

DESCRIPTION

MULTI-SPLIT AIR CONDITIONING APPARATUS

TECHNICAL FIELD

The present invention relates to a multi-split air conditioning apparatus, more particularly, to a multi-split air conditioning apparatus including a plurality of indoor units each having an indoor heat exchanger capable of exchanging heat between air and refrigerant.

BACKGROUND ART

In conventional air conditioning apparatus, when cooling load is low during a cooling operation, the air conditioning apparatus sometimes operates according to the low cooling load by lowering the operating frequency of the compressor, such as in the air conditioning apparatus described in Patent Literature 1 (Japanese Patent Unexamined Publication S56-122864). In the following description, an operation of reducing cooling capacity to correspond to low cooling load is referred to as a "low-capacity cooling operation." In this operation, operating frequency of the compressor is lowered and an superheat region in an indoor heat exchanger in an indoor unit is made larger than during a normal cooling operation. As described in Patent Literature 1, when one outdoor unit and one indoor unit are connected to each other, the operating frequency of the compressor can be changed to easily meet the requirements of the indoor unit during the low-capacity cooling operation even if, for example, the indoor temperature of the indoor unit varies.

However, in a multi-split air conditioning apparatus in which, for example, a plurality of indoor units is connected to one outdoor unit and the plurality of indoor units operates in parallel, it is difficult to change the operating frequency of the compressor in the outdoor unit to meet the requirements of any of the indoor units. Because of this, there has been conceived changing the opening degree of an expansion valve in one of the indoor units in the multi-split air conditioning apparatus for which required cooling capacity has been changed due to the set temperature being changed or the cooling capacity required of the indoor unit being changed, to thereby deal with the changed cooling load.

SUMMARY OF THE INVENTION

<Technical Problem>

However, when a multi-split air conditioning apparatus performs a low-capacity cooling operation, attempting to increase the opening degree of an expansion valve to improve cooling capacity may cause condensation to be generated in a rotor of an indoor fan due to air passing through an superheat region and air passing through a wet region in an indoor heat exchanger mixing together.

Embodiments of the present invention prevent condensation from being generated in a rotor in an indoor fan when a multi-split air conditioning apparatus performs a low-capacity cooling operation.

<Solution to Problem>

A multi-split air conditioning apparatus according to an aspect of the present invention includes an outdoor unit including a compressor configured to compress refrigerant that circulates and executes a refrigeration cycle; and a plurality of indoor units including: a plurality of indoor heat exchangers through which refrigerant discharged from the compressor circulates; a plurality of pressure reducing mechanisms through which refrigerant discharged from the compressor circulates; and a plurality of indoor fans through which passes air that passes through the plurality of indoor heat exchangers, in which at least one indoor unit among the plurality of indoor units is configured to, when an indoor temperature is higher than a set temperature during a low-capacity cooling operation which increases an superheat region more than during a normal cooling operation, increase an opening degree of the pressure reducing mechanism, to thereby narrow the superheat region of the indoor heat exchanger so as to expand a wet region of the indoor heat exchanger and increase flow rate of the indoor fan, so as to restrict expansion of the wet region to an upper limit at which condensation in the apparatus is not generated at a downstream of the indoor heat exchanger, and wherein the at least one indoor unit is configured to perform cooling with mixed air that has passed through the wet region and the superheat region during the low-capacity cooling operation.

According to the above aspect of the multi-split air conditioning apparatus, although cooling capacity is increased by expanding the wet region of the indoor heat exchanger by increasing the opening degree of the pressure reducing mechanism, the temperature of mixed air, which is a mix of air that passes through the superheat region of the indoor heat exchanger and air that passes through the wet region, increases when the wet region expands. Therefore, in order that condensation in the apparatus is not generated due to the temperature of the mixed air falls too far below the dew point temperature of the mixed air, necessary cooling capacity can be guaranteed by controlling the opening degree of the pressure reducing mechanism such that the opening degree does not exceed an upper limit at which condensation occurs in the apparatus downstream of the indoor heat exchanger so as to reduce an increase in size of the wet region. Further improvement of cooling capacity can be ensured by increasing the flow rate of the indoor fan and necessary cooling capacity can

be guaranteed. As a result, when the multi-split air conditioning apparatus performs the low-capacity cooling operation, condensation in the apparatus downstream of the indoor heat exchanger can be reduced while ensuring necessary cooling capacity.

In an embodiment, at least one indoor unit is configured to, when the indoor temperature is lower than the set temperature during the low-capacity cooling operation, decrease cooling capacity decreased by reducing the opening degree of the pressure reducing mechanism and/or reducing the flow rate of the indoor fan.

According to the above embodiment, if the room temperature during the low-capacity cooling operation while cooling is lower than the set temperature, cooling capacity is reduced by reducing the opening degree of the pressure reducing mechanism is reduced and/or lowering the flow rate of the indoor fan. As a result, the wet region is narrowed from the state in which expansion of the wet region is restricted to the upper limit at which condensation in the apparatus downstream of the indoor heat exchanger is not generated and/or flow rate is reduced.

In another embodiment, at least one indoor unit is configured to determine that expansion of the wet region is restricted to an upper limit at which condensation in the apparatus is not generated at a downstream of the indoor heat exchanger using a temperature of the mixed air or a humidity of the mixed air.

According to the above embodiment, a temperature of the mixed air or a humidity of the mixed air can be used to easily determine whether or not expansion of the wet region is restricted to the upper limit at which condensation in the apparatus downstream of the indoor heat exchanger is not generated.

