet of the third refrigerant joint portion **13***c* connects with the other outlet side of the second refrigerant joint portion **13***b*. A check valve **17** is provided for the refrigerant channel connecting the other outlet of the third refrigerant joint portion **13***c* and the other outlet of the second refrigerant joint portion **13***b*. The check valve **17** allows the refrigerant to flow from the third refrigerant joint portion **13***c* to the second refrigerant joint portion **13***b* and prevents the refrigerant from flowing from the second refrigerant joint portion **13***b* to the third refrigerant joint portion **13***c*.

**[0070]** The outlet of the second refrigerant joint portion **13***b* connects with the inlet side of a fifth refrigerant joint portion **13***e*. One outlet of the fifth refrigerant joint portion **13***e* connects with the inlet side of the cooling expansion valve **14***b*. The other outlet port of the fifth refrigerant joint portion **13***e* connects with the inlet side of the cooling expansion valve **14***c*.

**[0071]** The cooling expansion valve **14***b* is a cooling decompression portion that decompresses the refrigerant and adjusts the flow rate of the refrigerant flowing downstream in cooling mode (described later).

**[0072]** The cooling expansion valve **14***b* connects with the refrigerant inlet side of an interior evaporator **18**. The interior evaporator **18** is placed in an air-conditioning case **31** of the interior air-conditioning unit **30** (described later). The interior evaporator **18** is a cooling heat exchanger that provides heat exchange between the low-pressure refrigerant decompressed by the cooling expansion valve **14***b* and the air supplied into the vehicle compartment. The interior evaporator **18** cools the supplied air by evaporating the low-pressure refrigerant to activate an endothermic reaction.

**[0073]** The refrigerant outlet of the interior evaporator **18** connects with the inlet side of an evaporation pressure adjustment valve **19**. The evaporation pressure adjustment valve **19** is a variable throttle mechanism that varies valve openings to keep the refrigerant evaporation pressure in the interior evaporator **18** to be higher than or equal to a predetermined pressure so that the interior evaporator **18** is prevented from being frosted. More specifically, the evaporation pressure adjustment valve **19** is configured as a mechanical mechanism that increases the valve opening according to an increase in the refrigerant pressure on the inlet side. The outlet of the evaporation pressure adjustment valve **19** connects with one inlet of the sixth refrigerant joint portion **13***f*.

**[0074]** The cooling expansion valve **14***c* is a cooling decompression portion that decompresses the refrigerant and adjusts the flow rate of the refrigerant flowing downstream in B1C1 mode (described later), for example.

**[0075]** The outlet of the cooling expansion valve **14***c* connects with the inlet side of the refrigerant channel **20***a* of the chiller **20**. The chiller **20** includes a refrigerant channel **20***a* and a heating medium channel **20***b*. The refrigerant channel **20***a* allows a flow of the low-pressure refrigerant decompressed by cooling expansion valve **14***c*. The heating medium channel **20***b* allows a flow of the heating medium at the low-temperature-side circuit **42** of the heating medium circuit **40**. The chiller **20** is a low-temperature-side water-refrigerant heat exchange portion that provides heat exchange between the low-pressure refrigerant flowing through the refrigerant channel **20***a* and the heating medium flowing through the heating medium channel **20***b*. The chiller **20** cools the heating medium by evaporating the low-pressure refrigerant to activate an endothermic reaction.

**[0076]** The outlet of the refrigerant channel **20***a* of the chiller **20** connects with the other inlet side of the sixth refrigerant joint portion **13***f*. The outlet of the sixth refrigerant joint portion **13***f* connects with the other inlet side of the fourth refrigerant joint portion **13***d*.

**[0077]** The outlet of the fourth refrigerant joint portion **13***d* connects with the inlet side of the accumulator **21**. The accumulator **21** is a low-pressure-side gas-liquid separator that separates the gas-liquid from the refrigerant flowing inside and stores an excess liquid-phase refrigerant in the cycle. A gas-phase refrigerant outlet of the accumulator **21** connects with the suction port side of the compressor **11**.

**[0078]** The description below explains the heating medium circuit **40**. The heating medium circuit **40** is a heating medium circuit that circulates the heating medium. The heating medium circuit **40** uses an ethylene glycol aqueous solution as the heating medium. The heating medium circuit **40** includes a high-temperature-side circuit **41**, a low-temperature-side circuit **42**, a connection channel **43**, and a three-way valve **44**, for example.

**[0079]** The high-temperature-side circuit **41** includes a high-temperature-side pump **411**, an electric heater **412**, and a heater core **413**, for example. The high-temperature-side circuit **41** connects with the heating medium channel **12***b* of the water-refrigerant heat exchanger **12** and the three-way valve **44**, for example.

**[0080]** The high-temperature-side pump **411** is a high-temperature-side heating-medium pumping portion that pumps the heating medium to the inlet side of the heating medium channel **12***b* of the water-refrigerant heat exchanger **12**. The high-temperature-side pump **411** is comparable to an electric pump whose rotation speed (or pumping capability) is controlled by the control voltage output from the controller **60**.

**[0081]** As will be described later, the heating medium circuit **40** includes a first low-temperature-side pump **421***a* and a second low-temperature-side pump **421***b* at the side of the low-temperature-side circuit **42**. The basic configuration of the first low-temperature-side pump **421***a* and the second low-temperature-side pump **421***b* is similar to that of the high-temperature-side pump **411**.

**[0082]** An electric heater **412** is provided on the outlet side of the heating medium channel **12***b* of the water-refrigerant heat exchanger **12**. The electric heater **412** is a heating portion that heats the heating medium flowing from the water-refrigerant heat exchanger **12**. According to the present embodiment, the electric heater **412** uses a PTC heater including a PTC element that generates heat when supplied with power. The amount of heat generated by the electric heater **412** is controlled by the control voltage output from the controller **60**.

**[0083]** The inlet side of the three-way valve **44** is connected to the electric heater **412** at the downstream side of the flowing heating medium. The three-way valve **44** is a three-way flow control valve that allows the heating medium flowing from the water-refrigerant heat exchanger **12** to flow into the inside and allows the heating medium to flow toward at least either the heater core **413** or an inlet-side connection channel **431** (described later).

**[0084]** The three-way valve **44** is configured to be able to continuously adjust the flow ratio between the flow rate of the heating medium flowing into the heater core **413** and the flow rate of the heating medium flowing into the inlet-side connection channel **431**. The three-way valve **44** can thereby adjust the flow rate of the heating medium flowing through the inlet-side connection channel **431**.

**[0085]** In addition, the three-way valve **44** adjusts the flow ratio and thereby enables the total flow of the heating medium flowing from the water-refrigerant heat exchanger **12** to be directed to either the heater core **413** or the inlet-side connection channel **431**. Therefore, the three-way valve **44** also functions as a high-temperature-side circuit switching portion that switches the circuit configuration of the high-temperature-side circuit **41**. Operations of the three-way valve **44** are controlled by the control signal output from the controller **60**.

**[0086]** The heater core **413** is placed in the air-conditioning case **31** of the interior air-conditioning unit **30**. The heater core **413** is a heating heat exchange portion that provides heat exchange between the heating medium heated by the water-refrigerant heat exchanger **12**, for example, and the supplied air supplied into the vehicle compartment. The heater core **413** radiates the heat of the heating medium to the supplied air to heat the supplied air. Therefore, the supplied air is comparable to a fluid to be heated in the thermal management system **1**.

**[0087]** The heating medium outlet of the heater core **413** connects with the suction port side of the high-temperature-side pump **411** via a first heating medium joint portion **45***a*. The first heating medium joint portion **45***a* is a three-way joint for the heating medium.

**[0088]** As will be described later, the heating medium circuit **40** includes second through sixth medium joint portions **45***b* through **45***f* at the side of the low-temperature-side circuit **42**. The basic configuration of the first through sixth heating medium joint portions **45***a* through **45***f* is similar to that of the first refrigerant joint portion **13***a* of the refrigeration cycle equipment **10**, for example.

**[0089]** The low-temperature-side circuit **42** includes the first low-temperature-side pump **421***a*, the second low-temperature-side pump **421***b*, a cooling water channel **51***a* for the battery **51**, a five-way valve **422**, and a low-temperature-side radiator **423**, for example. The low-temperature-side circuit **42** connects with the heating medium channel **20***b* of the chiller **20**.

**[0090]** The first low-temperature-side pump **421***a* is a battery-side heating-medium pumping portion that pumps the heating medium to the cooling water channel **51***a* of the battery **51**. The cooling water channel **51***a* of the battery **51** is formed in a dedicated case that accommodates multiple battery cells configuring the battery **51**. The cooling water channel **51***a* of the battery **51** is comparable to a first heat exchange portion that provides heat exchange between the multiple battery cells forming the battery **51** and the heating medium.

**[0091]** The outlet of the cooling water channel **51***a* of the battery **51** connects with the five-way valve **422** at the battery-side inlet **422***a* via the second heating medium joint portion **45***b*.

**[0092]** The second low-temperature-side pump **421***b* is a high-voltage instrument-side heating-medium pumping portion that pumps the heating medium to cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. The cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** are formed in the housing or the case configuring an outer shell of each high-voltage instrument **50**. Each of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** is a second heat exchange portion that provides heat exchange between the high-voltage instrument **50** and the heating medium.

**[0093]** According to the present embodiment, the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** specifically correspond to the cooling water channel **52***a* of the inverter **52**, the cooling water channel **53***a* of the motor generator **53**, and the cooling water channel **54***a* of the ADAS controller **54**. The heating medium pumped from the second low-temperature-side pump **421***b* flows through the cooling water channel **52***a* of the inverter **52**, the cooling water channel **53***a* of the motor generator **53**, and the cooling water channel **54***a* of the ADAS controller **54** in this order.

**[0094]** The outlet of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** (that is, the outlet of the cooling water channel **54***a* of the ADAS controller **54**) connects with the five-way valve **422** at the high-voltage instrument-side inlet **422***b*.

**[0095]** The five-way valve **422** is a low-temperature-side circuit switching portion that switches the circuit configuration of the low-temperature-side circuit **42**. The five-way valve **422** includes a battery-side inlet **422***a* and a high-voltage instrument-side inlet **422***b* as inlets for the heating medium. The five-way valve **422** includes a chiller-side outlet **422***c*, a bypass-channel-side outlet **422***d*, and a radiator-side outlet **422***e* as outlets for the heating medium. The detailed configuration of the five-way valve **422** will be described later.

**[0096]** The chiller-side outlet **422***c* of the five-way valve **422** connects with the inlet side of the heating medium channel **20***b* of the chiller **20**. The outlet of the heating medium channel **20***b* of the chiller **20** connects with the inlet side of a third heating medium joint portion **45***c*. One outlet of the third heating medium joint portion **45***c* connects with one inlet side of a fourth heating medium joint portion **45***d*. The other outlet of the third heating medium joint portion **45***c* connects with one inlet side of a fifth heating medium joint portion **45***e*.

**[0097]** The outlet of the fourth heating medium joint portion **45***d* connects with the suction port side of the first low-temperature-side pump **421***a* via the sixth heating medium joint portion **45***f*. A bypass-channel-side outlet **422***d* of the five-way valve **422** connects with the inlet side of a heating medium bypass channel **424**. The outlet side of the heating medium bypass channel **424** connects with the other inlet of the fourth heating medium joint portion **45***d*.

**[0098]** The heating medium bypass channel **424** forms a flow channel where the heating medium flowing out of the cooling water channel **51***a* of the battery **51** bypasses the chiller **20** and the low-temperature-side radiator **423** and returns to the inlet side of the cooling water channel **51***a* of the battery **51**.

**[0099]** The outlet port of the fifth heating medium joint portion **45***e* connects with the suction port side of the second low-temperature-side pump **421***b*. The radiator-side outlet **422***e* of the five-way valve **422** connects with the heating medium inlet side of the low-temperature-side radiator **423**. The low-temperature-side radiator **423** is a low-temperature-side outdoor air heat exchange portion that provides heat exchange between the outdoor air and the heating medium flowing from the radiator-side outlet **422***e* of the five-way valve **422**. The heating medium outlet of the low-temperature-side radiator **423** connects with the other inlet side of the fifth heating medium joint portion **45***e*.

**[0100]** The connection channel **43** is a heating medium flow channel that connects the high-temperature-side circuit **41** and the low-temperature-side circuit **42**. The connection channel **43** includes the inlet-side connection channel **431** and an outlet-side connection channel **432**. The inlet-side connection channel **431** forms a flow channel that guides the heating medium flowing through the high-temperature-side circuit **41** to the low-temperature-side circuit **42**. The outlet-side connection channel **432** forms a flow channel that guides the heating medium flowing through the low-temperature-side circuit **42** to the high-temperature-side circuit **41**.

**[0101]** The entry of the inlet-side connection channel **431** is connected to one outlet side of the three-way valve **44**. The exit of the inlet-side connection channel **431** is connected to one inlet of the sixth heating medium joint portion **45***f*. The entry of the outlet-side connection channel **432** is connected to one outlet of the second heating medium joint portion **45***b*. The exit of the outlet-side connection channel **432** is connected to one inlet of the first heating medium joint portion **45***a*.

**[0102]** The inlet-side connection channel **431** can guide the heating medium, being heated by the water-refrigerant heat exchanger **12** of the high-temperature-side circuit **41** and upstream of the heater core **413**, to the suction port side of the first low-temperature-side pump **421***a* of the low-temperature-side circuit **42**. The outlet-side connection channel **432** can guide the heating medium, flowing from the cooling water channel **51***a* of the battery **51**, to the suction port side of the high-temperature-side pump **411**, downstream of the heater core **413** in the high-temperature-side circuit.

**[0103]** The three-way valve **44** flows the heating medium through the inlet-side connection channel **431** and the outlet-side connection channel **432** as the connection channel **43**, making it possible to mix the heating medium flowing through the high-temperature-side circuit **41** and the heating medium flowing through the low-temperature-side circuit **42**. Heat can be transferred between the heating medium flowing through the high-temperature-side circuit **41** and the heating medium flowing through the low-temperature-side circuit **42**. Therefore, the connection channel **43** is comparable to a heat transfer portion.

**[0104]** The three-way valve **44** regulates the flow rate of the heating medium flowing through the inlet-side connection channel **431**, making it possible to adjust the heat transfer amount between the heating medium flowing through the high-temperature-side circuit **41** and the heating medium flowing through the low-temperature-side circuit **42**. Therefore, the three-way valve **44** is a heat transfer amount adjusting portion that adjusts the heat transfer amount in the connection channel **43**.

**[0105]** The description below explains the detailed configuration of the five-way valve **422** by reference to FIGS. **2** through **4**. As illustrated in FIGS. **2** through **4**, the five-way valve **422** allows the heating medium to flow inside from the battery-side inlet **422***a* and the high-voltage instrument-side inlet **422***b*. Furthermore, the heating medium flowing inside is forced to flow from at least one of the chiller-side outlet **422***c*, the bypass-channel-side outlet **422***d*, and the radiator-side outlet **422***e*.

**[0106]** As illustrated in the explanatory diagrams of FIGS. **2** through **4**, the five-way valve **422** can be formed by combining multiple three-way flow control valves, for example.

**[0107]** As indicated by the thick solid line in the explanatory diagram of FIG. **2**, the five-way valve **422** allows the battery-side inlet **422***a* to flow inside the heating medium flowing from the cooling water channel **51***a* of the battery **51**. Then, the heating medium flowing inside through the battery-side inlet **422***a* can flow to at least either the heating medium bypass channel **424** or the heating medium channel **20***b* of the chiller **20**.

**[0108]** The five-way valve **422** is configured to be able to continuously adjust the flow ratio between the flow rate of the heating medium flowing into the heating medium bypass channel **424** and the flow rate of the heating medium flowing into the heating medium channel **20***b* of the chiller **20**. By adjusting the flow ratio, the five-way valve **422** can also allow the total flow of the heating medium flowing from the cooling water channel **51***a* of the battery **51** to be directed to either the heating medium bypass channel **424** or the heating medium channel **20***b* of the chiller **20**.

**[0109]** The five-way valve **422** can thereby switch circuits, that is, the circuit connecting the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium bypass channel **424** and the circuit connecting the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium channel **20***b* of the chiller **20**.

**[0110]** As indicated by the thick solid line in the explanatory diagram of FIG. **3**, the five-way valve **422** allows the high-voltage instrument-side inlet **422***b* to flow inside the heating medium flowing from the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. The refrigerant flowing into the interior through the high-voltage instrument-side inlet **422***b* can flow out to at least either the low-temperature-side radiator **423** or the heating medium channel **20***b* of the chiller **20**.

**[0111]** The five-way valve **422** is configured to be able to continuously adjust the flow ratio between the flow rate of the heating medium flowing into the low-temperature-side radiator **423** and the flow rate of the heating medium flowing into the heating medium channel **20***b* of the chiller **20**. By adjusting the flow ratio, the five-way valve **422** can also allow the total flow of the heating medium flowing from the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** to be directed to either the low-temperature-side radiator **423** or the heating medium channel **20***b* of the chiller **20**.

**[0112]** The five-way valve **422** can thereby switch circuits, that is, the circuit connecting the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the inlet side of the heating medium of the low-temperature-side radiator **423** and the circuit connecting the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the inlet side of the heating medium channel **20***b* of the chiller **20**.