In another embodiment, at least one indoor unit further comprises an indoor heat exchanger temperature sensor provided to the indoor heat exchanger, and in which the at least one indoor unit is configured to determine that expansion of the wet region is restricted to the upper limit at which condensation in the apparatus downstream of the indoor heat exchanger is not generated using detection results of the indoor heat exchanger temperature sensor during the low-capacity cooling operation.

According to the above embodiment, detection results of the indoor heat exchanger temperature sensor can be used to easily determine whether or not expansion of the wet region is restricted to the upper limit at which condensation in the apparatus downstream of the indoor heat exchanger is not generated.

In another embodiment, at least one indoor unit switches from a low-capacity cooling operation mode to a normal cooling operation mode to obtain necessary cooling

capacity when expansion of the wet region cannot be restricted to the upper limit at which condensation in the apparatus is not generated at a downstream of the indoor heat exchanger by increasing the flow rate of the indoor fan.

According to the above embodiment, by switching from the low-capacity cooling operation mode to the normal cooling operation mode, all of the indoor heat exchanger can be made a wet region. As a result, air that passes through the superheat region of the indoor heat exchanger can be eliminated.

<Advantageous Effects of Invention>

With the multi-split air conditioning apparatus according to embodiments of the present invention, condensation in the apparatus downstream of the internal heat exchanger can be reduced when the multi-split air conditioning apparatus performs a low-capacity cooling operation.

With the multi-split air conditioning apparatus according to embodiments of the present invention, cooling capacity can be reduced while maintaining a state in which condensation in the apparatus downstream of the internal heat exchanger is not generated.

With the multi-split air conditioning apparatus according to embodiments of the present invention, condensation within the apparatus can be more reliably reduced downstream of the internal heat exchanger.

With the multi-split air conditioning apparatus according to embodiments of the present invention, condensation in the apparatus downstream of the internal heat exchanger can be reduced while ensuring required cooling capacity.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a circuit diagram for illustrating a schematic configuration of a multi-split air conditioning apparatus according to an embodiment of the present invention.

FIG. 2 is a cross-sectional diagram for illustrating an exemplary configuration of an indoor unit in the multi-split air conditioning apparatus in FIG. 1.

FIG. 3 is a perspective diagram for illustrating the configuration around an indoor heat exchanger when a front panel or another component of the indoor unit in FIG. 2 has been removed.

FIG. 4 is a conceptual diagram of the indoor heat exchanger for explaining a normal

cooling operation of the multi-split air conditioning apparatus.

FIG. 5 is a conceptual diagram of the indoor heat exchanger for explaining a low-capacity cooling operation of the multi-split air conditioning apparatus.

FIG. 6 is a graph for explaining the concept of control during the low-capacity cooling operation.

FIG. 7 is a graph for explaining an example of control during the low-capacity cooling operation.

FIG. 8 is a graph for explaining another example of control during the low-capacity cooling operation.

FIG. 9 is a circuit diagram for illustrating a schematic configuration of an air conditioning apparatus according to a modification example 1C of the present invention.

FIG. 10 is a perspective diagram for illustrating the external appearance of an outdoor unit according to the modification example 1C.

DESCRIPTION OF EMBODIMENTS

(1) Overall configuration of air conditioning apparatus

FIG. 1 is a schematic configuration diagram for illustrating a multi-split air conditioning apparatus according to an embodiment of the present invention. The multi-split air conditioning apparatus 10 is an apparatus used for cooling a room inside an office building or other structure by performing a vapor-compression refrigeration cycle operation. The multi-split air conditioning apparatus 10 includes one outdoor unit 20 as a heat source unit, a plurality of (in this embodiment, three) indoor units 40, 50, 60 as usage units connected in parallel to the outdoor unit 20, and a liquid refrigerant communication pipe 71 and a gas refrigerant communication pipe 72 as refrigerant communication pipes which connect the outdoor unit 20 and the indoor units 40, 50, 60 to each other.

A refrigerant circuit 11 of the multi-split air conditioning apparatus 10 is formed through the outdoor unit 20, the indoor units 40, 50, 60, the liquid refrigerant communication pipe 71 and the gas refrigerant communication pipe 72 being connected to each other. The refrigerant circuit 11 includes indoor-side refrigerant circuits 11a, 11b, 11c and an outdoor-side refrigerant circuit 11d. Refrigerant flows through the refrigerant circuit 11.

The multi-split air conditioning apparatus 10 also includes an operation control device 80 configured to control the entire operation of the multi-split air conditioning apparatus 10. Indoor-side control apparatus 47, 57, 67 and an outdoor-side control apparatus 37 form the operation control device 80 by being connected to each other via a transmission line 80a. The indoor-side control apparatus 47, 57, 67 of the indoor units 40,

50, 60 are configured to send/receive control signals and the like to/from each other via the transmission line 80a.

The operation control device 80 is connected to an intake pressure sensor 29, a discharge pressure sensor 30, an intake temperature sensor 31, a discharge temperature sensor 32, an outdoor temperature sensor 36, liquid-side temperature sensors 44, 54, 64 and gas-side temperature sensors 45, 55, 65 in order to receive detection signals output from those components. The operation control device 80 is also connected to a compressor 21, a four-way valve 22, an outdoor fan 28, an outdoor expansion valve 38, indoor expansion valves 41, 51, 61 and indoor fans 43, 53, 63 in order to control the outdoor unit 20 and the indoor units 40, 50, 60 on the basis of the detection signals.

(2) Detailed configuration

(2-1) Outdoor unit 20

The outdoor unit 20 includes an outdoor-side refrigerant circuit 11d which configures part of the refrigerant circuit 11. A compressor 21, a four-way valve 22, an outdoor heat exchanger 23, an outdoor expansion valve 38 and an accumulator 24 are connected to the outdoor-side refrigerant circuit 11d.

The compressor 21 is a positive-displacement compressor with varying operating capacity and is driven by a motor 21m whose rotational speed is controlled by an inverter. The four-way valve 22 is a valve used for switching direction of the flow of refrigerant.

During a cooling operation, the four-way valve 22 illustrated in FIG. 1 switches the connection state to that indicated by the solid line in FIG. 1. In other words, the four-way valve 22 causes a discharge side of the compressor 21 and the outdoor heat exchanger 23 to connect to each other and an intake side (more specifically, the accumulator 24) of the compressor 21 and the gas refrigerant communication pipe 72 to connect to each other and, during the cooling operation, causes the outdoor heat exchanger 23 to function as a radiator for refrigerant compressed by the compressor 21 and the indoor heat exchangers 42, 52, 62 to function as evaporators for refrigerant which has been removed of heat by the outdoor heat exchanger 23.

During a heating operation, the four-way valve 22 illustrated in FIG. 1 switches the connection state to that indicated by the broken line in FIG. 1. The four-way valve 22 causes the discharge side of the compressor 21 and the gas refrigerant communication pipe 72 side to connect to each other and the intake side of the compressor 21 and the outdoor heat exchanger 23 to connect to each other, and the indoor heat exchangers 42, 52, 62 to function as radiators for refrigerant compressed by the compressor 21 and the outdoor heat exchanger

23 to function as an evaporator for refrigerant which has been removed of heat by the indoor heat exchangers 42, 52, 62.

The outdoor heat exchanger 23 is, for example, a cross-finned tube heat exchanger and is a device used for exchanging heat between air and refrigerant in order to use the air as a heat source. A gas side of the outdoor heat exchanger 23 is connected to the four-way valve 22 and a liquid side of the outdoor heat exchanger 23 is connected to the outdoor expansion valve 38.

The outdoor expansion valve 38 is a solenoid expansion valve disposed on a downstream side of the outdoor heat exchanger 23 in a direction of flow of refrigerant in the refrigerant circuit 11 when performing a cooling operation. The outdoor expansion valve 38 is used for adjusting pressure and flow rate of refrigerant that flows through the outdoor-side refrigerant circuit 11d. The outdoor expansion valve 38 is connected to the liquid side of the outdoor heat exchanger 23.

The outdoor unit 20 includes an outdoor fan 28 as a ventilation fan for discharging outside air which has been sucked into the outdoor unit 20 and undergone heat exchange with refrigerant in the outdoor heat exchanger 23. The outdoor fan 28 can change the flow rate of air supplied to the outdoor heat exchanger 23 and, for example, is a propeller fan driven by a motor 28m, which is a DC fan motor or the like.

The outdoor unit 20 is provided with, for example, an intake pressure sensor 29 configured to detect intake pressure (in other words, refrigerant pressure corresponding to evaporation pressure P_e during a cooling operation) of the compressor 21, a discharge pressure sensor 30 configured to detect discharge pressure of the compressor 21, an intake temperature sensor 31 configured to detect intake temperature of the compressor 21, a discharge temperature sensor 32 configured to detect discharge temperature of the compressor 21, and other components. In addition, an intake port of the outdoor unit 20 for outside air is provided with an outdoor temperature sensor 36 configured to detect temperature of the outside air flowing into the outdoor unit 20.

The outdoor unit 20 further includes an outdoor-side control apparatus 37 used for controlling operation of the components that make up the outdoor unit 20. The outdoor-side control apparatus 37 includes a microcomputer (not shown) provided in order to control the outdoor unit 20, a memory (not shown), an inverter circuit (not shown) configured to control the motor 21m, and other components.

Set temperature, set humidity, indoor temperature, indoor humidity and other values of the plurality of indoor units 40, 50, 60 greatly vary. Because these values fluctuate, it is

difficult to adjust the required capacity of the outdoor unit 20 to suit all of the individual indoor units 40, 50, 60. Therefore, the outdoor-side control apparatus 37 controls operating capacity of the compressor 21 and/or flow rate of the outdoor fan 28 according to the requirements of one of/some of the plurality of indoor units 40, 50, 60, such as an indoor unit with the highest requirements among the plurality of indoor units 40, 50, 60. As a result, there are cases where, for most of the plurality of indoor units 40, 50, 60, the operating capacity of the compressor 21 and/or the flow rate of the outdoor fan 28 is set higher than necessary.

(2-2) Indoor unit

10 (2-2-1) Summary of indoor unit

The indoor units 40, 50, 60 are installed in rooms in an office building such as meeting rooms by being installed in or hung from the ceilings of those rooms. The plurality of indoor units 40, 50, 60 may be all installed in one room or may be installed in different rooms. Note that the indoor units 50, 60 have the same configuration as the indoor unit 40, and hence only the configuration of the indoor unit 40 is described herein. Configurations of the indoor units 50, 60 are denoted by numbers that start with 5 or 6, respectively, instead of numbers that start with 4, which denote units of the indoor unit 40. In addition, descriptions of components of the indoor units 50, 60 are omitted.