**[0113]** As indicated by the thick solid and dashed lines in the explanatory diagram of FIG. **4**, the five-way valve **422** can allow the heating medium to flow inside, that is, at least the heating medium flowing from the cooling water channel **51***a* of the battery **51** or the heating medium flowing from the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, and can allow the heating medium to flow out to the heating medium channel **20***b* of the chiller **20**.

**[0114]** The five-way valve **422** is configured to be able to continuously adjust the flow ratio between the flow rate of the heating medium flowing from the cooling water channel **51***a* of the battery **51** and the flow rate of the heating medium flowing from the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** under the condition that the heating medium flows into the heating medium channel **20***b* of the chiller **20**.

**[0115]** By adjusting the flow ratio, the five-way valve **422** can ensure that the total flow of the heating medium, flowing into the heating medium channel **20***b* of the chiller **20**, corresponds to either the heating medium flowing from the cooling water channel **51***a* of the battery **51** or the heating medium flowing from the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**.

**[0116]** The five-way valve **422** can thereby switch circuits, that is, the circuit connecting the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium channel **20***b* of the chiller **20** and the circuit connecting the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the inlet side of the heating medium channel **20***b* of the chiller **20**.

**[0117]** Furthermore, the five-way valve **422** can combine the above-described switching function of the heating medium circuit. For example, it is possible to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium bypass channel **424**. At the same time, it is possible to connect the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the inlet side of the heating medium channel **20***b* of the chiller **20**.

**[0118]** For example, it is possible to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium channel **20***b* of the chiller **20**. At the same time, it is possible to connect the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the heating medium inlet side of the low-temperature-side radiator **423**.

**[0119]** For example, it is possible to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium channel **20***b* of the chiller **20**. At the same time, it is possible to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the heating medium inlet side of the low-temperature-side radiator **423**.

**[0120]** The description below explains the interior air-conditioning unit **30**. The interior air-conditioning unit **30** integrates multiple components to blow out the supplied air to appropriate locations in the vehicle compartment under the condition that the supplied air is adjusted to the appropriate temperature for the air conditioning in the vehicle compartment. The interior air-conditioning unit **30** is placed inside an instrument panel in the forefront of the vehicle compartment.

**[0121]** As illustrated in FIG. **1**, the interior air-conditioning unit **30** accommodates an interior blower **32**, the interior evaporator **18**, and the heater core **413**, for example, in the air-conditioning case **31** forming an air channel for the supplied air. The air-conditioning case **31** is made of a resin (such as polypropylene) that is elastic to some degree and excels in strength.

**[0122]** An indoor/outdoor air switch **33** is placed in the air-conditioning case **31**, most upstream of the flow of the supplied air. The indoor/outdoor air switch **33** selectively introduces indoor air (air inside the vehicle compartment) and outdoor air (air outside the vehicle compartment) into the air-conditioning case **31**. Operations of the indoor/outdoor air switch **33** are controlled by the control signal output from the controller **60**.

**[0123]** The interior blower **32** is provided for the indoor/outdoor air switch **33** at the downstream side of the flow of the supplied air. The interior blower **32** blows the air, drawn through the indoor/outdoor air switch **33**, into the vehicle compartment. The interior blower **32** is an electric blower that uses an electric motor to drive a centrifugal multi-blade fan. The interior blower **32** controls the rotation speed (or blowing capability) based on the control voltage output from the controller **60**.

**[0124]** The interior blower **32** is provided with the interior evaporator **18** and the heater core **413**, downstream of the flow of the supplied air. The interior evaporator **18** is positioned upstream of the heater core **413** in terms of the flow of the supplied air. A cold air bypass channel **35** is formed in the air-conditioning case **31** to flow the supplied air after passing through the interior evaporator **18** while bypassing the heater core **413**.

**[0125]** An air mix door **34** is provided downstream of the supplied air referring to the interior evaporator **18** in the air-conditioning case **31** and upstream of the supplied air referring to the heater core **413** and the cold air bypass channel **35**.

**[0126]** In terms of the supplied air after passing through the interior evaporator **18**, the air mix door **34** provides an airflow rate adjustment portion that adjusts the airflow rate of the supplied air passing through the heater core **413** and the airflow rate of the supplied air passing through the cold air bypass channel **35**. The air mix door **34** is driven by an electric actuator for the air mix door. Operations of the electric actuator for the air mix door are controlled by the control signal output from the controller **60**.

**[0127]** A mixing space **36** is provided downstream of the flow of the supplied air, referring to the heater core **413** and the cold air bypass channel **35**. The mixing space **36** mixes the supplied air heated by the heater core **413** and the supplied air that passes through the cold air bypass channel **35** and is not heated.

**[0128]** The interior air-conditioning unit **30** allows the air mix door **34** to adjust the airflow rate, making it possible to adjust the temperature of the supplied air (air-conditioned wind) mixed in the mixing space **36**.

**[0129]** Multiple holes (not shown) are formed in the air-conditioning case **31** most downstream of the flow of the supplied air to blow out the supplied air mixed in the mixing space **36** into the vehicle compartment.

**[0130]** The opening holes lead to multiple outlets formed in the vehicle compartment. The outlets include a face outlet, a foot outlet, and a defroster outlet. The face outlet blows out the supplied air toward the upper body of an occupant. The foot outlet blows out the supplied air toward the feet of the occupant. The defroster outlet blows out the supplied air toward the front window glass of the vehicle.

**[0131]** A blow-out mode door (not shown) is provided for each of the holes. The blow-out mode door opens and closes each hole. The blow-out mode door is driven by an electric actuator for the blow-out mode door. Operations of the electric actuator for the blow-out mode door are controlled by the control signal output from the controller **60**.

**[0132]** The interior air-conditioning unit **30** can change positions to blow the air-conditioned wind by switching the holes opened by the blow-out mode door.

**[0133]** The description below outlines the electric control portion of the present embodiment. The controller **60** is composed of a well-known microcomputer including CPU, ROM, RAM, and peripheral circuits. The controller **60** performs various calculations and processes based on a control program stored in the ROM and controls operations of the control-target devices **11**, **14***a* through **14***c*, **15***a*, **15***b*, **32**, **33**, **34**, **44**, **411**, **412**, **421***a*, **421***b*, and **422**, for example, connected to the output side.

**[0134]** As illustrated in the block diagram of FIG. **5**, the input side of the controller **60** connects with an indoor air temperature sensor **61**, an outdoor air temperature sensor **62**, a solar radiation sensor **63**, a first refrigerant temperature sensor **64***a* through a third refrigerant temperature sensor **64***c*, an evaporator temperature sensor **64***f*, a first refrigerant pressure sensor **65***a* through a third refrigerant pressure sensor **65***c*, a high-temperature-side heating medium temperature sensor **66***a*, a first low-temperature-side heating medium temperature sensor **67***a*, a second low-temperature-side heating medium temperature sensor **67***b*, a battery temperature sensor **68**, and an air-conditioned wind temperature sensor **69**. The controller **60** is supplied with detection signals from these sensors.

**[0135]** The indoor air temperature sensor **61** is an indoor air temperature detection portion that detects the temperature inside the vehicle compartment (indoor air temperature) Tr. The outdoor air temperature sensor **62** is an outdoor air temperature detection portion that detects the temperature outside the vehicle compartment (outdoor air temperature) Tam. The solar radiation sensor **63** is a solar radiation amount detection portion that detects the amount of solar radiation As irradiated into the vehicle compartment.

**[0136]** The first refrigerant temperature sensor **64***a* is a first refrigerant temperature detection portion that detects first refrigerant temperature TR**1**, which is the temperature of the refrigerant discharged from the compressor **11**. The second refrigerant temperature sensor **64***b* is a second refrigerant temperature detection portion that detects second refrigerant temperature TR**2**, which is the temperature of the refrigerant flowing from the refrigerant channel **12***a* of the water-refrigerant heat exchanger **12**. The third refrigerant temperature sensor **64***c* is a third refrigerant temperature detection portion that detects third refrigerant temperature TR**3**, which is the temperature of the refrigerant flowing from the outdoor heat exchanger **16**.

**[0137]** The evaporator temperature sensor **64***f* is an evaporator temperature detection portion that detects refrigerant evaporation temperature (evaporator temperature) Tefin in the interior evaporator **18**. Specifically, the evaporator temperature sensor **64***f* according to the present embodiment detects the temperature of a heat exchange fin of the interior evaporator **18**.

**[0138]** The first refrigerant pressure sensor **65***a* is a first refrigerant pressure detection portion to detect a first refrigerant pressure PR**1**, that is, the pressure of the refrigerant discharged from the compressor **11**. The second refrigerant pressure sensor **65***b* is a second refrigerant pressure detection portion to detect a second refrigerant pressure PR**2**, that is, the pressure of the refrigerant flowing from the refrigerant channel **12***a* of the water-refrigerant heat exchanger **12**. The third refrigerant pressure sensor **65***c* is a third refrigerant pressure detection portion to detect a third refrigerant pressure PR**3**, that is, the pressure of the refrigerant flowing from the outdoor heat exchanger **16**.

**[0139]** A high-temperature-side heating medium temperature sensor **66***a* is a high-temperature-side heating medium temperature detection portion that is provided downstream of the electric heater **412** in terms of the flow of the heating medium and detects a high-temperature-side heating medium temperature TWH, that is, the temperature of the heating medium flowing into the three-way valve **44**.

**[0140]** The first low-temperature-side heating medium temperature sensor **67***a* is a first low-temperature-side heating medium temperature detection portion to detect a first low-temperature-side heating medium temperature TWL**1**, that is, the temperature of the heating medium which is pumped from the first low-temperature-side pump **421***a* and flows into the cooling water channel **51***a* of the battery **51**.

**[0141]** The second low-temperature-side heating medium temperature sensor **67***b* is a second low-temperature-side heating medium temperature detection portion to detect the second low-temperature-side heating medium temperature TWL**2**, that is, the temperature of the heating medium which is pumped from the second low-temperature-side pump **421***b* and flows into the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. More specifically, the second low-temperature-side heating medium temperature TWL**2** is the temperature of the heating medium flowing into the cooling water channel **52***a* of the inverter **52**.

**[0142]** The battery temperature sensor **68** is a battery temperature detection portion to detect the battery temperature TB (temperature of the battery **51**). The battery temperature sensor **68** according to the present embodiment includes multiple temperature sensors and detects temperatures at multiple locations of the battery **51**. Therefore, the controller **60** can detect temperature differences among battery cells forming the battery **51**. The battery temperature TB uses an average of detection values from the multiple temperature sensors.

**[0143]** The air-conditioned wind temperature sensor **69** is an air-conditioned wind temperature detection portion to detect temperature TAV of the supplied air blown from the mixing space **36** into the vehicle compartment.

**[0144]** As illustrated in FIG. **5**, the input side of the controller **60** connects with an air-conditioning operation panel **70**. The air-conditioning operation panel **70** is placed near the instrument panel in the front of the vehicle compartment. The controller **60** is supplied with operation signals from various operation switches provided for the air-conditioning operation panel **70**.

**[0145]** Specifically, the operation switches provided for the air-conditioning operation panel **70** include an auto switch, an air conditioner switch, an air flow rate setting switch, and a temperature setting switch, for example.

**[0146]** The auto switch is an operation portion that allows the user to enable or disable the automatic control operation of the air conditioning in the vehicle compartment. The air conditioner switch is an operation portion that allows the user to cool the supplied air by using the interior evaporator **18**. The air flow rate setting switch is an operation portion that allows the user to manually set the air flow rate of the interior blower **32**. The temperature setting switch is an operation portion that allows the user to configure setup temperature Tset in the vehicle compartment.

**[0147]** The controller **60** according to the present embodiment is integrated with a control portion that controls various control-target instruments connected to the output side. The controller **60** configures the hardware and the software as a control portion that controls operations of the control-target instruments.

**[0148]** For example, the configuration of the controller **60** includes a compressor control portion **60***a* configured to control the refrigerant discharge capacity of the compressor **11** (specifically, the rotation speed of the compressor **11**). A low-temperature-side heating medium circuit control section **60***b* is configured to control operations of the five-way valve **422**. A heat transfer amount control section **60***c* is configured to control operations of the three-way valve **44**.

**[0149]** The description below explains the operations of the thermal management system **1** configured as above. As described above, the thermal management system **1** can air-condition the vehicle compartment inside and adjust the temperatures of the in-vehicle units. The thermal management system **1** provides various operation modes by switching the circuit configurations of the refrigeration cycle equipment **10** and the heating medium circuit **40**.

**[0150]** The thermal management system **1** includes operation modes such as an operation mode for air conditioning in the vehicle compartment and an operation mode for temperature adjustment of the in-vehicle units. The thermal management system **1** can appropriately combine the operation mode for air conditioning and the operation mode for temperature adjustment.

**[0151]** The thermal management system **1** can only air-condition the vehicle compartment without adjusting the temperatures of the in-vehicle units. It is possible to adjust the temperatures of the in-vehicle units without air conditioning in the vehicle compartment. It is also possible to simultaneously air-condition the vehicle compartment and adjust the temperatures of the in-vehicle units.

**[0152]** The description below explains the operation modes for air conditioning. The operation modes for air conditioning include (A1) cooling mode, (A2) serial dehumidification and heating mode, (A3) parallel dehumidification and heating mode, and (A4) heating mode.

**[0153]** (A1) The cooling mode, as the operation mode, cools the vehicle compartment by cooling and blowing the supplied air into the vehicle compartment.

**[0154]** (A2) The serial dehumidification and heating mode, as the operation mode, dehumidifies and heats the vehicle compartment by reheating the cooled and dehumidified supplied air and blowing it out into the vehicle compartment.

**[0155]** (A3) The parallel dehumidification and heating mode, as the operation mode, heats and dehumidifies the vehicle compartment by reheating the cooled and dehumidified supplied air through the use of a heating capability higher than the serial dehumidification and heating mode and blowing the supplied air out into the vehicle compartment.

**[0156]** (A4) The heating mode, as the operation mode, heats the vehicle compartment by heating the supplied air and blowing it out into the vehicle compartment.

**[0157]** The operation modes for air conditioning are switched by executing a control program for air conditioning stored in the controller **60**. The control program for air conditioning is executed when the auto switch of the operation panel **70** is turned on to activate the automatic control operation of air conditioning in the vehicle compartment.

**[0158]** The main routine of the control program for air conditioning reads detection signals from the above-described sensors and operation signals corresponding to the operation switches on the operation panel **70** at predetermined intervals. The main routine calculates target blowout temperature TAO, that is, the target temperature of the air to be blown into the vehicle compartment, based on values of the read detection signals and operation signals.

**[0159]** More specifically, target outlet temperature TAO is calculated through the use of equation F1 as follows.

$$TAO = Kset \times Tset - Kr \times Tr - Kam \times Tam - Ks \times As + C \quad \text{(F1)}$$

**[0160]** Tset denotes the setup temperature, in the vehicle compartment, entered by the temperature setting switch on the operation panel **70**. Tr denotes the indoor air temperature detected by the indoor air temperature sensor **61**. Tam denotes the outdoor air temperature detected by the outdoor air temperature sensor **62**. As denotes the amount of solar radiation detected by the solar radiation sensor **63**. Kset, Kr, Kam, and Ks denote control gains, and C denotes a correction constant.

**[0161]** The target outlet temperature TAO may be lower than the predetermined cooling reference temperature KTAO**1** while the air conditioner switch on the operation panel **70** is turned on. In this case, the operation mode for air conditioning is switched to the cooling mode.

**[0162]** The target air outlet temperature TAO may be higher than or equal to the cooling reference temperature KTAO**1** and the outdoor air temperature Tam may be higher than the predetermined dehumidification and heating reference temperature KTAO**2** while the air conditioner switch is turned on. In this case, the operation mode for air conditioning is switched to the serial dehumidification and heating mode.

**[0163]** The target outlet temperature TAO may be higher than or equal to the cooling reference temperature KTAO**1** and the outdoor air temperature Tam is lower than the dehumidification and heating standard temperature KTAO**2** while the air conditioner switch is turned on. In this case, the operation mode for air conditioning is switched to the parallel dehumidification and heating mode.

**[0164]** When the cooling switch as an air conditioner switch is not turned on, the operation mode for air conditioning is switched to the heating mode.

**[0165]** The cooling mode is activated mainly in summer when the outdoor air temperature is relatively high. The serial dehumidification and heating mode is activated mainly in spring or autumn. The parallel dehumidification and heating mode is activated mainly in early spring or late autumn when the supplied air needs to be heated through the use of a heating capability higher than the serial dehumidification and heating mode. The heating mode is activated mainly in winter when the outdoor air temperature is low. The description below explains in detail the operations of the operation modes for air conditioning.

**[0166]** (A1) Cooling Mode

**[0167]** In the cooling mode, the controller **60** fully opens the heating expansion valve **14***a* and throttles the cooling expansion valve **14***b* to reduce the refrigerant pressure. The cooling expansion valve **14***c* is controlled according to the operation mode for temperature adjustment. The same applies to the other operation modes for air conditioning. The controller **60** closes the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0168]** The refrigeration cycle equipment **10** in the cooling mode configures a vapor-compression refrigeration cycle where the refrigerant discharged from the compressor **11** circulates through the water-refrigerant heat exchanger **12**, the fully open heating expansion valve **14***a*, the outdoor heat exchanger **16**, the check valve **17**, the cooling expansion valve **14***b*, the interior evaporator **18**, the evaporation pressure adjustment valve **19**, the accumulator **21**, and the suction port of compressor **11** in order.