The indoor units 40, 50, 60 are connected to the outdoor unit 20 via the liquid refrigerant communication pipe 71 and the gas refrigerant communication pipe 72. For example, the indoor unit 40 includes an indoor-side refrigerant circuit 11a (an indoor-side refrigerant circuit 11b for the indoor unit 50 and an indoor-side refrigerant circuit 11c for the indoor unit 60) which forms part of the refrigerant circuit 11. The indoor-side refrigerant circuit 11a includes the indoor expansion valve 41 as a pressure reducing mechanism and the indoor heat exchanger 42. Note that, in this embodiment, the indoor expansion valves 41, 51, 61 are provided to each indoor unit 40, 50, 60, respectively, as pressure reducing mechanisms, but the present invention is not limited thereto and a plurality of pressure reducing mechanisms corresponding to the indoor units 40, 50, 60 may be provided to the outdoor unit 20, or a connection unit independent of the indoor units 40, 50, 60 and the outdoor unit 20 may be provided.

The indoor expansion valve 41 is a solenoid expansion valve connected to the liquid side of the indoor heat exchanger 42. The indoor expansion valve 41 is used for regulating the flow rate of refrigerant flowing through the indoor-side refrigerant circuit 11a and can shut off flow of the refrigerant. The indoor expansion valve 41 is controlled by the indoor-

side control apparatus 47 and is configured to change opening degree to adjust flow rate of refrigerant and reduction in pressure.

The indoor heat exchanger 42 is a heat exchanger used for exchanging heat between air and refrigerant and is, for example, a cross-finned tube heat exchanger formed of heat transfer tubes and a plurality of fins. During a cooling operation, the indoor heat exchanger 42 functions as an evaporator for refrigerant to cool indoor air. During a heating operation, the indoor heat exchanger 42 functions as a radiator for refrigerant to heat indoor air.

The indoor unit 40 includes an indoor fan 43 as a ventilation fan for supplying indoor air to a room as supply air after the indoor air has been sucked into the indoor unit 40 and undergone heat exchange with refrigerant in the indoor heat exchanger 42. The indoor fan 43 can change the flow rate of the air supplied to the indoor heat exchanger 42 within a predetermined flow rate range and is, for example, a centrifugal fan or a multi-blade fan driven by a motor 43m which is a DC fan motor. In the indoor unit 40 illustrated in FIG. 2, a cross-flow fan is used as the indoor fan 43.

(2-2-2) Detailed configuration of indoor unit

FIG. 2 illustrates a cross section of the indoor unit 40. The indoor unit 40 illustrated in FIG. 2 is mounted to a wall. In FIG. 2, the arrow Ar1 indicated by the double dashed-dotted line represents the flow of sucked in indoor air and the arrow Ar2 indicated by the dashed-dotted line represents the flow of conditioned air to be discharged. As illustrated in FIG. 2, the indoor unit 40 includes a casing 411, an air filter 412, the indoor heat exchanger 42, the indoor fan 43, a perpendicular blade 416 and a horizontal blade 417. FIG. 3 is a perspective diagram for illustrating configurations around a front heat exchange portion 421 and a rear heat exchange portion 422 of the indoor unit 40 illustrated in FIG. 2.

An opening of the casing 411, that is, an intake port 431 is provided on an upper portion of the wall-mounted indoor unit 40 illustrated in FIG. 2. Indoor air that is sucked in through the intake port 431 enters an intake space S1. Space on a downstream side of the air filter 412 is also included in the intake space S1. An indoor temperature sensor 451 configured to measure the temperature of sucked-in air and an indoor humidity sensor 452 configured to measure the relative humidity of sucked-in air are installed in the intake space S1, for example. The temperature measured by the indoor temperature sensor 451 is an indoor temperature Tr1 or a suction temperature Ti.

An intermediate space S2 is located downstream of the indoor heat exchanger 42 and upstream of the indoor fan 43. A discharge space S3 is located downstream of the indoor fan 43. Indoor air that has been sucked in from above the casing 411 travels from the

intake space S1 to the intermediate space S2. During this time, the temperature and humidity of the indoor air is regulated by the indoor heat exchanger 42 of the casing 411. The air in the intermediate space S2 is mixed when passing through the indoor fan 43 to become mixed air. The mixed air passes through the discharge space S3 and is discharged
5 from the discharge port 432 on a lower side as conditioned air.

(2-2-3) Casing 411 and air filter 412

The casing 411 forms the outline and frame of the indoor unit 40. The discharge space S3, which is a discharge flow path continuous with the discharge port 432, is formed by a rear guider 433 and a stabilizer 434 in the casing 411. The air filter 412 is disposed
10 between the intake port 431 and the indoor heat exchanger 42. Before the indoor air passes through the indoor heat exchanger 42, dust and dirt in the indoor air is removed through the air passing through the air filter 412. For this reason, the air filter 412 is mounted to the casing 411 so as to surround the indoor heat exchanger 42. In this embodiment, the space around the air filter 412 is regarded to be the same as the intake space S1 because
15 temperature and humidity does not change around the air filter 412. Therefore, the indoor temperature sensor 451 and the indoor humidity sensor 452 can be provided either upstream or downstream of the air filter 412.

(2-2-4) Indoor heat exchanger 42

The indoor heat exchanger 42 is made up of the front heat exchange portion 421 and
20 the rear heat exchange portion 422. The indoor heat exchanger 42 includes a plurality of fins 481 and a plurality of heat transfer tubes 482. Each fin 481 is made of a thin metal plate and is disposed so as to be parallel to adjacent fins 481 and perpendicular to a longitudinal direction of the indoor unit 40. Therefore, air that passes through the indoor heat exchanger 42 passes between adjacent fins 481. Each of the plurality of heat transfer
25 tubes 482 are metal pipes and extend through the fins 481 along the longitudinal direction of the indoor unit 40. The heat transfer tubes 482 are members used for performing heat exchange between refrigerant that flows through the heat transfer tubes 482 and air that passes through gaps between the fins 481 and the heat transfer tubes 482. The refrigerant and air undergo heat exchange via the plurality of fins 481 and the plurality of heat transfer
30 tubes 482. Further, the indoor heat exchanger 42 can remove humidity by condensing moisture in the indoor air and adhering that moisture to the fins 481 and the heat transfer tubes 482. The heat exchange portion 421 includes an upper front heat exchange portion 426 inclined forward and downward and a lower front heat exchange portion 427 inclined rearward and downward from a lower end of the upper front heat exchange portion 426.