**[0169]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speeds of the compressor **11** so that the evaporator temperature Tefin detected by the evaporator temperature sensor **64***f* approximates the target evaporator temperature TEO. The target evaporator temperature TEO is determined by reference to a control map previously stored in the controller **60** based on the target blowout temperature TAO.

**[0170]** The controller **60** controls the throttle opening of the cooling expansion valve **14***b* so that the supercooling degree SC**3** of the refrigerant flowing into the cooling expansion valve **14***b* approximates the target supercooling degree SCO**3**.

**[0171]** The supercooling degree SC**3** of the refrigerant flowing into the cooling expansion valve **14***b* is calculated through the use of the third refrigerant temperature TR**3** detected by the third refrigerant temperature sensor **64***c* and the third refrigerant pressure PR**3** detected by the third refrigerant pressure sensor **65***c*. The target supercooling degree SCO**3** is determined by reference to a control map stored in advance in the controller **60** based on the outdoor air temperature Tam so that the performance coefficient (COP) of the cycle approximates the local maximum value.

**[0172]** The controller **60** controls the high-temperature-side pump **411** to provide a predetermined pumping capability. The controller **60** controls the three-way valve **44** so that at least part of the heating medium flowed inside flows out toward the heater core **413**. The first low-temperature-side pump **421***a*, the second low-temperature-side pump

**421***b*, and the five-way valve **422** are controlled according to the operation mode for temperature adjustment. The same applies to the other operation modes for air conditioning.

**[0173]** The controller **60** operates the electric heater **412** when the high-temperature-side heating medium temperature TWH, detected by the high-temperature-side heating medium temperature sensor **66***a*, is lower than the predetermined reference high-temperature-side heating medium temperature KTWH.

**[0174]** The controller **60** determines the blowing capability of the interior blower **32** based on the target blowout temperature TAO by reference to a control map previously stored in the controller **60**. The controller **60** controls the opening of the air mix door **34** so that the supplied air temperature TAV, detected by the air-conditioned wind temperature sensor **69**, approximates the target blowout temperature TAO.

**[0175]** The refrigeration cycle equipment **10** in the cooling mode configures a vapor-compression refrigeration cycle that allows the water-refrigerant heat exchanger **12** and the outdoor heat exchanger **16** to function as condensers (or radiators) to radiate and condense the refrigerant and allows the interior evaporator **18** to function as an evaporator to evaporate the refrigerant. As a result, the refrigeration cycle equipment **10** in the cooling mode allows the water-refrigerant heat exchanger **12** to heat the heating medium. The interior evaporator **18** cools the supplied air.

**[0176]** The heating medium circuit **40** in the cooling mode supplies the heater core **413** with the heating medium heated by the water-refrigerant heat exchanger **12**.

**[0177]** The interior air-conditioning unit **30** in the cooling mode allows the interior evaporator **18** to cool the supplied air blown from the interior blower **32**. The supplied air cooled by the interior evaporator **18** passes through the heater core **413** and the cold air bypass channel **35** according to the opening of the air mix door **34**. The temperature is adjusted to approximate the target blowout temperature TAO. The temperature-regulated supplied air is blown out into the vehicle compartment, thereby cooling the inside of the vehicle compartment.

**[0178]** (A2) Serial Dehumidification and Heating Mode

**[0179]** In the serial dehumidification and heating mode, the controller **60** throttles the heating expansion valve **14***a* and the cooling expansion valve **14***b*. The controller **60** closes the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0180]** The refrigeration cycle equipment **10** in the serial dehumidification and heating mode configures a vapor-compression refrigeration cycle where the refrigerant discharged from the compressor **11** circulates through the water-refrigerant heat exchanger **12**, the heating expansion valve **14***a*, the outdoor heat exchanger **16**, the check valve **17**, the cooling expansion valve **14***b*, the interior evaporator **18**, the evaporation pressure adjustment valve **19**, the accumulator **21**, and the suction port of compressor **11** in order.

**[0181]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** similarly to the cooling mode.

**[0182]** The controller **60** determines the throttle opening of the heating expansion valve **14***a* and the throttle opening of the cooling expansion valve **14***b* based on the target blowout temperature TAO by reference to the control map previously stored in the controller **60** so that the COP approximates the local maximum value. The serial dehumidification and heating mode control map is configured to decrease the throttle opening of the heating expansion valve **14***a* and increase the throttle opening of the cooling expansion valve **14***b*, corresponding to an increase in the target blowout temperature TAO.

**[0183]** The controller **60** controls operations of the high-temperature-side pump **411** of the heating medium circuit **40**, for example, similarly to the cooling mode. The controller **60** controls operations of the interior blower **32** of the interior air-conditioning unit **30**, for example, similarly to the cooling mode.

**[0184]** Therefore, the refrigeration cycle equipment **10** in the serial dehumidification and heating mode configures a vapor-compression refrigeration cycle where the water-refrigerant heat exchanger **12** functions as a condenser and the interior evaporator **18** functions as an evaporator. The outdoor heat exchanger **16** functions as a condenser when the saturation temperature of the refrigerant in the outdoor heat exchanger **16** is higher than the outdoor air temperature Tam. The outdoor heat exchanger **16** functions as an evaporator when the saturation temperature of the refrigerant in the outdoor heat exchanger **16** is lower than the outdoor air temperature Tam.

**[0185]** As a result, the refrigeration cycle equipment **10** in the serial dehumidification and heating mode allows the water-refrigerant heat exchanger **12** to heat the heating medium. The interior evaporator **18** cools the supplied air.

**[0186]** The heating medium circuit **40** in the serial dehumidification and heating mode supplies the heater core **413** with the heating medium heated by the water-refrigerant heat exchanger **12**.

**[0187]** The interior air-conditioning unit **30** in the serial dehumidification and heating mode allows the interior evaporator **18** to cool and dehumidify the supplied air from the interior blower **32**. The supplied air cooled and dehumidified by the interior evaporator **18** is temperature-regulated to approximate the target blowout temperature TAO according to the adjustment of the opening of the air mix door **34**. The temperature-regulated supplied air is blown out into the vehicle compartment to provide dehumidification and heating in the vehicle compartment.

**[0188]** The refrigeration cycle equipment **10** in the serial dehumidification and heating mode decreases the throttle opening of the heating expansion valve **14***a* and increases the throttle opening of the cooling expansion valve **14***b*, corresponding to an increase in the target blowout temperature TAO. It is possible to improve the heating capability of the supplied air in the heater core **413** corresponding to an increase in the target blowout temperature TAO.

**[0189]** More specifically, when the saturation temperature of the refrigerant in the outdoor heat exchanger **16** is higher than the outdoor air temperature Tam, it is possible to decrease a temperature difference between the saturation temperature of the refrigerant in the outdoor heat exchanger **16** and the outdoor air temperature Tam corresponding to an increase in the target blowout temperature TAO. Therefore, as the target blowout temperature TAO increases, it is possible to decrease the amount of heat discharge from the refrigerant in the outdoor heat exchanger **16** to the outdoor air and increase the amount of heat discharge from the refrigerant in the water-refrigerant heat exchanger **12** to the heating medium.

**[0190]** When the saturation temperature of the refrigerant in the outdoor heat exchanger **16** is lower than the outdoor air temperature Tam, it is possible to increase a temperature difference between the outdoor air temperature Tam and the refrigerant in the outdoor heat exchanger **16**, corresponding to an increase in the target blowout temperature TAO. It is possible to increase the amount of heat absorbed by the refrigerant in the outdoor heat exchanger **16** from the outdoor air and increase the amount of heat discharged from the refrigerant in the water-refrigerant heat exchanger **12** to the heating medium, corresponding to an increase in the target blowout temperature TAO.

**[0191]** As a result, the serial dehumidification and heating mode can improve the heating capability of the supplied air in the heater core **413**, corresponding to an increase in the target blowout temperature TAO.

**[0192]** (A3) Parallel Dehumidification and Heating Mode

**[0193]** In the parallel dehumidification and heating mode, the controller **60** throttles the heating expansion valve **14***a* and the cooling expansion valve **14***b*. The controller **60** opens the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0194]** The refrigeration cycle equipment **10** in the parallel dehumidification and heating mode allows the refrigerant discharged from the compressor **11** to circulate through the water-refrigerant heat exchanger **12**, the first refrigerant joint portion **13***a*, the heating expansion valve **14***a*, the outdoor heat exchanger **16**, the heating channel **22***b*, the accumulator **21**, and the suction port of compressor **11** in order. At the same time, a vapor-compression refrigeration cycle is configured to allow the refrigerant discharged from the compressor **11** to circulate through the water-refrigerant heat exchanger **12**, the first refrigerant joint portion **13***a*, the dehumidification channel **22***a*, the cooling expansion valve **14***b*, the interior evaporator **18**, the evaporation pressure adjustment valve **19**, the accumulator **21**, and the suction port of compressor **11** in order. In other words, the configured cycle connects the outdoor heat exchanger **16** and the interior evaporator **18** in parallel, referring to the refrigerant flow.

**[0195]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** so that the first refrigerant pressure PR**1** detected by the first refrigerant pressure sensor **65***a* approximates a target condensation pressure PDO. The target condensing pressure PDO is configured so that the high-temperature-side heating medium temperature TWH approximates a predetermined target water temperature TWHO.

**[0196]** The controller **60** determines the throttle opening of the heating expansion valve **14***a* and the throttle opening of the cooling expansion valve **14***b* based on the target blowout temperature TAO by reference to the control map previously stored in the controller **60** so that the COP approximates the local maximum value. The control map in the parallel dehumidification and heating mode is configured to decrease the throttle opening of heating expansion valve **14***a* and increase the opening of the cooling expansion valve **14***b* corresponding to an increase in the target blowout temperature TAO.

**[0197]** The controller **60** controls operations of the high-temperature-side pump **411** of the heating medium circuit **40**, for example, similarly to the cooling mode. The controller **60** controls operations of the interior blower **32** of the interior air-conditioning unit **30**, for example, similarly to the cooling mode.

**[0198]** The refrigeration cycle equipment **10** in the parallel dehumidification and heating mode configures a vapor-compression refrigeration cycle where the water-refrigerant heat exchanger **12** functions as a condenser, and the outdoor heat exchanger **16** and the interior evaporator **18** function as evaporators. As a result, the refrigeration cycle equipment **10** in the parallel dehumidification and heating mode allows the water-refrigerant heat exchanger **12** to heat the heating medium. The interior evaporator **18** cools the supplied air.

**[0199]** The heating medium circuit **40** in the parallel dehumidification and heating mode supplies the heater core **413** with the heating medium heated by the water-refrigerant heat exchanger **12**.

**[0200]** The interior air-conditioning unit **30** in the parallel dehumidification and heating mode allows the interior evaporator **18** to cool and dehumidify the supplied air from the interior blower **32**. The supplied air cooled and dehumidified by the interior evaporator **18** is temperature-regulated to approximate the target blowout temperature TAO according to the adjustment of the opening of the air mix door **34**. The temperature-regulated supplied air is blown out into the vehicle compartment to provide dehumidification and heating in the vehicle compartment.

**[0201]** Furthermore, the refrigeration cycle equipment **10** in the parallel dehumidification and heating mode can cause the throttle opening of the heating expansion valve **14***a* to be smaller than the throttle opening of the cooling expansion valve **14***b*. It is possible to cause the refrigerant evaporation temperature in the outdoor heat exchanger **16** to be lower than the refrigerant evaporation temperature in the interior evaporator **18**.

**[0202]** Compared to the serial dehumidification and heating mode, it is possible to increase the amount of heat absorbed by the refrigerant in the outdoor heat exchanger **16** from the outdoor air and increase the amount of heat discharged from the refrigerant in the water-refrigerant heat exchanger **12** to the heating medium. As a result, the parallel dehumidification and heating mode can improve the heating capability of the supplied air in the heater core **413** more efficiently than the serial dehumidification and heating mode.

**[0203]** (A4) Heating Mode

**[0204]** In the heating mode, the controller **60** throttles the heating expansion valve **14***a* and fully closes the cooling expansion valve **14***b*. The controller **60** closes the on-off dehumidification valve **15***a* and opens the on-off heating valve **15***b*.

**[0205]** Consequently, the refrigeration cycle equipment **10** in the heating mode configures a vapor-compression refrigeration cycle where the refrigerant discharged from the compressor **11** circulates through the water-refrigerant heat exchanger **12**, the heating expansion valve **14***a*, the outdoor heat exchanger **16**, the heating channel **22***b*, the accumulator **21**, and the suction port of the compressor **11** in order.

**[0206]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** similarly to the parallel dehumidification and heating mode.

**[0207]** The controller **60** controls the throttle opening of the heating expansion valve **14***a* so that the supercooling degree SC**2** of the refrigerant flowing into the heating expansion valve **14***a* approximates the target supercooling degree SCO**2**.

**[0208]** The supercooling degree SC**2** of the refrigerant flowing into the heating expansion valve **14***a* is calculated through the use of the second refrigerant temperature TR**2** detected by the second refrigerant temperature sensor **64***b* and the second refrigerant pressure PR**2** detected by the second refrigerant pressure sensor **65***b*. The target supercooling degree SCO**2** is configured based on the first refrigerant temperature TR**1** detected by the first refrigerant temperature sensor **64***a* by reference to the control map previously stored in the controller **60** so that COP approximates the local maximum value.

**[0209]** The controller **60** controls operations of the high-temperature-side pump **411** of the heating medium circuit **40**, for example, similarly to the cooling mode. The controller **60** controls operations of the interior blower **32** of the interior air-conditioning unit **30**, for example, similarly to the cooling mode.

**[0210]** The refrigeration cycle equipment **10** in the heating mode configures a vapor-compression refrigeration cycle where the water-refrigerant heat exchanger **12** functions as a condenser and the outdoor heat exchanger **16** functions as an evaporator. As a result, the refrigeration cycle equipment **10** in the heating mode allows the water-refrigerant heat exchanger **12** to heat the heating medium.

**[0211]** The heating medium circuit **40** in the heating mode supplies the heater core **413** with the heating medium heated by the water-refrigerant heat exchanger **12**.

**[0212]** The interior air-conditioning unit **30** in the heating mode allows the supplied air blown from the interior blower **32** to pass through the interior evaporator **18**. The opening of the air mix door **34** is adjusted so that the supplied air having passed through the interior evaporator **18** is temperature-regulated to approximate the target blowout temperature TAO. The temperature-regulated supplied air is blown into the vehicle compartment to heat the vehicle compartment.

**[0213]** The description below explains the operation mode for temperature adjustment. The operation mode for temperature adjustment adjusts the temperatures of the battery **51** as a first temperature adjustment target and the high-voltage instrument **50** as a second temperature adjustment target.

**[0214]** According to the present embodiment, as above, the appropriate temperature zone for the battery **51** as the first temperature adjustment target differs from the appropriate temperature zone for the high-voltage instrument **50** as the second temperature adjustment target. For this reason, the operation mode for temperature adjustment combines the operation mode for the battery to adjust the temperature of the battery **51** and the operation mode for the high-voltage instrument to adjust the temperature of the high-voltage instrument **50**.

**[0215]** Operation modes for the battery include (B1) battery warming mode, (B2) battery warming mode, and (B3) battery cooling mode.

**[0216]** (B1) The battery warming mode is an operation mode that warms up the battery **51** through the use of a temperature-regulated heating medium.

**[0217]** (B2) The battery-temperature averaging mode is an operation mode that averages the temperatures of battery cells forming the battery **51**.

**[0218]** (B3) The battery cooling mode is an operation mode that cools the battery **51** through the use of the heating medium cooled by the chiller **20**.

**[0219]** Operation modes for high-voltage instruments include (C1) high-voltage-instrument heat storage mode, (C2) high-voltage-instrument waste heat recovery mode, and (C3) high-voltage-instrument cooling mode.

**[0220]** (C1) The high-voltage-instrument heat storage mode is an operation mode that uses the heat generated by the high-voltage instrument **50** to warm up the high-voltage instrument **50** and heat the heating medium.

**[0221]** (C2) The high-voltage-instrument waste heat recovery mode is an operation mode that uses the heating medium cooled by the chiller **20** to cool the high-voltage instrument **50**. In other words, this operation mode is an operation mode in which the chiller **20** allows the low-pressure refrigerant to absorb the waste heat from the high-voltage instrument **50**.

**[0222]** (C3) The high-voltage-instrument cooling mode is an operation mode that cools the high-voltage instrument **50** through the use of the heating medium cooled by the low-temperature-side radiator **423**.

**[0223]** The operation modes for temperature adjustment are switched in response to the execution of the control program for temperature adjustment stored in the controller **60**. The control program for temperature adjustment is executed when the vehicle system starts or when the battery **51** is being charged from an external power source, regardless of whether the user requests air conditioning in the vehicle compartment.

**[0224]** The control program for temperature adjustment reads detection signals from the above-described sensors at predetermined intervals. The operation modes for temperature adjustment are switched based on the read detection signals.

**[0225]** More specifically, the control program for temperature adjustment references the control map previously stored in the controller **60** and switches the operation modes for temperature adjustment based on the battery temperature TB detected by the battery temperature sensor **68** and the second low-temperature-side heating medium temperature TWL**2** detected by the second low-temperature-side heating medium temperature sensor **67***b*.

**[0226]** As illustrated in the control characteristics diagram in FIG. **6**, the control program for temperature adjustment references the control map to switch the operation mode for the battery to the (B1) battery warming mode when the battery temperature TB is lower than the first reference battery temperature KTB**1**.

**[0227]** The (B1) battery warming mode switches to the (B2) battery-temperature averaging mode when the battery temperature TB increases to be higher than or equal to the second reference battery temperature KTB**2**. The (B2) battery-temperature averaging mode switches to the (B3) battery cooling mode when the battery temperature TB reaches or exceeds the fourth reference battery temperature KTB**4**.

**[0228]** The (B3) battery cooling mode switches to the (B2) battery-temperature averaging mode when the battery temperature TB decreases to be lower than or equal to the third reference battery temperature KTB**3**. The (B2) battery-temperature averaging mode switches to the (B1) battery warming mode when the battery temperature TB decreases to be lower than or equal to the first reference battery temperature KTB**1**.

**[0229]** As above, there is a temperature difference between the fourth reference battery temperature KTB**4** and the third reference battery temperature KTB**3**. There is a temperature difference between the second reference battery temperature KTB**2** and the first reference battery temperature KTB**1**. These temperature differences are configured as hysteresis widths to prevent control hunting.

**[0230]** As illustrated in the control characteristics diagram in FIG. **6**, the second low-temperature side heating medium temperature TWL**2** is lower than or equal to the first reference high-voltage instrument side temperature KTWL**21**. In this case, the operation mode for the high-voltage instrument switches to the (C1) high-voltage-instrument heat storage mode.

**[0231]** The (C1) high-voltage-instrument heat storage mode switches to the (C2) high-voltage-instrument waste heat recovery mode when the second low-temperature side heating medium temperature TWL**2** increases to be higher than or equal to the second reference high-voltage instrument side temperature KTWL**22**, The (C2) high-voltage-instrument waste heat recovery mode switches to the (C3) high-voltage-instrument cooling mode when the second low-temperature side heating medium temperature TWL**2** reaches or exceeds the fourth reference high-voltage instrument side temperature KTWL**24**.

**[0232]** The (C3) high-voltage-instrument cooling mode switches to the (C2) high-voltage-instrument waste heat recovery mode when the second low-temperature side heating medium temperature TWL**2** decreases to be lower than or equal to the third reference high-voltage instrument side temperature KTWL**23**. The (C2) high-voltage-instrument waste heat recovery mode switches to the (C1) high-voltage-instrument heat storage mode when the second low-temperature side heating medium temperature TWL**2** decreases to be lower than or equal to the first reference high-voltage instrument side temperature KTWL**21**.

**[0233]** As illustrated in the control characteristics diagram in FIG. **6**, however, the present embodiment cools the battery **51** when the operation mode for the battery is set to the (B3) battery cooling mode. Then, the operation mode for high-voltage instruments switches to the (C3) high-voltage-instrument cooling mode.

**[0234]** The description below explains the detailed operations of each operation mode for temperature adjustment. Each operation mode for temperature adjustment will be described by combining the code attached to the operation mode for the battery and the code attached to the operation mode for the high-voltage instrument. For example, B1C1 mode represents the operation mode that performs the (B1) battery warming mode and the (C1) high-voltage-instrument heat storage mode.

**[0235]** First, the operation mode for temperature adjustment will be explained during air-conditioning such as air-conditioning the vehicle compartment while the vehicle travels, for example.

**[0236]** The operation mode for temperature adjustment during air conditioning assumes activation of any one of the (A1) cooling mode, the (A2) serial dehumidification and heating mode, the (A3) parallel dehumidification and heating mode, and the (A4) heating mode described above. In other words, the operation mode for temperature adjustment during air conditioning assumes active operations of the compressor **11** of the refrigeration cycle equipment **10**, the interior blower **32** of the interior air-conditioning unit **30**, and the high-temperature-side pump **411** of the high-temperature-side circuit **41** of the heating medium circuit **40**, for example.

**[0237]** (B1C1 Mode During Air Conditioning)

**[0238]** The B1C1 mode is an operation mode that performs the (B1) battery warming mode and (C1) the high-voltage-instrument heat storage mode.

**[0239]** In the B1C1 mode, the controller **60** fully closes the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. Therefore, the refrigeration cycle equipment **10** in the B1C1 mode prevents the refrigerant from flowing into the chiller **20**.

**[0240]** The controller **60** controls operations of the three-way valve **44** so that the heating medium flowing inside flows out to both the heater core **413** and the inlet-side connection channel **431**. The controller **60** operates the first low-temperature-side pump **421***a* and the second low-temperature-side pump **421***b* to provide the predetermined pumping capability.

**[0241]** The controller **60** controls operations of the five-way valve **422** to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium bypass channel **424**. At the same time, the controller **60** switches to the circuit that connects the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the inlet side of the heating medium channel **20***b* of the chiller **20**.

**[0242]** The heating medium flows through the heating medium circuit **40** of the B1C1 mode as indicated by the arrow in FIG. **7**. Specifically, the high-temperature-side circuit **41** in the B1C1 mode circulates the heating medium pumped from the high-temperature-side pump **411** through the heating medium channel **12***b* of the water-refrigerant heat exchanger **12**, the electric heater **412**, the three-way valve **44**, the heater core **413**, and the suction port of the high-temperature-side pump **411** in order.

**[0243]** The low-temperature-side circuit **42** in the B1C1 mode allows a heating medium pumped from the first low-temperature-side pump **421***a* to circulate through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the heating medium bypass channel **424**, and the suction port of the first low-temperature-side pump **421***a* in order. A heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the heating medium channel **20***b* of the chiller **20**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0244]** The connection channel **43** in the B1C1 mode flows part of the heating medium flowing into the three-way valve **44** to the suction port side of the first low-temperature-side pump **421***a* via the inlet-side connection channel **431**. Part of the heating medium flowing from the cooling water channel **51***a* of the battery **51** flows toward the suction port of the high-temperature-side pump **411** via the outlet-side connection channel **432**.

**[0245]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls operations of three-way valve **44** so that the first low-temperature-side heating medium temperature TWL**1** detected by the first low-temperature-side heating medium temperature sensor **67***a* approximates a predetermined targeted warming temperature TWLW**1**. In other words, the controller **60** controls operations of the three-way valve **44** so that the temperature of the heating medium flowing into the cooling water channel **51**_a_ of the battery **51** approximates the targeted warming temperature TWLW**1**. The targeted warming temperature TWLW**1** is configured to be able to appropriately warm up the battery **51**.

**[0246]** The heating medium circuit **40** in the B1C1 mode flows the heating medium into the three-way valve **44** under the condition that the heating medium is heated by the water-refrigerant heat exchanger **12** or the electric heater **412** for air conditioning in the vehicle compartment. The heating medium flowing into the three-way valve **44** is divided by the three-way valve **44** and flows into the heater core **413** and the inlet-side connection channel **431**.

**[0247]** The heating medium flowing into the inlet-side connection channel **431** from the three-way valve **44** flows into the sixth heating medium joint portion **45**_f_. The sixth heating medium joint portion **45**_f_ joins the flow of the heating medium flowing out of the inlet-side connection channel **431** with the flow of the heating medium flowing out of the heating medium bypass channel **424**. At this time, the three-way valve **44** adjusts the flow rate of the heating medium flowing through the inlet-side connection channel **431** so that the temperature of the heating medium flowing into the cooling water channel **51**_a_ of the battery **51** approximates the targeted warming temperature TWLW**1** for warming-up.

**[0248]** The heating medium flowing out of the sixth heating medium joint portion **45**_f_ is drawn into the first low-temperature-side pump **421**_a_ and is pumped to the cooling water channel **51**_a_ of the battery **51**. The heating medium flowing into the cooling water channel **51**_a_ of the battery **51** radiates heat to each battery cell of the battery **51**. Consequently, the battery **51** warms up.

**[0249]** The second heating medium joint portion **45**_b_ branches the flow of the heating medium flowing out of the cooling water channel **51**_a_ of the battery **51**. One of the heating media branched at the second heating medium joint portion **45**_b_ flows into the first heating medium joint portion **45**_a_ through the outlet-side connection channel **432**.

**[0250]** The first heating medium joint portion **45**_a_ joints the flow of the heating medium flowing out of the outlet-side connection channel **432** with the flow of the heating medium flowing out of the heater core **413**. The heating medium joined at the first heating medium joint portion **45**_a_ is drawn into the high-temperature-side pump **411**.

**[0251]** The other heating medium branched at the second heating medium joint portion **45**_b_ flows into the heating medium bypass channel **424** via the five-way valve **422**. The heating medium flowing out of the heating medium bypass channel **424** flows into the sixth heating medium joint portion **45**_f_ via the fourth heating medium joint portion **45**_d_.

**[0252]** The B1C1 mode low-temperature-side circuit **42** allows the heating medium pumped from the second low-temperature-side pump **421**_b_ to flow into the cooling water channels **52**_a_ through **54**_a_ of the high-voltage instrument **50**. At this time, the temperature of the heating medium flowing through the cooling water channels **52**_a_ through **54**_a_ of the high-voltage instrument **50** may be lower than the temperature of the high-voltage instrument **50**. Then, the heating medium absorbs the waste heat of the high-voltage instrument **50**.

**[0253]** The heating medium flowing out of the cooling water channels **52**_a_ through **54**_a_ of the high-voltage instrument **50** flows into the heating medium channel **20**_b_ of the chiller **20** via the five-way valve **422**. The B1C1 mode fully closes the cooling expansion valve **14**_c_. Therefore, the chiller **20** does not perform heat exchange between the heating medium and the refrigerant.

**[0254]** The heating medium flowing out of the heating medium channel **20**_b_ of the chiller **20** is drawn into the second low-temperature-side pump **421**_b_ via the third heating medium joint portion **45**_c_ and the fifth heating medium joint portion **45**_e_. The low-temperature-side circuit **42** in the B1C1 mode warms up the high-voltage instrument **50** and heats the heating medium without allowing the waste heat from the high-voltage instrument **50** to be radiated to refrigerant or outdoor air.

**[0255]** (B1C2 Mode During Air Conditioning)

**[0256]** The B1C2 mode is an operation mode that performs the (B1) battery warming mode and the (C2) high-voltage-instrument waste heat recovery mode. The (C2) high-voltage-instrument waste heat recovery mode is not an operation mode to cool the high-voltage instrument **50**. In the B1C2 mode, there may be no need to recover waste heat from the high-voltage instrument **50** for air conditioning or warming up the battery **51**. In this case, operations similar to those in the B1C1 mode may be performed.

**[0257]** In the B1C2 mode during air conditioning, the controller **60** throttles the cooling expansion valve **14**_c_ of the refrigeration cycle equipment **10**. When the operation mode for air conditioning is set to the (A4) heating mode, the controller **60** opens the on-off dehumidification valve **15**_a_ and the on-off heating valve **15**_b_.

**[0258]** The refrigeration cycle equipment **10** in the B1C2 mode flows the low-pressure refrigerant decompressed by the cooling expansion valve **14**_c_ into the refrigerant channel **20**_a_ of the chiller **20**. The refrigerant flowing out of the refrigerant channel **20**_a_ of the chiller **20** flows into the accumulator **21** via the sixth refrigerant joint portion **13**_f_ and the fourth refrigerant joint portion **13**_d_.

**[0259]** When the operation mode for air conditioning is set to the (A4) heating mode, the refrigerant discharged from the compressor **11** circulates through the water-refrigerant heat exchanger **12**, the first refrigerant joint portion **13**_a_, the heating expansion valve **14**_a_, the outdoor heat exchanger **16**, the heating channel **22**_b_, the accumulator **21**, and the suction port of compressor **11** in order. At the same time, a vapor-compression refrigeration cycle is formed so that the refrigerant discharged from the compressor **11** circulates through the water-refrigerant heat exchanger **12**, the first refrigerant joint portion **13**_a_, the dehumidification channel **22**_a_, the cooling expansion valve **14**_c_, the chiller **20**, the accumulator **21**, and the suction port of the compressor **11** in order. That is, the configured cycle parallel connects the outdoor heat exchanger **16** and the chiller **20**, referring to the refrigerant flow.

**[0260]** Similar to the B1C1 mode, the controller **60** controls operations of the three-way valve **44**, the five-way valve **422**, the first low-temperature-side pump **421**_a_, and the second low-temperature-side pump **421**_b_.

**[0261]** Similar to the B1C1 mode, the heating medium circuit **40** in the B1C2 mode flows the heating medium as indicated by arrows in FIG. **7**.

**[0262]** In addition, the controller **60** can accordingly control the operations of other control-target instruments. For example, the controller **60** may control the throttle opening of the cooling expansion valve **14**_c_ so that the second low-temperature-side heating medium temperature TWL**2** approximates the predetermined targeted warming temperature TWLO**2** for high-voltage instruments. In other words, the controller **60** controls the throttle opening of the cooling expansion valve **14***c* so that the temperature of the heating medium flowing into the cooling water channel **50***a* of the high-voltage instrument **50** approximates the targeted warming temperature TWLO**2** for high-voltage instruments. The targeted warming temperature TWLO**2** for high-voltage instruments is configured so that the high-voltage instrument **50** can function properly.

**[0263]** The refrigeration cycle equipment **10** in the B1C2 mode configures a vapor-compression refrigeration cycle where the water-refrigerant heat exchanger **12** functions as a condenser and at least the chiller **20** functions as an evaporator. The water-refrigerant heat exchanger **12** can heat the heating medium circulating through the high-temperature-side circuit **41** by using a heat source, that is, at least the waste heat of the high-voltage instrument **50**, recovered by the chiller **20** in the low-pressure refrigerant.

**[0264]** Similar to the B1C1 mode, the heating medium circuit **40** in the B1C2 mode warms up the battery **51**.

**[0265]** The low-temperature-side circuit **42** in the B1C2 mode flows the heating medium pumped from the second low-temperature-side pump **421***b* into the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. The heating medium flowing through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** absorbs the waste heat of the high-voltage instrument **50**. The high-voltage instrument **50** is thus cooled.

**[0266]** The heating medium flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** flows into the heating medium channel **20***b* of the chiller **20** via the five-way valve **422**. In the B1C2 mode, the cooling expansion valve **14***c* is throttled. The heating medium flowing into the chiller **20** is cooled by performing heat exchange with the low-pressure refrigerant decompressed by the cooling expansion valve **14***c*. Consequently, the temperature of the heating medium flowing into the cooling water channel **50***a* of the high-voltage instrument **50** approximates the targeted warming temperature TWLO**2** for high-voltage instruments.

**[0267]** The heating medium flowing out of the heating medium channel **20***b* of the chiller **20** is drawn into the second low-temperature-side pump **421***b* via the third heating medium joint portion **45***c* and the fifth heating medium joint portion **45***e*.

**[0268]** The low-pressure refrigerant flowing into the chiller **20** absorbs the heat of the heating medium and evaporates. In other words, the low-pressure refrigerant flowing into the chiller **20** recovers the waste heat of the high-voltage instrument **50**.

**[0269]** In the B1C2 mode during air conditioning, the compressor **11** of the refrigeration cycle equipment **10** is operating. When the refrigeration cycle equipment **10** operates in the B1C2 mode during air conditioning, the compressor **11** compresses the refrigerant, recovering the waste heat of the high-voltage instrument **50** in the chiller **20**, and discharges the refrigerant toward the refrigerant channel **12***a* of the water-refrigerant heat exchanger **12**.

**[0270]** The water-refrigerant heat exchanger **12** radiates at least part of the waste heat of the high-voltage instrument **50**, recovered by the chiller **20** in the low-pressure refrigerant, to the heating medium flowing through the high-temperature-side circuit **41**. The heating medium flowing through the high-temperature-side circuit **41** is thereby heated. The B1C2 mode heats the heating medium flowing through the high-temperature-side circuit **41** by using a heat source, that is, the waste heat from the high-voltage instrument **50**. Furthermore, the heated heating medium is used as a heat source to heat the supplied air and warm up the battery **51**.

**[0271]** A possible means of warming up the battery **51** may be to flow the heating medium, flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, directly into the cooling water channel **51***a* of the battery **51**.

**[0272]** However, the heating medium flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** may be heated to a relatively high temperature (such as 60° C. or higher). There is a possibility of increasing the temperature of the battery **51** and hastening the deterioration of the battery **51** if the heating medium flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** directly flows into the cooling water channel **51***a* of the battery **51**.

**[0273]** Meanwhile, the B1C2 mode allows the refrigerant of refrigeration cycle equipment **10** to recover the waste heat of high-voltage instrument **50** and uses the waste heat as a heat source to heat the heating medium circulating through the high-temperature-side circuit **41**. Therefore, it is possible to set the temperature of the heating medium flowing through the high-temperature-side circuit **41** to an intended temperature lower than the temperature of the heating medium immediately after flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**.