The rear heat exchange portion 422 is inclined rearward and downward.

In this embodiment, for brevity of description, there is described a case where the heat transfer tubes 482 of the indoor heat exchanger 42 are arranged in one row. However, the heat transfer tubes 482 in the indoor heat exchanger 42 to which the present invention can
5 be applied are not limited to being arranged in one row and can be arranged in two or more rows. In addition, there is described that, during a cooling operation, refrigerant enters from the lowest heat transfer tube 483 in the lower front heat exchange portion 427 and exits from the lowest heat transfer tube 484 in the rear heat exchange portion 422. One heat transfer
10 tube 482 on each level is connected to a heat transfer tube 482 on another level, but with the U-shaped pipes 485 illustrated in FIG. 3 for example, heat transfer tubes 482 on different levels are connected to each other. In this indoor heat exchanger 42, refrigerant flows to adjacent heat transfer tubes 482 in order.

(2-2-5) Indoor fan 43

The indoor fan 43 is positioned between the heat exchange portion 421 and the rear
15 heat exchange portion 422 and the discharge port 432. The indoor fan 43 includes a long cylindrical fan rotor 43a which extends in the longitudinal direction of the indoor unit 40 and the motor 43m which rotates the fan rotor 43a. The fan rotor 43a is formed of a plurality of fan blades which extend along the circumference of the fan rotor 43a. In FIG. 2, the fan rotor 43a rotates clockwise about a center point O. By rotating about the center point O, air
20 is caused to flow from the front heat exchange portion 421 and the rear heat exchange portion 422 to the discharge port 432. The air flowing toward the discharge port 432 passes through the fan rotor 43a. Because of this, condensation is generated when the temperature of the fan rotor 43a is lower than a condensation temperature of the mixed air (conditioned air). In other words, in this case, fan rotor condensation is generated downstream of the indoor heat
25 exchanger 42. Rotation of the indoor fan 43 is controlled by the indoor-side control apparatus 47 and the flow rate of the indoor fan 43 can be changed according to a command output from the indoor-side control apparatus 47.

(2-2-6) Perpendicular blade 416 and horizontal blade 417

The perpendicular blade 416 is disposed within the discharge flow path, which is the
30 discharge space S3. The perpendicular blade 416 is made to rotate by a stepper motor (not shown) to adjust the direction of flow in the longitudinal direction of the indoor unit 40. The horizontal blade 417 is disposed along the discharge port 432 and is made to rotate by a stepper motor (not shown) to adjust the direction of flow in an up/down direction. Condensation is generated when temperatures of both the perpendicular blade 416 and the

horizontal blade 417 are lower than the condensation temperature of mixed air. Condensation generated in this case also corresponds to fan rotor condensation generated downstream of the indoor heat exchanger 42.

(2-2-7) Indoor-side control apparatus 47 and various sensors

5 The indoor-side control apparatus 47 is housed in an electrical component box (not shown) disposed within the casing 411. The indoor-side control apparatus 47 controls the indoor unit 40 according to, for example, commands stored in a memory (not shown) and commands output from a remote controller (not shown).

10 The indoor unit 40 is provided with various sensors in addition to the above-described indoor temperature sensor 451 and indoor humidity sensor 452. However, descriptions of sensors not important to the description herein are omitted. A liquid-side temperature sensor 44 configured to detect refrigerant temperature (refrigerant temperature corresponding to an evaporation temperature T_e during the cooling operation) is provided on the liquid side of the indoor heat exchanger 42. A gas-side temperature sensor 45
15 configured to detect refrigerant temperature is provided on the gas side of the indoor heat exchanger 42. A discharge temperature sensor 453 configured to measure air temperature (temperature of mixed air) in the discharge space S3 is provided in the discharge space S3. In addition, a discharge humidity sensor 454 configured to measure air humidity (humidity of mixed air) in the discharge space S3 is provided in the discharge space S3. For example,
20 thermistors can be used for the liquid-side temperature sensor 44, the gas-side temperature sensor 45, the indoor temperature sensor 451 and the discharge temperature sensor 453.

(3) Operation of air conditioning apparatus

25 In the multi-split air conditioning apparatus 10, during a cooling operation and a heating operation, the user uses an input device such as a remote controller to perform, for each indoor unit 40, 50, 60, indoor temperature control of approximating indoor temperatures $Tr1$, $Tr2$, $Tr3$ to set temperatures $Ts1$, $Ts2$, $Ts3$ set separately for each indoor unit 40, 50, 60. With this indoor temperature control, when the indoor fan 43, 53, 63 is set to an automatic flow rate mode, the flow rate of the indoor fan 43 and the opening degree of the indoor expansion valve 41 are regulated such that indoor temperature $Tr1$ converges to the set
30 temperature $Ts1$, the flow rate of the indoor fan 53 and the opening degree of the indoor expansion valve 51 are regulated such that indoor temperature $Tr2$ converges to the set temperature $Ts2$, and the flow rate of the indoor fan 63 and the opening degree of the indoor expansion valve 61 are regulated such that indoor temperature $Tr3$ converges to the set temperature $Ts3$. In a low-capacity cooling operation mode, the flow rate of the indoor fan

43, 53, 63 is automatically regulated by the operation control device 80.