**[0274]** As a result, the B1C2 mode can appropriately warm up the battery **51** without causing a rapid temperature rise of the battery **51**.

**[0275]** (B1C3 Mode During Air Conditioning)

**[0276]** The B1C3 mode is an operation mode that performs the (B1) battery warming mode and the (C3) high-voltage-instrument cooling mode.

**[0277]** In the B1C3 mode, the controller **60** fully closes the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. Therefore, the refrigeration cycle equipment **10** in the B1C3 mode prevents the refrigerant from flowing into the chiller **20**.

**[0278]** Similar to the B1C1 mode, the controller **60** controls operations of the three-way valve **44**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b*. The controller **60** controls operations of the five-way valve **422** to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium bypass channel **424**. At the same time, the controller **60** activates the circuit that connects the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the heating-medium inlet side of the low-temperature-side radiator **423**.

**[0279]** The heating medium circuit **40** in the B1C3 mode allows the heating medium to flow as indicated by the arrows in FIG. **8**. Specifically, the high-temperature-side circuit **41** in the B1C3 mode circulates the heating medium pumped from the high-temperature-side pump **411** similarly to the B1C1 mode. The heating medium flows through the connection channel **43** in the B1C3 mode similarly to the B1C1 mode.

**[0280]** The low-temperature-side circuit **42** in the B1C3 mode allows the heating medium pumped from the first low-temperature-side pump **421***a* to circulate through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the heating medium bypass channel **424**, and the suction port of the first low-temperature-side pump **421***a* in order. The heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the low-temperature-side radiator **423**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0281]** Similar to the B1C1 mode, the heating medium circuit **40** in the B1C3 mode properly warms up the battery **51**.

**[0282]** The low-temperature-side circuit **42** in the B1C3 mode flows the heating medium pumped from the second low-temperature-side pump **421***b* into the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. The heating medium flowing through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** absorbs the waste heat of the high-voltage instrument **50**. The high-voltage instrument **50** is thus cooled.

**[0283]** The heating medium flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** flows into low-temperature-side radiator **423** via the five-way valve **422**. The heating medium flowing into the low-temperature-side radiator **423** dissipates heat to the outdoor air and is cooled. The heating medium flowing into the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** is cooled approximately to the outdoor air temperature.

**[0284]** The heating medium flowing out of the low-temperature-side radiator **423** is drawn into the second low-temperature-side pump **421***b* via the fifth heating medium joint portion **45***e*. The low-temperature-side circuit **42** in the B1C3 mode allows the low-temperature-side radiator **423** to dissipate waste heat from the high-voltage instrument **50** to the outdoor air, thus cooling the high-voltage instrument **50**.

**[0285]** (B2C1 Mode During Air Conditioning)

**[0286]** The B2C1 mode is an operation mode that performs the (B2) battery-temperature averaging mode and the (C1) high-voltage-instrument heat storage mode.

**[0287]** In the B2C1 mode, the controller **60** fully closes the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. Therefore, the refrigeration cycle equipment **10** in the B1C1 mode prevents the refrigerant from flowing into the chiller **20**.

**[0288]** The controller **60** controls operations of the three-way valve **44** to direct the total flow of the heating medium flowing inside to flow toward the heater core **413**. Similar to the B1C1 mode, the controller **60** controls operations of the five-way valve **422**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b*.

**[0289]** The heating medium flows through the heating medium circuit **40** of the B2C1 mode as indicated by the arrow in FIG. **9**. Specifically, the high-temperature-side circuit **41** in the B2C1 mode circulates the heating medium pumped from a high-temperature-side pump **411** through the heating medium channel **12***b* of the water-refrigerant heat exchanger **12**, the electric heater **412**, the three-way valve **44**, the heater core **413**, and the suction port of the high-temperature-side pump **411** in order. The connection channel **43** in the B2C1 mode does not flow the heating medium.

**[0290]** The low-temperature-side circuit **42** in the B2C1 mode circulates the heating medium pumped from the first low-temperature-side pump **421***a* through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the heating medium bypass channel **424**, and the suction port of the first low-temperature-side pump **421***a* in order. The heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the heating medium channel **20***b* of the chiller **20**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0291]** The low-temperature-side circuit **42** in the B2C1 mode pumps the heating medium pumped from the first low-temperature-side pump **421***a* to the cooling water channel **51***a* of the battery **51**. The heating medium circulates through the cooling water channel **51***a* of the battery **51**, thus averaging temperatures of the battery cells forming the battery **51**. Similar to the B1C1 mode, the low-temperature-side circuit **42** in the B2C1 mode warms up the high-voltage instrument **50** and heats the heating medium.

**[0292]** In the B2C1 mode, a temperature difference ΔTB between the battery cells may be smaller than or equal to a predetermined reference temperature difference ΔKTB. In such a case, it may be favorable to perform a temperature averaging OFF mode that stops the first low-temperature-side pump **421***a*. The temperature difference ΔTB can be calculated from the detection values of the battery temperature sensor **68**. The reference temperature difference ΔKTB needs to be set not to cause the degradation of the battery **51**.

**[0293]** (B2C2 Mode During Air Conditioning)

**[0294]** The B2C2 mode is an operation mode that performs the (B2) battery-temperature averaging mode and the (C2) high-voltage-instrument waste heat recovery mode. In the B2C2 mode as well, there may be no need to recover waste heat from the high-voltage instrument **50** for air conditioning or warming up the battery **51**. In this case, operations similar to those in the B2C1 mode may be performed.

**[0295]** In the B2C2 mode during air conditioning, the controller **60** throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**, similar to the B1C2. When the operation mode for air conditioning is set to the (A4) heating mode, the controller **60** opens the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0296]** The refrigeration cycle equipment **10** in the B2C2 mode flows the low-pressure refrigerant decompressed by the cooling expansion valve **14***c* into the refrigerant channel **20***a* of the chiller **20**. The refrigerant flowing out of the refrigerant channel **20***a* of the chiller **20** flows into the accumulator **21** via the sixth refrigerant joint portion **13***f* and the fourth refrigerant joint portion **13***d*.

**[0297]** When the operation mode for air conditioning is set to the (A4) heating mode, a cycle is configured to parallel connect the outdoor heat exchanger **16** and the chiller **20**, referring to the refrigerant flow, similar to the B1C2 mode.

**[0298]** Similar to the B2C1 mode, the controller **60** controls operations of the three-way valve **44**, the five-way valve **422**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b*.

**[0299]** The B2C2 mode heating medium circuit **40** flows the heating medium similar to the B2C1 mode, as indicated by the arrows in FIG. **9**.

**[0300]** Similar to the B1C2 mode, the controller **60** appropriately controls the operations of the other control-target instruments.

**[0301]** Similar to the B2C1 mode, the low-temperature-side circuit **42** in the B2C2 mode averages the temperatures of the battery cells forming the battery **51**.

**[0302]** Similar to the B1C2 mode, the low-temperature-side circuit **42** in the B2C2 mode allows the heating medium cooled by the chiller **20** to flow through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. The high-voltage instrument **50** is thereby cooled.

**[0303]** The B2C2 mode during air conditioning operates the compressor **11** of the refrigeration cycle equipment **10**. Similar to the B1C2 mode, the refrigeration cycle equipment **10** in the B2C2 mode during air conditioning heats the heating medium flowing through the high-temperature-side circuit **41** by using a heat source, that is, the waste heat of the high-voltage instrument **50**, recovered by the chiller **20** in the low-pressure refrigerant. Moreover, the heated heating medium is used as a heat source to heat the supplied air.

**[0304]** Similar to the B2C1 mode, the B2C2 mode may also perform the temperature averaging OFF mode.

**[0305]** (B2C3 Mode During Air Conditioning)

**[0306]** The B2C3 mode is an operation mode that performs the (B2) battery-temperature averaging mode and the (C3) high-voltage-instrument cooling mode.

**[0307]** In the B2C3 mode, the controller **60** fully closes the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. Therefore, the refrigeration cycle equipment **10** in the B2C3 mode prevents the refrigerant from flowing into the chiller **20**.

**[0308]** Similar to the B2C1 mode, the controller **60** controls operations of the three-way valve **44**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b*. The controller **60** controls operations of the five-way valve **422** to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium bypass channel **424**. At the same time, the controller **60** activates the circuit that connects the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the heating-medium inlet side of the low-temperature-side radiator **423**.

**[0309]** The heating medium circuit **40** in the B2C3 mode allows the heating medium to flow as indicated by the arrows in FIG. **10**. Specifically, the high-temperature-side circuit **41** in the B2C3 mode circulates the heating medium pumped from the high-temperature-side pump **411** similarly to the B2C1 mode. The connection channel **43** in the B2C3 mode does not flow the heating medium same as the B2C1 mode.

**[0310]** The low-temperature-side circuit **42** in the B2C3 mode circulates the heating medium pumped from the first low-temperature-side pump **421***a* through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the heating medium bypass channel **424**, and the suction port of the first low-temperature-side pump **421***a* in order. The heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the low-temperature-side radiator **423**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0311]** Similar to the B2C1 mode, the low-temperature-side circuit **42** in the B2C3 mode averages the temperatures of the battery cells forming the battery **51**. The low-temperature-side circuit **42** in the B2C3 mode allows the low-temperature-side radiator **423** to dissipate waste heat from the high-voltage instrument **50** to the outdoor air, thus cooling the high-voltage instrument **50**.

**[0312]** Similar to the B2C1 mode, the B2C3 mode may also perform the temperature averaging OFF mode.

**[0313]** (B3C3 Mode During Air Conditioning)

**[0314]** The B3C3 mode is an operation mode that performs the (B3) battery cooling mode and the (C3) high-voltage-instrument cooling mode.

**[0315]** In the B3C3 mode during air conditioning, the controller **60** throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**, similar to the B1C2. When the operation mode for air conditioning is set to the (A4) heating mode, the controller **60** opens the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0316]** The refrigeration cycle equipment **10** in the B3C3 mode flows the low-pressure refrigerant decompressed by the cooling expansion valve **14***c* into the refrigerant channel **20***a* of the chiller **20**. The refrigerant flowing out of the refrigerant channel **20***a* of the chiller **20** flows into the accumulator **21** via the sixth refrigerant joint portion **13***f* and the fourth refrigerant joint portion **13***d*.

**[0317]** When the operation mode for air conditioning is set to the (A4) heating mode, a cycle is configured to parallel connect the outdoor heat exchanger **16** and the chiller **20**, referring to the refrigerant flow, similar to the B1C2 mode.

**[0318]** The controller **60** controls operations of the three-way valve **44** to direct the total flow of the heating medium flowing inside to flow toward the heater core **413**. The controller **60** operates the first low-temperature-side pump **421***a* and the second low-temperature-side pump **421***b* to provide the predetermined pumping capability.

**[0319]** The controller **60** controls operations of the five-way valve **422** to connect the outlet side of the cooling water channel **51***a* of the battery **51** and the inlet side of the heating medium channel **20***b* of the chiller **20**. At the same time, the controller **60** activates the circuit that connects the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the heating-medium inlet side of the low-temperature-side radiator **423**.

**[0320]** The heating medium circuit **40** in the B3C3 mode allows the heating medium to flow as indicated by the arrows in FIG. **11**. Specifically, the high-temperature-side circuit **41** in the B3C3 mode circulates the heating medium pumped from the high-temperature-side pump **411** similarly to the B2C1 mode. The connection channel **43** in the B3C3 mode does not flow the heating medium same as the B2C1 mode.

**[0321]** The low-temperature-side circuit **42** in the B3C3 mode circulates the heating medium pumped from the first low-temperature-side pump **421***a* through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the heating medium channel **20***b* of the chiller **20**, and the suction port of the first low-temperature-side pump **421***a* in order. The heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the low-temperature-side radiator **423**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0322]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the throttle opening of the cooling expansion valve **14***c* so that the first cold side heating medium temperature TWL**1** approximates the targeted warming temperature TWLO**1** for the battery. In other words, the controller **60** controls the throttle opening of the cooling expansion valve **14***c* so that the temperature of the heating medium flowing into the cooling water channel **51***a* of the battery **51** approximates the targeted warming temperature TWLO**1** for the battery. The targeted warming temperature TWLO**1** for the battery is configured so that the battery **51** can operate appropriately.

**[0323]** The low-temperature-side circuit **42** in the B3C3 mode flows the heating medium pumped from the first low-temperature-side pump **421***a* into the cooling water channel **51***a* of the battery **51**. The heating medium flowing through the cooling water channel **51***a* of the battery **51** absorbs the waste heat of the battery **51**. The battery **51** is thereby cooled.

**[0324]** The heating medium flowing out of the cooling water channel **51***a* of the battery **51** flows into the heating medium channel **20***b* of the chiller **20** via the five-way valve **422**. The heating medium flowing into the chiller **20** is cooled by performing heat exchange with the low-pressure refrigerant decompressed by the cooling expansion valve **14***c*. Consequently, the temperature of the heating medium flowing into the cooling water channel **51***a* of the battery **51** approximates the targeted warming temperature TWLO**1** for the battery.

**[0325]** The heating medium flowing out of the heating medium channel **20***b* of the chiller **20** is drawn into the first low-temperature-side pump **421***a* via the third heating medium joint portion **45***c* and the fourth heating medium joint portion **45***d*.

**[0326]** The low-pressure refrigerant flowing into the chiller **20** absorbs the heat of the heating medium and evaporates. In other words, the low-pressure refrigerant flowing into the chiller **20** recovers the waste heat of the battery **51**.

**[0327]** The B3C3 mode during air conditioning operates the compressor **11** of the refrigeration cycle equipment **10**. When the refrigeration cycle equipment **10** operates in the B3C3 mode during air conditioning, the compressor **11** compresses the refrigerant, recovering the waste heat of the battery **51** in the chiller **20**, and discharges the refrigerant toward the refrigerant channel **12***a* of the water-refrigerant heat exchanger **12**.

**[0328]** The water-refrigerant heat exchanger **12** radiates at least part of the waste heat of the battery **51**, recovered by the chiller **20** in the low-pressure refrigerant, to the heating medium flowing through the high-temperature-side circuit **41**. Thereby, the heating medium flowing through the high-temperature-side circuit **41** is heated. Moreover, the heated heating medium is used as a heat source to heat the supplied air.

**[0329]** The low-temperature-side circuit **42** in the B3C3 mode allows the low-temperature-side radiator **423** to dissipate waste heat from the high-voltage instrument **50** to the outdoor air, thus cooling the high-voltage instrument **50**.

**[0330]** The description below explains operation modes for temperature adjustment during no air-conditioning, such as a case where the vehicle compartment is not air-conditioned while the battery **51** is being charged.

**[0331]** When the vehicle compartment is not air-conditioned, it is possible to stop the compressor **11** of the refrigeration cycle equipment **10**, the interior blower **32** of the interior air-conditioning unit **30**, and the high-temperature-side pump **411** of the high-temperature-side circuit **41** of the heating medium circuit **40**, for example. The operation mode for temperature adjustment during no air-conditioning operates, for example, the compressor **11** of the refrigeration cycle equipment **10** as necessary to suppress unnecessary energy consumption.

**[0332]** (B1C1 Mode During No Air-Conditioning)

**[0333]** The B1C1 mode needs to heat the heating medium flowing through the high-temperature-side circuit **41** to warm up the battery **51**.

**[0334]** In the B1C1 mode during no air-conditioning, the controller **60** throttles the heating expansion valve **14***a* and fully closes the cooling expansion valve **14***b* and the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** closes the on-off dehumidification valve **15***a* and opens the on-off heating valve **15***b*.

**[0335]** The refrigeration cycle equipment **10** in the B1C1 mode during no air-conditioning configures a vapor-compression refrigeration cycle that circulates the refrigerant in the same order as in the (A4) heating mode.

**[0336]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** to provide a predetermined discharge capability. The controller **60** controls the high-temperature-side pump **411** to provide a predetermined pumping capability. Other operations are the same as those in the B1C1 mode during air conditioning.

**[0337]** Similar to the (A4) heating mode, the refrigeration cycle equipment **10** in the B1C1 mode during no air-conditioning can allow the water-refrigerant heat exchanger **12** to heat the heating medium flowing through the high-temperature-side circuit **41** by using a heat source such as heat absorbed from the outdoor air in the outdoor heat exchanger **16**.

**[0338]** The interior air-conditioning unit **30** in the B1C1 mode during no air-conditioning stops the interior blower **32**. Therefore, the heater core **413** does not perform heat exchange between the heating medium and the supplied air. No heated supplied air is blown into the vehicle compartment.

**[0339]** The heating medium circuit **40** in the B1C1 mode allows the heating medium to flow as indicated by the arrows in FIG. **7**. Similar to the B1C1 mode during air conditioning, the B1C1 mode during no air-conditioning warms up the battery **51** and the high-voltage instrument **50**, and heats the heating medium.

**[0340]** (B1C2 Mode During No Air-Conditioning)

**[0341]** The B1C2 mode needs to heat the heating medium flowing through the high-temperature-side circuit **41** to warm up the battery **51**. In the B1C2 mode, the chiller **20** needs to absorb the waste heat of the high-voltage instrument **50** into the low-pressure refrigerant. Similar to air conditioning in process, there may be no need to recover waste heat from the high-voltage instrument **50** for warming up the battery **51**. In this case, operations similar to those in the B1C1 mode may be performed.

**[0342]** In the B1C2 mode during no air-conditioning, the controller **60** throttles the heating expansion valve **14***a*, fully closes the cooling expansion valve **14***b*, and throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** opens the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0343]** The refrigeration cycle equipment **10** in B1C2 mode during no air-conditioning configures a cycle to parallel connect the outdoor heat exchanger **16** and the chiller **20**, referring to the refrigerant flow, similar to the B1C2 mode during air conditioning when the operation mode for air conditioning is set to the (A4) heating mode.

**[0344]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** to provide a predetermined discharge capability. The controller **60** controls the high-temperature-side pump **411** to provide a predetermined pumping capability. Other operations are the same as those in the B1C2 mode during air conditioning.

**[0345]** Therefore, the refrigeration cycle equipment **10** in the B1C2 mode during no air-conditioning configures a vapor-compression refrigeration cycle where the water-refrigerant heat exchanger **12** functions as a condenser and the outdoor heat exchanger **16** and the chiller **20** function as an evaporator. The water-refrigerant heat exchanger **12** can heat the heating medium circulating through the high-temperature-side circuit **41** by using a heat source, that is, waste heat from the high-voltage instrument **50** recovered by the low-pressure refrigerant in the chiller **20** and heat absorbed from outdoor air by the refrigerant in the outdoor heat exchanger **16**.

**[0346]** The interior air-conditioning unit **30** in the B1C1 mode during no air-conditioning stops the interior blower **32**. Therefore, the heater core **413** does not perform heat exchange between the heating medium and the supplied air. No heated supplied air is blown into the vehicle compartment.

**[0347]** The heating medium circuit **40** in the B1C2 mode allows the heating medium to flow as indicated by the arrows in FIG. **7**. Similar to the B1C2 mode during air conditioning, the heating medium circuit **40** during no air-conditioning warms up the battery **51** and recovers the waste heat of the high-voltage instrument **50**.

**[0348]** The refrigeration cycle equipment in the B1C2 mode for no air-conditioning **10** can heat the heating medium circulating through the high-temperature-side circuit **41** by using a heat source, that is, waste heat from the high-voltage instrument **50** recovered by the low-pressure refrigerant in the chiller **20** and heat absorbed from outdoor air by the refrigerant in the outdoor heat exchanger **16**. There may be a case where the battery **51** can be sufficiently warmed up by using only the waste heat of the high-voltage instrument **50** as a heat source. In such a case, the heating expansion valve **14***a* may be fully closed.

**[0349]** (B1C3 Mode During No Air-Conditioning)

**[0350]** The B1C3 mode needs to heat the heating medium flowing through the high-temperature-side circuit **41** to warm up the battery **51**.

**[0351]** In the B1C3 mode during no air-conditioning, similar to the B1C1 mode during no air-conditioning, the controller **60** throttles the heating expansion valve **14***a* and fully closes the cooling expansion valve **14***b* and the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** closes the on-off dehumidification valve **15***a* and opens the on-off heating valve **15***b*.

**[0352]** The refrigeration cycle equipment **10** in the B1C3 mode during no air-conditioning configures a vapor-compression refrigeration cycle that circulates the refrigerant in the same order as in the (A4) heating mode.

**[0353]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** to provide a predetermined discharge capability. The controller **60** controls the high-temperature-side pump **411** to provide a predetermined pumping capability. Other operations are the same as those in the B1C3 mode during air conditioning.

**[0354]** Similar to the (A4) heating mode, the refrigeration cycle equipment **10** in the B1C3 mode during no air-conditioning can allow the water-refrigerant heat exchanger **12** to heat the heating medium flowing through the high-temperature-side circuit **41** by using a heat source such as heat absorbed from the outdoor air in the outdoor heat exchanger **16**.

**[0355]** The interior air-conditioning unit **30** in the B1C3 mode during no air-conditioning stops the interior blower **32**. Therefore, the heater core **413** does not perform heat exchange between the heating medium and the supplied air. No heated supplied air is blown into the vehicle compartment.

**[0356]** The heating medium circuit **40** in the B1C3 mode allows the heating medium to flow as indicated by the arrows in FIG. **8**. Similar to the B1C3 mode during air conditioning, the B1C3 mode during no air-conditioning warms up the battery **51** and cools down the high-voltage instrument **50**.

**[0357]** (B2C1 Mode During No Air-Conditioning)

**[0358]** The B2C1 mode during no air-conditioning need not heat the heating medium flowing through the high-temperature-side circuit **41** or absorb the waste heat of the high-voltage instrument **50** into the low-pressure refrigerant in the chiller **20**. In the B2C1 mode during no air-conditioning, the controller **60** stops the compressor **11** of the refrigeration cycle equipment **10** and the interior blower **32** of the interior air-conditioning unit **30**, for example. Other operations are the same as those in the B2C1 mode during air conditioning.

**[0359]** The heating medium circuit **40** in the B2C1 mode allows the heating medium to flow as indicated by the arrows in FIG. **9**. Similar to the B2C1 mode during air conditioning, the B2C1 mode during no air-conditioning averages the temperatures of the battery cells forming the battery **51**, warms up the high-voltage instrument **50**, and heats the heating medium.

**[0360]** FIG. **9** illustrates an example where the heating medium pumped from the high-temperature-side pump **411** circulates through the high-temperature-side circuit **41**. However, the high-temperature-side pump **411** may be stopped in the B2C1 mode during no air-conditioning. The temperature averaging OFF mode may be performed also in the B2C1 mode during no air-conditioning.

**[0361]** (B2C2 Mode During No Air-Conditioning)

**[0362]** In the B2C2 mode, the chiller **20** needs to absorb the waste heat of the high-voltage instrument **50** into the low-pressure refrigerant. Similar to air conditioning in process, there may be no need to recover waste heat from the high-voltage instrument **50** for warming up the battery **51**. In this case, operations similar to those in the B2C1 mode may be performed.

**[0363]** In the B2C2 mode during no air-conditioning, the controller **60** fully opens the heating expansion valve **14***a*, fully closes the cooling expansion valve **14***b*, and throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** closes the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0364]** Consequently, the refrigeration cycle equipment **10** in the B2C2 mode during no air-conditioning configures a vapor-compression refrigeration cycle where the refrigerant discharged from the compressor **11** circulates through the water-refrigerant heat exchanger **12**, the fully opened heating expansion valve **14***a*, the outdoor heat exchanger **16**, the check valve **17**, the cooling expansion valve **14***c*, the chiller **20**, the accumulator **21**, and the suction port of the compressor **11** in order.

**[0365]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** to provide a predetermined discharge capability. The controller **60** controls the high-temperature-side pump **411** similarly to the B1C1 mode during no air-conditioning. Other operations are the same as those in the B2C2 mode during air conditioning.

**[0366]** Therefore, the refrigeration cycle equipment **10** in the B2C2 mode during no air-conditioning configures a vapor-compression refrigeration cycle where the outdoor heat exchanger **16** functions as a condenser and the chiller **20** function as an evaporator. As a result, it is possible to radiate the waste heat of the high-voltage instrument **50**, recovered by the low-pressure refrigerant in the chiller **20**, to the outdoor air.

**[0367]** The temperature of the heating medium flowing through the high-temperature-side circuit **41** may be lower than the high-pressure refrigerant. Then, the water-refrigerant heat exchanger **12** can function as a condenser. In this case, the water-refrigerant heat exchanger **12** can dissipate waste heat from the high-voltage instrument **50** to the heating medium.

**[0368]** The interior air-conditioning unit **30** in the B2C2 mode during no air-conditioning stops the interior blower **32**. The heater core **413** does not perform heat exchange between the heating medium and the supplied air. No heated supplied air is blown into the vehicle compartment.

**[0369]** The heating medium circuit **40** in the B2C2 mode allows the heating medium to flow as indicated by the arrows in FIG. **9**. Similar to the B2C2 mode during air conditioning, the B2C2 mode during no air-conditioning averages the temperatures of the battery cells forming the battery **51** and recovers the waste heat of the high-voltage instrument **50**.

**[0370]** FIG. **9** illustrates an example where the heating medium pumped from the high-temperature-side pump **411** circulates through the high-temperature-side circuit **41**. However, the high-temperature-side pump **411** may be stopped in the B2C2 mode for no air-conditioning. The temperature averaging OFF mode may be performed also in the B2C2 mode during no air-conditioning.

**[0371]** (B2C3 Mode During No Air-Conditioning)

**[0372]** The B2C3 mode during no air-conditioning need not heat the heating medium flowing through the high-temperature-side circuit **41** or absorb the waste heat of the high-voltage instrument **50** into the low-pressure refrigerant in the chiller **20**. In the B2C3 mode during no air-conditioning, the controller **60** stops the compressor **11** of the refrigeration cycle equipment **10** and the interior blower **32** of the interior air-conditioning unit **30**, for example. Other operations are the same as those in the B2C3 mode during air conditioning.

**[0373]** The heating medium circuit **40** in the B2C3 mode allows the heating medium to flow as indicated by the arrows in FIG. **10**. Similar to the B2C3 mode during air conditioning, the B2C3 mode during no air-conditioning averages the temperatures of the battery cells forming the battery **51** and cools the high-voltage instrument **50**.

**[0374]** FIG. **10** illustrates an example where the heating medium pumped from the high-temperature-side pump **411** circulates through the high-temperature-side circuit **41**. However, the high-temperature-side pump **411** may be stopped in the B2C3 mode during no air-conditioning. The temperature averaging OFF mode may be performed also in the B2C3 mode during no air-conditioning.

**[0375]** (B3C3 Mode During No Air-Conditioning)

**[0376]** In the B3C3 mode, the chiller **20** needs to absorb the waste heat of the battery **51** into the low-pressure refrigerant.

**[0377]** In the B3C3 mode during no air-conditioning, similar to the B2C2 mode during no air-conditioning, the controller **60** fully opens the heating expansion valve **14***a*, fully closes the cooling expansion valve **14***b*, and throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** closes the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0378]** The B3C3 mode during no air-conditioning configures a vapor-compression refrigeration cycle that circulates the refrigerant in the same order as in the B2C2 mode during no air-conditioning.

**[0379]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** to provide a predetermined discharge capability. The controller **60** controls the high-temperature-side pump **411** to provide a predetermined pumping capability. Other operations are the same as those in the B3C3 mode during air conditioning.

**[0380]** Therefore, the refrigeration cycle equipment **10** in the B3C3 mode during no air-conditioning configures a vapor-compression refrigeration cycle where the outdoor heat exchanger **16** functions as a condenser and the chiller **20** function as an evaporator. As a result, it is possible to radiate the waste heat of the battery **51**, recovered by the low-pressure refrigerant in the chiller **20**, to the outdoor air.

**[0381]** The temperature of the heating medium flowing through the high-temperature-side circuit **41** may be lower than the high-pressure refrigerant. Then, the water-refrigerant heat exchanger **12** can function as a condenser. In this case, the water-refrigerant heat exchanger **12** can dissipate waste heat from the battery **51** to the heating medium.

**[0382]** The interior air-conditioning unit **30** in the B3C3 mode during no air-conditioning stops the interior blower **32**. The heater core **413** does not perform heat exchange between the heating medium and the supplied air. No heated supplied air is blown into the vehicle compartment.

**[0383]** The heating medium circuit **40** in the B3C3 mode allows the heating medium to flow as indicated by the arrows in FIG. **11**. Similar to the B3C3 mode during air conditioning, the B3C3 mode during no air-conditioning cools the battery **51** and the high-voltage instrument **50**.

**[0384]** FIG. **11** illustrates an example where the heating medium pumped from the high-temperature-side pump **411**

circulates through the high-temperature-side circuit **41**. However, the high-temperature-side pump **411** may be stopped in the B3C3 mode during no air-conditioning.

**[0385]** The B3C3 mode during no air-conditioning described above is an operation mode that cools the battery **51** when the battery temperature TB reaches a relatively high temperature higher than or equal to the fourth reference battery temperature KTB**4**. Therefore, the B3C3 mode during no air-conditioning may be performed when the battery **51** generates an increased amount of heat during charging.

**[0386]** The battery **51** generates more heat during quick charging than during normal charging while quick charging charges the battery **51** in a shorter time than normal charging. During quick charging, the battery **51** may be insufficiently cooled even if the thermal management system **1** activates the B3B3 mode.

**[0387]** According to the present embodiment, the thermal management system **1** can perform the (D) quick charging and cooling mode that cools the battery **51** based on a cooling capability higher than that of the B3B3 mode. The (D) quick charging and cooling mode is performed when the quick charging of the battery **51** starts. The description below explains in detail the operations of the (D) quick charging and cooling mode.

**[0388]** (D) Quick Charging and Cooling Mode

**[0389]** In the quick charging and cooling mode, similar to the B3C3 mode during no air-conditioning, the controller **60** fully opens the heating expansion valve **14***a*, fully closes the cooling expansion valve **14***b*, and throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** closes the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0390]** The quick charging and cooling mode configures a vapor-compression refrigeration cycle that circulates the refrigerant in the same order as in the B3C3 mode during no air-conditioning.

**[0391]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** controls the rotation speed of the compressor **11** to provide a predetermined discharge capability.

**[0392]** The controller **60** controls operations of the five-way valve **422** to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium channel **20***b* of the chiller **20**. At the same time, the controller **60** activates the circuit that connects the outlet side of the cooling water channel **51***a* of the battery **51** with the heating medium inlet side of the low-temperature-side radiator **423**.

**[0393]** In the quick charging and cooling mode, the low-temperature-side circuit **42** of the heating medium circuit **40** flows the heating medium as indicated by the arrows in FIG. **12**.

**[0394]** Specifically, the low-temperature-side circuit **42** in the quick charging and cooling mode circulates the heating medium, pumped from the first low-temperature-side pump **421***a*, through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the heating medium channel **20***b* of the chiller **20**, and the suction port of the first low-temperature-side pump **421***a* in order. At the same time, the heating medium pumped from the first low-temperature-side pump **421***a* circulates through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the low-temperature-side radiator **423**, and the suction port of the first low-temperature-side pump **421***a* in order. Other operations are the same as those in the B3C3 mode during air conditioning.

**[0395]** Therefore, the refrigeration cycle equipment **10** in the quick charging and cooling mode configures a vapor-compression refrigeration cycle where the outdoor heat exchanger **16** functions as a condenser and the chiller **20** function as an evaporator. It is possible to radiate the waste heat of the battery **51** recovered by the low-pressure refrigerant in the chiller **20** to the outdoor air.

**[0396]** The interior air-conditioning unit **30** in the quick charging and cooling mode stops the interior blower **32**. The heater core **413** does not perform heat exchange between the heating medium and the supplied air. No heated supplied air is blown into the vehicle compartment.

**[0397]** The low-temperature-side circuit **42** in the quick charging and cooling mode flows the heating medium pumped from the first low-temperature-side pump **421***a* into the cooling water channel **51***a* of the battery **51**. The heating medium flowing through the cooling water channel **51***a* of the battery **51** absorbs the waste heat of the battery **51**. The battery **51** is thereby cooled.

**[0398]** The five-way valve **422** branches the flow of the heating medium flowing out of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**. One heating medium branched at the five-way valve **422** flows into the heating medium channel **20***b* of the chiller **20**. The heating medium flowing into the heating medium channel **20***b* of the chiller **20** is cooled by the heat exchange with the low-pressure refrigerant. The heating medium flowing out of the heating medium channel **20***b* of the chiller **20** flows into one inlet/outlet of the third heating medium joint portion **45***c*.

**[0399]** The low-pressure refrigerant flowing into the chiller **20** absorbs the heat of the heating medium and evaporates. In other words, the low-pressure refrigerant absorbs the heat of the heating medium and evaporates.

**[0400]** The other heating medium branched at the five-way valve **422** flows into the low-temperature-side radiator **423**. The heating medium flowing into the low-temperature-side radiator **423** dissipates heat to the outdoor air and is cooled. The heating medium flowing out of the low-temperature-side radiator **423** flows into another inlet/outlet of the third heating medium joint portion **45***c*.

**[0401]** The third heating medium joint portion **45***c* allows the flow of the heating medium flowing out of the heating medium channel **20***b* of the chiller **20** to join the flow of the heating medium flowing out of low-temperature-side radiator **423**. The heating medium joined at the third heating medium joint portion **45***c* is drawn into the first low-temperature-side pump **421***a* via the fourth heating medium joint portion **45***d* and the sixth heating medium joint portion **45***f*.

**[0402]** The quick charging and cooling mode can not only allow the chiller **20** to absorb the waste heat of the battery **51** into the low-pressure refrigerant but also allow the low-temperature-side radiator **423** to dissipate heat to the outdoor air. The quick charging and cooling mode can improve the ability to cool the battery **51** more efficiently than the B3C3 mode.

**[0403]** As a result, the quick charging and cooling mode can cool the temperature of the battery **51** to an appropriate temperature zone even during quick charging which increases the amount of heat generated by the battery **51** compared to normal charging.

**[0404]** As above, the thermal management system **1** according to the present embodiment can provide comfortable air conditioning in the vehicle compartment and appropriate temperature adjustment of multiple in-vehicle units.