The low-capacity cooling operation is important in the present invention. The heating operation may have the same configuration as a conventional apparatus, and hence only the cooling operation is described herein. During the cooling operation, the multi-split
5 air conditioning apparatus 10 is configured to perform the cooling operation in the low-capacity cooling operation mode in addition to a normal cooling operation mode. The normal cooling operation mode is a mode in which a normal cooling operation is performed and the low-capacity cooling operation mode is a mode in which the low-capacity cooling operation is performed. The low-capacity cooling operation is a cooling operation in which
10 the superheat region in the indoor heat exchanger 42 is increased further than during the normal cooling operation and cooling is performed with mixed air which is a mix of air that has passed through the superheat region and air that has passed through a wet region.

(3-1) Cooling operation

During the cooling operation, the four-way valve 22 is in the state indicated by the
15 solid line in FIG. 1, that is, a state in which the discharge side of the compressor 21 is connected to the gas side of the outdoor heat exchanger 23 and the intake side of the compressor 21 is connected to the gas side of the indoor heat exchanger 42, 52, 62 via the gas refrigerant communication pipe 72. During the cooling operation in this case, the outdoor expansion valve 38 is fully open. The opening degree of the indoor expansion valve 41 is
20 regulated such that an superheat temperature SH1 of refrigerant at an outlet of the indoor heat exchanger 42 (in other words, the gas side of the indoor heat exchanger 42) reaches a target superheat temperature SHt1, the opening degree of the indoor expansion valve 51 is regulated such that an superheat temperature SH2 of refrigerant at an outlet of the indoor heat exchanger 52 (in other words, a gas side of the indoor heat exchanger 52) is constant at a
25 target superheat temperature SHt2, and the opening degree of the indoor expansion valve 61 is regulated such that an superheat temperature SH3 of refrigerant at an outlet of the indoor heat exchanger 62 (in other words, a gas side of the indoor heat exchanger 62) reaches a target superheat temperature SHt3.

Note that the target superheat temperature SHt1, SHt2, SHt3 is set as an optimal
30 temperature value for causing the indoor temperature Tr1, Tr2, Tr3 to converge to the set temperature Ts1, Ts2, Ts3 within a predetermined superheat temperature range. Each superheat temperature SH1, SH2, SH3 of refrigerant at each outlet of each indoor heat exchanger 42, 52, 62 is, for example, detected by subtracting a refrigerant temperature value (corresponding to the evaporation temperature Te) detected by the liquid-side temperature

sensor 44, 54, 64 from a refrigerant temperature value detected by the gas-side temperature sensor 45, 55, 65, respectively. However, the superheat temperature SH1, SH2, SH3 of refrigerant at each outlet of each indoor heat exchanger 42, 52, 62 is not limited to being detected using this method.

5 When the compressor 21, the outdoor fan 28 and the indoor fan 43, 53, 63 are operated while the refrigerant circuit 11 is under such a state, low-pressure gas refrigerant is sucked into a compressed by the compressor 21 to become high-pressure gas refrigerant. Then, the high-pressure gas refrigerant is sent to the outdoor heat exchanger 23 via the four-way valve 22 and exchanges heat with outside air supplied by the outdoor fan 28 to dissipate
10 heat and become high-pressure liquid refrigerant. Then, the high-pressure liquid refrigerant is sent to the indoor unit 40, 50, 60 via the liquid refrigerant communication pipe 71.

 The high-pressure liquid refrigerant sent to the indoor unit 40, 50, 60 is reduced in pressure by the indoor expansion valve 41, 51, 61 until the high-pressure liquid refrigerant becomes approaches the suction pressure of the corresponding compressor 21 to become low-
15 pressure gas-liquid two phase refrigerant. This refrigerant is sent to the indoor heat exchanger 42, 52, 62 and exchanges heat with indoor air in the indoor heat exchanger 42, 52, 62 to evaporate and become low-pressure gas refrigerant.

 The low-pressure gas refrigerant is sent to the outdoor unit 20 via the gas refrigerant communication pipe 72 and flows into the accumulator 24 after passing through the four-way
20 valve 22. Then, the low-pressure gas refrigerant that has entered the accumulator 24 is once again sucked into the compressor 21. In this way, the multi-split air conditioning apparatus 10 can perform a cooling operation in which the outdoor heat exchanger 23 is made to function as a radiator for refrigerant compressed by the compressor 21 and the indoor heat exchanger 42, 52, 62 is made to function as an evaporator for refrigerant which is sent after
25 passing through the liquid refrigerant communication pipe 71 and the indoor expansion valve 41, 51, 61 after being condensed by the outdoor heat exchanger 23. Note that, in the multi-split air conditioning apparatus 10, none of the indoor units 40, 50, 60 have a mechanism for regulating the pressure of refrigerant on the gas side of the indoor heat exchanger 42, 52, 62, and hence the evaporation pressure P_e in all of the indoor heat exchangers 42, 52, 62 is a
30 common pressure.

(3-2) Normal cooling operation and low-capacity cooling operation

 In the normal cooling operation, as illustrated in FIG. 4, substantially all components of the indoor heat exchanger 42 are within a wet region 491 (region indicated by the hatching). In contrast, as illustrated in FIG. 5, in the low-capacity operation, the wet region

491 (region indicated by the hatching) is a region from the lowest heat transfer tube 483 in the lower front heat exchange portion 427 closest to the refrigerant inlet to the fourth heat transfer tube 486 from the bottom of the upper front heat exchange portion 426. However, a region from the fifth heat transfer tube 487 from the bottom of the upper front heat exchange portion 426 to the last heat transfer tube 484 of the rear heat exchange portion 422 is an superheat region 492 (region not hatched). The superheat region 492 is also referred to as a "dry region" herein. Note that, during the normal cooling operation, almost all of the indoor heat exchanger 42 is the wet region 491 in order to achieve high cooling capacity, but a portion close to the outlet of the indoor heat exchanger 42 can be the superheat region (dry region) due to reasons related superheat control.