**[0405]** The thermal management system **1** according to the present embodiment makes a difference between an appropriate temperature zone for the battery **51** as the first temperature adjustment target and an appropriate temperature zone for the high-voltage instrument **50** as the second temperature adjustment target. Therefore, the thermal management system **1** according to the present embodiment involves an operating condition that requires warming up the battery **51** and concurrently cooling the high-voltage instrument **50**.

**[0406]** The thermal management system **1** according to the present embodiment includes the connection channel **43** as a heat transfer portion. As described in the B1C2 mode, for example, the heat of the heating medium heated by the water-refrigerant heat exchanger **12** can be transferred to the heating medium flowing into the cooling water channel **51***a* of the battery **51**. It is possible to heat and warm up the battery **51**.

**[0407]** While the heating medium flows to the connection channel **43** to transfer heat, the five-way valve **422** activates the circuit configuration in which the heating medium circulates between the cooling water channel **51***a* of the battery **51** and the heating medium bypass channel **424** and concurrently circulates between the cooling water channel **50***a* of the high-voltage instrument **50** and the heating medium channel **20***b* of the chiller **20**.

**[0408]** The heating medium can circulate between the cooling water channel **50***a* of the high-voltage instrument **50** and the heating medium channel **20***b* of the chiller **20**, being unaffected by the temperature of the heating medium circulating between the cooling water channel **51***a* of the battery **51** and the heating medium bypass channel **424**.

**[0409]** The chiller **20** performs heat exchange between the heating medium flowing out of the cooling water channel **50***a* of the high-voltage instrument **50** and the low-pressure refrigerant decompressed by the cooling expansion valve **14***c*. The low-pressure refrigerant can thereby absorb the waste heat of the high-voltage instrument **50**. It is possible to cool the heating medium flowing into the cooling water channel **50***a* of the high-voltage instrument **50**.

**[0410]** The refrigeration cycle equipment **10** can allow the water-refrigerant heat exchanger **12** to heat A heating medium flowing through the high-temperature-side circuit **41** by using the heat source of waste heat recovered by the low-pressure refrigerant in the chiller **20**. As described in the B1C2 mode, the battery **51** can be warmed up by using, as a heat source, the heating medium flowing through the high-temperature-side circuit **41**.

**[0411]** The thermal management system **1** according to the present embodiment can warm up the battery **51**, meanwhile, recover the waste heat of the high-voltage instrument **50**, and use the waste heat, as a heat source, to heat the heating medium flowing through the high-temperature-side circuit **41**. The thermal management system **1** according to the present embodiment can fully effectively use the heat generated from the temperature adjustment target, despite the difference between the proper temperature zone of the first temperature adjustment target and the proper temperature zone of the second temperature adjustment target.

**[0412]** The high-temperature-side circuit **41** of the thermal management system **1** of the present embodiment includes the heater core **413**. The heater core **413** is a heating heat exchange portion that performs heat exchange between the heating medium flowing through the high-temperature-side circuit **41** and the supplied air as a fluid to be heated. As explained in the B1C2 mode during air conditioning, for example, the waste heat of the high-voltage instrument **50** can be recovered and fully effectively used as a heat source for the supplied air.

**[0413]** The thermal management system **1** according to the present embodiment uses the connection channel **43** as a heat transfer portion. The inlet-side connection channel **431** of connection channel **43** is connected to guide the heating medium flowing out of water-refrigerant heat exchanger **12** to the inlet side of cooling water channel **51***a* of battery **51**. The heat of the heating medium circulating through the high-temperature-side circuit **41** can be used to warm up the battery **51**.

**[0414]** The inlet-side connection channel **431** guides the heating medium flowing out of the water-refrigerant heat exchanger **12** to the suction port side of the first low-temperature-side pump **421***a* that pumps the heating medium to the cooling water channel **51***a* of the battery **51**. The heating medium flowing out of the water-refrigerant heat exchanger **12** can be reliably supplied to the cooling water channel **51***a* of the battery **51**. The heat in the heating medium flowing through the high-temperature-side circuit **41** can be reliably used to warm up the battery **51**.

**[0415]** The outlet-side connection channel **432** of the connection channel **43** is connected to guide the heating medium flowing out of the cooling water channel **51***a* of the battery **51** to the suction port side of the high-temperature-side pump **411**. The heater core **413** is placed between the three-way valve **44** and the first heating medium joint portion **45***a*. The heater core **413** is placed between the three-way valve **44** and the first heating medium joint portion **45***a*.

**[0416]** The heating medium flowing through the connection channel **43** hardly affects the temperature of the heating medium flowing into the heater core **413**. Warming up the battery **51** hardly affects the air conditioning in the vehicle compartment.

**[0417]** In the thermal management system **1** according to the present embodiment, the five-way valve **422** activates the circuit configuration to circulate the heating medium between the cooling water channel **51***a* of the battery **51** and the heating medium bypass channel **424**. Meanwhile, the heat transfer amount controller **60***c* controls operations of the three-way valve **44** so that the first low-temperature side heating medium temperature TWL**1** approximates the targeted warming temperature TWLW**1** for warm-up.

**[0418]** It is possible to mix the heating medium circulating through the inlet-side connection channel **431** with the heating medium circulating through the heating medium bypass channel **424** and flow the heating medium into the cooling water channel **51***a* of the battery **51**. Therefore, it is possible to inhibit a sudden change in the temperature of the heating medium flowing into the cooling water channel **51***a* of the battery **51** and more effectively inhibit the battery **51** from being degraded.

**[0419]** The high-temperature-side circuit **41** of the thermal management system **1** according to the present embodiment includes the electric heater **412** as a heating portion. It is possible to increase the temperature of the heating medium flowing through the high-temperature-side circuit **41** and warm up the battery **51** and heat the supplied air even if the refrigeration cycle equipment **10** results in a shortage in the capability of heating the heating medium.

**[0420]** The five-way valve **422** according to the thermal management system **1** of the present embodiment can allow the heating medium flowing out of the cooling water channel **51***a* of the battery **51** to flow into at least the heating medium bypass channel **424** or the heating medium channel **20***b* of the chiller **20**. It is possible to switch between the circuit configurations that differ in cooling or not cooling the heating medium flowing out of the cooling water channel **51***a* of the battery **51**.

**[0421]** The five-way valve **422** of the thermal management system **1** according to the present embodiment can allow the heating medium flowing out of cooling water channel **50***a* of high-voltage instrument **50** to flow into at least the low-temperature-side radiator **423** or the heating medium channel **20***b* in the chiller **20**. It is possible to switch between the circuit configurations that differ in performing heat exchange with the low-pressure refrigerant or the outdoor air to cool the heating medium flowing out of the cooling water channel **50***a* of the high-voltage instrument **50**.

**[0422]** The waste heat from the high-voltage instrument **50** may not be needed to heat the heating medium flowing through the high-temperature-side circuit **41**. In such a case, the waste heat from the high-voltage instrument **50** can be dissipated into the outdoor air. The thermal management system **1** according to the present embodiment can effectively use the heat generated from the temperature adjustment target as needed.

**[0423]** The five-way valve **422** of the thermal management system **1** according to the present embodiment can allow the heating medium flowing out of the cooling water channel **51***a* of the battery **51** or the heating medium flowing out of the cooling water channel **50***a* of the high-voltage instrument **50** to flow into the heating medium channel **20***b* of the chiller **20**.

**[0424]** The common chiller **20** in common can cool the heating medium flowing out of the cooling water channel **51***a* of the battery **51** and the heating medium flowing out of the cooling water channel **50***a* of the high-voltage instrument **50**.

**[0425]** The five-way valve **422** of the thermal management system **1** according to the present embodiment can allow the heating medium flowing out of the cooling water channel **51***a* of the battery **51** to flow into both the low-temperature-side radiator **423** and the heating medium channel **20***b* of the chiller **20**. Like in the quick charging and cooling mode, it is possible to activate the circuit configuration where the chiller **20** absorbs the waste heat of the battery **51** in the low-pressure refrigerant, and the low-temperature-side radiator **423** dissipates heat to outdoor air. Therefore, the battery **51** can be effectively cooled.

## Second Embodiment

**[0426]** The present embodiment will describe an example where a battery-side radiator **423***a* and a three-way switching valve **425** are added to the low-temperature-side circuit **42** of the heating medium circuit **40** in the thermal management system **1** described in the first embodiment, by reference to an overall configuration diagram in FIG. **13**.

**[0427]** The battery-side radiator **423***a* is a battery-side outdoor air heat-exchange portion that performs heat exchange between the outdoor air and the heating medium flowing out of the bypass-channel-side outlet **422***d* of the five-way valve **422**. The basic configuration of the battery-side radiator **423***a* is similar to that of the low-temperature-side radiator **423**. The outlet of the battery-side radiator **423***a* is connected to the outlet of the heating medium bypass channel **424** via a seventh heating medium joint portion **45***g*.

**[0428]** The three-way switching valve **425** allows the heating medium flowing out of the bypass-channel-side outlet **422***d* of the five-way valve **422** to flow toward either the heating medium bypass channel **424** or the battery-side radiator **423***a*. The three-way switching valve **425** is a low-temperature-side circuit switching portion that switches circuit configurations of the low-temperature-side circuit **42**. Operations of the three-way switching valve **425** are controlled by a control signal output from the controller **60**. Other configurations of the thermal management system **1** are similar to those of the first embodiment.

**[0429]** The description below explains the operations of the thermal management system **1** according to the present embodiment based on the above-described configuration. The thermal management system **1** according to the present embodiment can perform operation modes for battery such as (B4) battery outdoor-air cooling mode in addition to the (B1) battery warming mode, the (B2) battery-temperature averaging mode, and the (B3) battery cooling mode.

**[0430]** The (B4) battery outdoor-air cooling mode is an operation mode that cools the battery **51** through the use of the heating medium cooled by the battery-side radiator **423***a*.

**[0431]** The control program for temperature adjustment according to the present embodiment references the control map illustrated in the control characteristics diagram of FIG. **14** and switches the operation modes for temperature adjustment.

**[0432]** Specifically, suppose the operation mode for high-voltage instruments is set to the (C1) high-voltage-instrument heat storage mode or the (C2) high-voltage-instrument waste heat recovery mode. In this case, the battery temperature TB may increase to reach or exceed the fourth reference battery temperature KTB**4**. Then, the (B2) battery-temperature averaging mode switches to the (B4) battery outdoor-air cooling mode.

**[0433]** Meanwhile, suppose the operation mode for high-voltage instruments is set to the (C1) high-voltage-instrument heat storage mode or the (C2) high-voltage-instrument waste heat recovery mode. In this case, the battery temperature TB may decrease to be lower than or equal to the third reference battery temperature KTB**3**. Then, the (B4) battery outdoor-air cooling mode switches to the (B2) battery-temperature averaging mode.

**[0434]** Suppose the operation mode for the high-voltage instrument is set to the (C3) high-voltage-instrument cooling mode. In this case, the battery temperature TB may increase to reach or exceed the fourth reference battery temperature KTB**4**. Then, the (B2) battery-temperature averaging mode switches to the (B3) battery cooling mode. When the battery temperature TB reaches or exceeds the sixth reference battery temperature KTB**6**, the (B3) battery cooling mode switches to the (B4) battery outdoor-air cooling mode.

**[0435]** Suppose the operation mode for the high-voltage instrument is set to the (C3) high-voltage-instrument cooling mode. In this case, the battery temperature TB may decrease to be lower than or equal to the fifth reference battery temperature KTB**5**. Then, the (B4) battery outdoor-air cooling mode switches to the (B3) battery cooling mode. When the battery temperature TB decreases to be lower than or equal to the third reference battery temperature KTB**3**, the (B3) battery cooling mode switches to the (B2) battery-temperature averaging mode.

**[0436]** The thermal management system **1** according to the present embodiment can perform the B4C1 mode, the B4C2 mode, and the B4C3 mode. The description below explains detailed operations of the operation modes for temperature adjustment.

**[0437]** (B4C1 Mode)

**[0438]** The B4C1 mode is an operation mode that performs the (B4) battery outdoor-air cooling mode and the (C1) high-voltage-instrument heat storage mode.

**[0439]** In the B4C1 mode, the controller **60** fully closes the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. Therefore, the refrigeration cycle equipment **10** in the B4C1 mode prevents the refrigerant from flowing into the chiller **20**. During no air-conditioning, it may be possible to stop the compressor **11** of the refrigeration cycle equipment **10**, the interior blower **32** of the interior air-conditioning unit **30**, and the high-temperature-side pump **411** of the high-temperature-side circuit **41**, for example.

**[0440]** The controller **60** controls operations of the five-way valve **422** to connect the outlet side of the cooling water channel **51***a* of the battery **51** with the inlet side of the heating medium bypass channel **424**. At the same time, the controller **60** activates the circuit that connects the outlet side of the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50** with the inlet side of the heating medium channel **20***b* of the chiller **20**.

**[0441]** The controller **60** controls operations of the three-way switching valve **425** to activate the circuit that allows the heating medium flowing out of the bypass-channel-side outlet **422***d* of the five-way valve **422** to flow out toward the battery-side radiator **423***a*.

**[0442]** The heating medium circuit **40** in the B4C1 mode allows the heating medium to flow as indicated by the arrows in FIG. **15**.

**[0443]** Specifically, the low-temperature-side circuit **42** in B4C1 mode allows the heating medium pumped from the first low-temperature-side pump **421***a* to circulate through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the battery-side radiator **423***a*, and the suction port of the first low-temperature-side pump **421***a* in order. The heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the heating medium channel **20***b* of the chiller **20**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0444]** In addition, the controller **60** accordingly controls the operations of other control-target instruments. For example, the controller **60** operates the first low-temperature-side pump **421***a* and the second low-temperature-side pump **421***b* to provide a predetermined pumping capability.

**[0445]** The B4C1 mode heating medium circuit **40** absorbs waste heat from the battery **51** when the heating medium pumped from the first low-temperature-side pump **421***a* flows through the cooling water channel **51***a* of the battery **51**. The battery **51** is thereby cooled. The heating medium flowing out of the cooling water channel **51***a* of the battery **51** flows through the battery-side radiator **423***a* and is cooled by dissipating heat to the outdoor air.

**[0446]** The heating medium circuit **40** in the B4C1 mode allows the battery-side radiator **423***a* to dissipate the waste heat of the battery **51** to the outdoor air, thereby cooling the battery **51**.

**[0447]** Similar to the B1C1 mode described in the first embodiment, for example, the heating medium circuit **40** in the B4C1 mode warms up the high-voltage instrument **50** and heats the heating medium.

**[0448]** FIG. **15** illustrates an example, where the heating medium pumped from the high-temperature-side pump **411** circulates through the high-temperature-side circuit **41**. Meanwhile, the B4C1 mode during no air-conditioning may stop the high-temperature-side pump **411**.

**[0449]** (B4C2 Mode During Air Conditioning)

**[0450]** The B4C2 mode is an operation mode that performs the (B4) battery outdoor-air cooling mode and the (C2) high-voltage-instrument waste heat recovery mode.

**[0451]** Similar to the B2C2 mode during air conditioning, the B4C1 mode during air conditioning allows the controller **60** to throttle the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**.

**[0452]** Similar to the B4C1 mode, the controller **60** controls operations of the five-way valve **422**, the three-way switching valve **425**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b*.

**[0453]** The heating medium circuit **40** in the B4C2 mode flows the heating medium flows similarly to the B4C1 mode, as indicated by the arrows in FIG. **15**.

**[0454]** The controller **60** controls operations of the other control-target instruments similarly to the B2C2 mode during air conditioning.

**[0455]** The heating medium circuit **40** in the B4C2 mode during air conditioning cools the battery **51** similarly to the B4C1 mode. The high-voltage instrument **50** is cooled similarly to the B2C2 mode during air conditioning.

**[0456]** (B4C2 Mode During No Air-Conditioning)

**[0457]** In the B4C2 mode during no air-conditioning, the chiller **20** needs to absorb the waste heat of the high-voltage instrument **50** into the low-pressure refrigerant.

**[0458]** In the B4C2 mode without air-conditioning, similar to the B2C2 mode during no air-conditioning, the controller **60** fully opens the heating expansion valve **14***a*, fully closes the cooling expansion valve **14***b*, and throttles the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. The controller **60** closes the on-off dehumidification valve **15***a* and the on-off heating valve **15***b*.

**[0459]** The refrigeration cycle equipment **10** in the B4C2 mode during no air-conditioning configures the vapor-compression refrigeration cycle in which the refrigerant circulates similarly to the B2C2 mode during no air-conditioning.

**[0460]** The controller **60** controls operations of the five-way valve **422**, the three-way switching valve **425**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b* similarly to the B4C1 mode.

**[0461]** The heating medium circuit **40** in the B4C2 mode flows the heating medium flows similarly to the B4C1 mode, as indicated by the arrows in FIG. **15**.

**[0462]** The controller **60** controls operations of the other control-target instruments similarly to the B2C2 mode during no air-conditioning.

**[0463]** The heating medium circuit **40** in the B4C2 mode during no air-conditioning cools the battery **51** similarly to the B4C1 mode. The high-voltage instrument **50** is cooled similarly to the B2C2 mode during air conditioning.

**[0464]** (B4C3 Mode)

**[0465]** The B4C3 mode is an operation mode that performs the (B4) battery outdoor-air cooling mode and the (C3) high-voltage-instrument cooling mode.