Gas-liquid two phase refrigerant flows through the wet region 491 and gas refrigerant flows through the superheat region 492. Because of this, heat exchange between refrigerant and air is rarely performed in the superheat region 492 and the temperature of air that has passed through the superheat region 492 is substantially equal to the temperature of air before passing through the superheat region 492.

When the low-capacity cooling operation mode is selected, the operation control device 80 regulates the opening degree of the indoor expansion valve 41 and the flow rate of the indoor fan 43 and low-capacity cooling operation is performed under the state illustrated in FIG. 5. During the low-capacity cooling operation, condensation is more easily generated in the multi-split air conditioning apparatus 10 downstream of the indoor heat exchanger 42 compared to during the normal cooling operation in which condensation water is removed by the indoor heat exchanger 42. Because of this, control for preventing condensation from being generated in the multi-split air conditioning apparatus 10, in particular, the indoor unit 40 during the low-capacity cooling operation is described herein.

(3-3) Control during low-capacity cooling operation

(3-3-1) Overview of control during low-capacity cooling operation

The plurality of arrows illustrated in FIG. 5 schematically indicate sucked-in air Ar6, mixed air Ar7, air passing through a wet region Ar8 and air passing through superheat region Ar9. During the low-capacity cooling operation, the operation control device 80 performs control of increasing the opening degree of the indoor expansion valve 41 and narrowing the superheat region 492 and expanding the wet region 491 when the indoor temperature Tr1 is higher than the set temperature Ts1. Here, the value of the indoor temperature Tr1 is the value of an intake temperature Ti of the sucked-in air Ar6. This value is measured by the indoor temperature sensor 451 and sent to the operation control device 80.

By making the wet region 491 which has higher heat exchange capacity than the superheat region 492 larger, the temperature of the mixed air Ar7 lowers, and hence the indoor temperature Tr1 can be made to approximate the set temperature Ts1 by operating the indoor unit 40 after increasing the opening degree of the indoor expansion valve 41.

5 However, if the wet region 491 is made too large during the low-capacity cooling operation, the indoor fan 43 enters a state in which condensation is generated in the fan rotor 43a.

Here, the state in which condensation is generated in the fan rotor 43a when the wet region 491 is made too large is described with reference to the air calculation graph illustrated in FIG. 6. In FIG. 6, RH100, RH90, RH80 and RH70 are all curved lines which represent

10 relative humidity at 100%, 90%, 80% and 70%, respectively. When the intake temperature of the sucked-in air Ar6 is 27°C and the relative humidity is approximately 85%, the point P1 in FIG. 6 corresponds to the state of the sucked-in air Ar6. When the evaporation temperature of the indoor heat exchanger 42 is 7°C, a point P2 at which a dry-bulb temperature of 7°C and the curved line RH100 (saturation line) intersect is taken. An

15 intersection between a straight line LN20 which connects the points P1 and P2 and the curved line RH100 is a point P3. Condensation is not generated if the state of the mixed air Ar7 is within a range D1 from the point P1 to the point P3. On the other hand, condensation is not generated if the state of the mixed air Ar7 is within a range D2 from the point P2 to the point P3. The size of the wet region 491 at the point P3 becomes the upper limit at which

20 condensation is not generated. The size of the wet region 491 is determined by a method to be described later in order to control the size of the wet region 491 such that the upper limit is not exceeded. Then, the opening degree of the indoor expansion valve 41 and the flow rate of the indoor fan 43 are regulated such that the size of the wet region 491 when the determined size (occupancy ratio of wet region 491) of the wet region 491 is at the point P3.

25 If the occupancy ratio of the wet region 491 during the low-capacity cooling operation approaches the occupancy ratio of the wet region 491 at the point P3, control is performed to increase cooling capacity by increasing flow rate of the indoor fan 43 without increasing the opening degree of the indoor expansion valve 41.

Herein, avoidance control for fan rotor condensation in which the size of the wet region 491 is determined by measuring temperature and humidity of the mixed air Ar7 is

30 described in (3-4), and avoidance control for fan rotor condensation in which the size of the wet region 491 is determined using detection results output by two or more indoor heat exchanger temperature sensors 455 is described in (3-5).

Note that, when the indoor temperature Tr1 is lower than the set temperature Ts1

during the low-capacity cooling operation, the opening degree of the indoor expansion valve 41 is reduced and/or the flow rate of the indoor fan 43 is reduced to lower cooling capacity. Control corresponding to when the indoor temperature T_{r1} is lower than the set temperature T_{s1} makes it even harder for fan rotor condensation to be generated, and hence determination of the size of the wet region 491 can be omitted.