**[0466]** In the B4C3 mode, the controller **60** fully closes the cooling expansion valve **14***c* of the refrigeration cycle equipment **10**. Therefore, the refrigeration cycle equipment **10** in the B4C3 mode prevents the refrigerant from flowing into the chiller **20**. During no air-conditioning, it may be possible to stop the compressor **11** of the refrigeration cycle equipment **10**, the interior blower **32** of the interior air-conditioning unit **30**, and the high-temperature-side pump **411** of the high-temperature-side circuit **41**, for example.

**[0467]** The controller **60** controls operations of the five-way valve **422**, the three-way switching valve **425**, the first low-temperature-side pump **421***a*, and the second low-temperature-side pump **421***b*, similarly to the B4C1 mode.

**[0468]** The heating medium flows through the heating medium circuit **40** of the B4C3 mode as indicated by the arrow in FIG. **16**.

**[0469]** Specifically, the low-temperature-side circuit **42** in the B4C3 mode allows the heating medium pumped from the first low-temperature-side pump **421***a* to flow through the cooling water channel **51***a* of the battery **51**, the five-way valve **422**, the battery-side radiator **423***a*, and the suction port of the first low-temperature-side pump **421***a* in order. The heating medium pumped from the second low-temperature-side pump **421***b* circulates through the cooling water channels **52***a* through **54***a* of the high-voltage instrument **50**, the five-way valve **422**, the low-temperature-side radiator **423**, and the suction port of the second low-temperature-side pump **421***b* in order.

**[0470]** The controller **60** controls operations of the other control-target instruments similarly to the B4C1 mode.

**[0471]** In the B4C3 mode, the battery **51** is cooled similarly to the B4C1 mode. The high-voltage instrument **50** is cooled similarly to the B3C3 mode.

**[0472]** The other operations are similar to those in the first embodiment. As above, the thermal management system **1** according to the present embodiment can comfortably air-condition the vehicle compartment and appropriately adjust the temperatures of multiple in-vehicle units. The thermal management system **1** according to the present embodiment can also fully effectively use the heat generated from the temperature adjustment target despite the difference between the proper temperature zone of the first temperature adjustment target and the proper temperature zone of the second temperature adjustment target.

**[0473]** The thermal management system **1** according to the present embodiment can perform the B4C1 mode, the B4C2 mode, and the B4C3 mode. It is possible to adjust the temperatures of the battery **51** as the first temperature adjustment target and the high-voltage instrument **50** as the second temperature adjustment target more appropriately than the first embodiment.

## Third Embodiment

**[0474]** According to the present embodiment, as illustrated in the overall configuration diagram of FIG. **17**, the thermal management system **1** described in the first embodiment uses a high-temperature-side reserve tank **46***a* instead of the first heating medium joint portion **45***a* on the side of the high-temperature-side circuit **41**. The fifth heating medium joint portion **45***e* at the low-temperature-side circuit **42** is replaced by a low-temperature-side reserve tank **46***b*.

**[0475]** The high-temperature-side reserve tank **46***a* and the low-temperature-side reserve tank **46***b* are heating medium reservation portions that reserve an excess heating medium in the heating medium circuit **40**.

**[0476]** More specifically, the inlet of the high-temperature-side reserve tank **46***a* connects with the heating medium outlet side of the heater core **413** and the outlet side of the outlet-side connection channel **432** of the connection channel **43**. The outlet of the high-temperature-side reserve tank **46***a* connects with the suction port side of the high-temperature-side pump **411**.

**[0477]** The inlet of the low-temperature-side reserve tank **46***b* connects with the outlet side of the heating medium channel **20***b* of the chiller **20** and the heating medium outlet side of the low-temperature-side radiator **423**, The outlet of the low-temperature-side reserve tank **46***b* connects with the suction port side of the second low-temperature-side pump **421***b*. The other configurations and operations of the thermal management system **1** are similar to those in the first embodiment.

**[0478]** The thermal management system **1** according to the present embodiment can also provide effects similar to those of the first embodiment. It is possible to comfortably air-condition the vehicle compartment and appropriately adjust the temperatures of multiple in-vehicle units. The heat generated from the temperature adjustment target can be fully used effectively despite the difference between the appropriate temperature zone for the first temperature adjustment target and the appropriate temperature zone for the second temperature adjustment target.

**[0479]** The thermal management system **1** of the present embodiment stores the heating medium in the high-temperature-side reserve tank **46***a* and the low-temperature-side reserve tank **46***b*, thereby making it possible to inhibit a decrease in the fluid measure of the heating medium circulating through the heating medium circuit **40**. The outlet of the high-temperature-side reserve tank **46***a* and the outlet of the low-temperature-side reserve tank **46***b* are connected to the suction port side of the high-temperature-side pump **411** and the suction port side of the second low-temperature-side pump **421***b*, respectively.

**[0480]** It is possible to inhibit fluctuations on the liquid level of the heating medium during the configuration switchover of the heating medium circuit **40**, for example, and inhibit the air from entering the high-temperature-side pump **411** and the second low-temperature-side pump **421***b*. Consequently, it is possible to inhibit a decrease in the pumping capability of the high-temperature-side pump **411** and the second low-temperature-side pump **421***b* and allow the heating medium to more effectively use the heat generated from the temperature adjustment target.

**[0481]** The present disclosure is not limited to the above-mentioned embodiments but may be variously modified within the spirit and scope of the disclosure, as will be described below.

[0482] The above-described embodiments have explained examples of applying the thermal management system **1** according to the present disclosure to a vehicle. However, the application of the thermal management system **1** is not limited thereto. For example, the thermal management system **1** according to the present disclosure may be applied to a stationary air conditioner with a temperature adjustment function that air-conditions the room and, meanwhile, adjusts temperatures of multiple temperature adjustment targets (such as computer systems and electrical equipment) that differ in the appropriate temperature zones.

[0483] The above-described embodiments have explained the examples where the inverter **52**, the motor generator **53**, and the ADAS controller **54** are assumed to be the high-voltage instrument **50**. However, the present disclosure is not limited thereto. For example, the high-voltage instrument **50** may represent a charger or a power control unit (PCU).

[0484] The configurations of the refrigeration cycle equipment **10** are not limited to those disclosed in the above-described embodiment.

[0485] Multiple cycle components may be integrated under the condition that the above-described effects can be provided. For example, it may be favorable to use a four-way-structured joint portion that integrates the fourth refrigerant joint portion **13*d*** and the sixth refrigerant joint portion **13*f***. The same also applies to the heating medium circuit **40**. For example, it may be favorable to use a four-way-structured joint portion that integrates the fourth heating medium joint portion **45*d*** and the sixth heating medium joint portion **45*f***.

[0486] The above-described embodiments have explained the examples where R1234yf is used as the refrigerant. However, the refrigerant is not limited thereto. For example, it may be favorable to use R134a, R600a, R410A, R404A, R32, or R407C. Alternatively, it may be favorable to use a mixed refrigerant, that is, a mixture of multiple types of these refrigerants, for example. Carbon dioxide may be used as the refrigerant to configure a supercritical refrigeration cycle in which the refrigerant pressure at the high-pressure side is higher than or equal to the critical pressure of the refrigerant.

[0487] The configurations of the heating medium circuit **40** are not limited to those disclosed in the above-described embodiments.

[0488] The above-described embodiments have explained the examples of using the five-way valve **422** formed by combining multiple three-way flow control valves. However, the present disclosure is not limited thereto.

[0489] For example, the five-way valve may include a first body and a second body forming multiple spaces inside, a slide valve intervening between the first body and the second body, and an electric actuator to displace the slide valve.

[0490] More specifically, the multiple spaces formed in the first body and the second body communicate with any of the inlets and outlets. A groove portion is formed in the slide valve to communicate the space at the first body with the space at the second body and the spaces at the first body with each other, or the spaces at the second body side with each other. It just needs to be able to switch the circuit configurations of the low-temperature-side circuit **42** similar to the five-way valve **422** by allowing the electric actuator to displace the slide valve.

[0491] The five-way valve **422** may not need to perfectly switch the circuit configurations. For example, the heating medium may partially circulate through the cooling water channel **50*a*** of the high-voltage instrument **50** or the heating medium bypass channel **424** in the (D) quick charging and cooling mode described above.

[0492] The above-described embodiments have explained the examples where the connection channel **43** is used as the heat transfer portion. However, the present disclosure is not limited thereto.

[0493] For example, the inlet-side connection channel **431** may be replaced by an inlet-side heat transfer portion that performs heat exchange between the heating medium flowing out of the three-way valve **44** and the heating medium flowing into the cooling water channel **51*a*** of the battery **51**. The outlet-side connection channel **432** may be replaced by an outlet-side heat transfer portion that performs heat exchange between the heating medium flowing out of the cooling water channel **51*a*** of the battery **51** and the heating medium flowing into the heating medium channel **12*b*** of the water-refrigerant heat exchanger **12**.

[0494] The above-described embodiments have explained the examples where a PTC heater is used as the electric heater **412**, that is, the heating portion. However, the present disclosure is not limited thereto. For example, it may be favorable to use a nichrome wire or a carbon fiber heater. As the heating portion, it may be favorable to use a hot water pipe that flows hot water heated by another heat source.

[0495] The third embodiment has explained the example of replacing the first heating medium joint portion **45*a*** with the high-temperature-side reserve tank **46*a*** and the example of replacing the third heating medium joint portion **45*c*** with the low-temperature-side reserve tank **46*b***. However, the present disclosure is not limited thereto. For example, the fifth heating medium joint portion **45*e*** or the sixth heating medium joint portion **45*f*** may be replaced by the low-temperature-side reserve tank **46*b***. Either the high-temperature-side reserve tank **46*a*** or the low-temperature-side reserve tank **46*b*** may be used.

[0496] The above-described embodiments have explained the examples where an ethylene glycol aqueous solution is used as the heating medium for the heating medium circuit **40**. However, the present disclosure is not limited thereto. As the heating medium, it may be favorable to use a solution containing dimethylpolysiloxane or nanofluid, an antifreeze solution, a water-based liquid refrigerant containing alcohol, for example, or a liquid medium containing oil.

[0497] The operations of the thermal management system **1** in the corresponding operation modes are not limited to those disclosed in the above-described embodiments.

[0498] For example, the B1C1 mode during no air-conditioning and the B1C3 mode during no air-conditioning may stop the compressor **11** of the refrigeration cycle equipment **10** and allow the electric heater **412** to heat the heating medium flowing through the high-temperature-side circuit **41**.

[0499] The operation mode for temperature adjustment during air conditioning may be performed even if the battery **51** is charged when an occupant stays in the vehicle compartment.

[0500] The technical means disclosed in the above-described embodiments may be combined as appropriate within a practicable range. For example, the high-temperature-side reserve tank **46*a*** and the low-temperature-side reserve tank **46***b* described in the third embodiment may be applied to the thermal management system **1** according to the second embodiment.

**[0501]** While there have been described the specific preferred embodiments of the present disclosure, it is to be distinctly understood that the disclosure is not limited to the embodiments and structures. The disclosure covers various modified examples and modifications within a commensurate scope. In addition, the category or the scope of the idea of the disclosure covers various combinations or forms as well as the other combinations or forms including only one element or more or fewer elements in the various combinations or forms described in the disclosure.

What is claimed is:

**1**. A thermal management system comprising:
a refrigeration cycle equipment including
a high-temperature-side water-refrigerant heat exchange portion configured to perform heat exchange between high-pressure refrigerant and heating medium and
a low-temperature-side water-refrigerant heat exchange portion configured to perform heat exchange between low-pressure refrigerant and the heating medium; and
a heating medium circuit configured to circulate the heating medium, wherein
the heating medium circuit includes
a high-temperature-side circuit connecting with a heating medium channel of the high-temperature-side water-refrigerant heat exchange portion,
a low-temperature-side circuit connecting with a heating medium channel of the low-temperature-side water-refrigerant heat exchange portion, and
a heat transfer portion configured to transfer heat between the heating medium, which flows through the high-temperature-side circuit, and the heating medium, which flows through the low-temperature-side circuit,
the low-temperature-side circuit includes
a first heat exchange portion configured to perform heat exchange between a first temperature adjustment target and the heating medium,
a second heat exchange portion configured to perform heat exchange between a second temperature adjustment target and the heating medium,
a heating medium bypass channel configured to
cause the heating medium, which flows out of one of the first heat exchange portion and the second heat exchange portion, to bypass the low-temperature-side water-refrigerant heat exchange portion and
return the heating medium toward a heating medium inlet of one of the first heat exchange portion and the second heat exchange portion, and
a low-temperature-side circuit switching portion configured to switch a circuit configuration of the low-temperature-side circuit,
when the first temperature adjustment target is heated,
the heat transfer portion is configured to transfer heat of the heating medium, which is heated by the high-temperature-side water-refrigerant heat exchange portion, to the heating medium, which flows into the first heat exchange portion, and
the low-temperature-side circuit switching portion is configured to switch a circuit configuration of the low-temperature-side circuit to a circuit configuration that returns the heating medium, which flows out of the first heat exchange portion, toward the heating medium inlet of the first heat exchange portion via the heating medium bypass channel.

**2**. The thermal management system according to claim **1**, wherein
when the first temperature adjustment target is heated,
the heat transfer portion is configured to transfer heat of the heating medium, which is heated by the high-temperature-side water-refrigerant heat exchange portion, to the heating medium, which flows into the first heat exchange portion, and
the low-temperature-side circuit switching portion is configured to switch a circuit configuration of the low-temperature-side circuit to a circuit configuration that
returns the heating medium, which flows out of the first heat exchange portion, toward the heating medium inlet of the first heat exchange portion via the heating medium bypass channel and
causes the heating medium, which flows out of the second heat exchange portion, toward the low-temperature-side water-refrigerant heat exchange portion.

**3**. The thermal management system according to claim **1**, wherein
the heat transfer portion is a connection channel that connects the high-temperature-side circuit with the low-temperature-side circuit, and
the connection channel includes an inlet-side connection channel configured to guide the heating medium, which flows out of the high-temperature-side water-refrigerant heat exchange portion, toward a heating medium inlet of the first heat exchange portion.

**4**. The thermal management system according to claim **3**, wherein
the low-temperature-side circuit includes a first low-temperature-side pump configured to draw and pump the heating medium to the first heat exchange portion, and
the inlet-side connection channel is connected to guide the heating medium, which flows out of the high-temperature-side water-refrigerant heat exchange portion, toward a suction port of the first low-temperature-side pump.

**5**. The thermal management system according to claim **3**, wherein
the high-temperature-side circuit includes a high-temperature-side pump configured to draw and pump the heating medium toward the high-temperature-side water-refrigerant heat exchange portion, and
the connection channel includes an outlet-side connection channel configured to guide the heating medium, which flows out of the first heat exchange portion, toward a suction port of the high-temperature-side pump.

**6**. The thermal management system according to claim **1**, wherein
the heating medium circuit includes a heat transfer amount adjusting portion configured to adjust a heat transfer amount of the heat transfer portion,

the thermal management system further comprising:

a heat transfer amount control unit configured to control an operation of the heat transfer amount adjusting portion, wherein

the heat transfer amount control unit is configured to,

when the low-temperature-side circuit switching portion activates a circuit configuration that returns the heating medium, which flows out of the first heat exchange portion, to the first heat exchange portion via the heating medium bypass channel,

control the operation of the heat transfer amount adjusting portion so that a temperature of the heating medium, which flows into the first heat exchange portion, approximates a predetermined targeted warming temperature.

**7**. The thermal management system according to claim **1**, wherein

the high-temperature-side circuit includes a heating heat exchange portion configured to perform heat exchange between a fluid to be heated and the heating medium.

**8**. The thermal management system according to claim **1**, wherein

the high-temperature-side circuit includes a heating portion configured to heat the heating medium.

**9**. The thermal management system according to claim **1**, wherein

the low-temperature-side circuit switching portion is configured to cause the heating medium, which flows out of the first heat exchange portion, to flow into at least one of the heating medium bypass channel or the low-temperature-side water-refrigerant heat exchange portion.

**10**. The thermal management system according to claim **1**, wherein

the low-temperature-side circuit includes a low-temperature-side outdoor air heat exchange portion configured to perform heat exchange between outdoor air and the heating medium, and

the low-temperature-side circuit switching portion is configured to cause the heating medium, which flows out of the second heat exchange portion, to flow toward at least one of the low-temperature-side outdoor air heat exchange portion or the low-temperature-side water-refrigerant heat exchange portion.

**11**. The thermal management system according to claim **1**, wherein

the low-temperature-side circuit switching portion is configured to switch the heating medium, which is to flow into the heating medium channel of the low-temperature-side water-refrigerant heat exchange portion, to one of the heating medium, which flows out of the first heat exchange portion, and the heating medium, which flows out of the second heat exchange portion.

**12**. The thermal management system according to claim **1**, wherein

the low-temperature-side circuit includes a low-temperature-side outdoor air heat exchange portion configured to perform heat exchange between outdoor air and the heating medium, and

the low-temperature-side circuit switching portion is configured to cause the heating medium, which flows out of the first heat exchange portion, to flow toward at least one of the low-temperature-side outdoor air heat exchange portion or the low-temperature-side water-refrigerant heat exchange portion.

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