(3-4) Avoidance control during low-capacity cooling operation

(3-4-1) Outline of avoidance control for fan rotor condensation

The plurality of arrows illustrated in FIG. 5 each schematically represent the sucked-in air Ar6, the mixed air Ar7, the air passing through the wet region Ar8 and the air passing through superheat region Ar9. During the low-capacity cooling operation, the operation control device 80 determines the size of the wet region 491 using the temperature of the mixed air Ar7 and performs control of preventing a state in which fan rotor condensation is generated downstream of the indoor heat exchanger 42 due to the temperature of the mixed air Ar7 exceeding a dew point temperature of the mixed air Ar7. More specifically, the operation control device 80 determines the size of the wet region 491 using the intake temperature and intake humidity (relative humidity) of the sucked-in air Ar6 and the temperature and evaporation temperature of the mixed air Ar7 to perform control on the basis of the determination results on the size of the wet region 491. The size of the wet region 491 (area of the wet region 491) is quantified by, for example, the formula (area of wet region 491)÷((area of wet region 491)+(area of superheat region 492))×100(=occupancy ratio of wet region 491). In other words, the size of the wet region 491 can be determined by calculating the occupancy ratio of the wet region 491. Control by the operation control device for preventing the state in which fan rotor condensation is generated downstream of the indoor heat exchanger 42 by calculating the occupancy ratio of the wet region 491 is described later.

(3-4-2) Calculation in avoidance control for fan rotor condensation

In the following description, intake temperature of the sucked-in air Ar6 is represented as $T_i^{\circ}\text{C}$ and intake humidity of the sucked-in air Ar6 is represented as $H_i\%\text{RH}$. Temperature of the mixed air Ar7 is represented as $T_m^{\circ}\text{C}$ and absolute humidity of the mixed air Ar7 is represented by $X_m \text{ kg/kgDA}$. Air temperature of the air passing through the wet region Ar8 is represented as $T_w^{\circ}\text{C}$ and absolute humidity of the air passing through the wet region Ar8 is represented as $X_w \text{ mkg/kgDA}$. Air temperature of the air passing through the superheat region Ar9 is represented as $T_d^{\circ}\text{C}$ and absolute humidity of the air passing through the superheat region Ar9 is represented as $X_d \text{ mkg/kgDA}$. However, T_i can be used to express using T_i assuming that the air temperature $T_d^{\circ}\text{C}$ of the air passing through superheat

region Ar9 is equal to the intake temperature $T_i^{\circ}\text{C}$. There is almost no change in accuracy if substituting values in this way, and a temperature sensor for measuring the air temperature $T_d^{\circ}\text{C}$ of the air passing through superheat region Ar9 may be omitted by substituting values.

The operation control device 80 stores information on a bypass factor BF of the indoor heat exchanger 42 in, for example, an internal memory. The bypass factor BF is a value determined by experiment or simulation in advance and is input to the operation control device 80. The operation control device 80 is configured to read out and acquire the necessary bypass factor BF from the internal memory or another component when performing the avoidance control for fan rotor condensation during the low-capacity cooling operation.

As described above, the intake temperature T_i of the sucked-in air Ar6 is detected using the indoor temperature sensor 451. The operation control device 80 acquires the value of the intake temperature T_i detected by the indoor temperature sensor 451 from the indoor temperature sensor 451.

The evaporation temperature $T_e^{\circ}\text{C}$ of the indoor heat exchanger 42 is detected using the liquid-side temperature sensor 44. The operation control device 80 acquires the value of the evaporation temperature T_e detected by the liquid-side temperature sensor 44 from the liquid-side temperature sensor 44.

The temperature $T_m^{\circ}\text{C}$ of the mixed air Ar7 is detected by the discharge temperature sensor 453. The operation control device 80 acquires the value of the temperature T_m of the mixed air Ar7 detected by the discharge temperature sensor 453 from the liquid-side temperature sensor 44.

The operation control device 80 calculates the value of the air temperature T_w which has passed through the wet region 491 using the following Equation (1). The operation control device 80 can acquire the value of the air temperature T_w which has passed through the wet region 491 through calculation of Equation (1).

$$T_w = (T_i - T_e) \times BF + T_e \quad (1)$$

The operation control device 80 calculates the value of the occupancy ratio $R_w\%$ of the wet region 491 using the following Equation (2). The operation control device 80 can acquire the value of the occupancy ratio R_w of the wet region 491 through calculation of Equation (2).

$$R_w = (T_m - T_i) / (T_w - T_i) \quad (2)$$

The operation control device 80 uses the occupancy ratio R_w of the wet region 491 to perform control such that fan rotor condensation is not generated downstream of the indoor

heat exchanger 42 through preventing the temperature T_m of the mixed air Ar7 from falling below the dew point temperature T_p of the mixed air Ar7 using results determined by calculation to be described later. In other words, during the low-capacity cooling operation, the operation control device 80 determines the size of the wet region 491 using the temperature T_m of the mixed air Ar7 and performs control such that fan rotor condensation is not generated downstream of the indoor heat exchanger 42 through preventing the temperature T_m of the mixed air Ar7 from exceeding the dew point temperature T_p of the mixed air Ar7.

Next, a method is described in which the occupancy ratio R_w of the wet region 491 is used to determine the relationship between the temperature T_m of the mixed air Ar7 and the dew point temperature T_p of the mixed air Ar7.

Intake humidity H_i of the sucked-in air Ar6 is detected using the indoor humidity sensor 452. The operation control device 80 acquires the value of the intake humidity H_i detected by the indoor humidity sensor 452 from the indoor humidity sensor 452.

Using dry-bulb temperature and relative humidity as parameters, the operation control device 80 uses the following Equation (3) to calculate the value of absolute humidity X_d of air which has passed through the superheat region 492 when a function for determining absolute humidity is expressed as f_x . The operation control device 80 can acquire the value of the absolute humidity X_d through calculation of Equation (3). The function f_x is, for example, a function in which an air calculation graph is approximated using a calculation formula.

$$X_d = f_x(T_i, H_i) \quad (3)$$

The operation control device 80 calculates the value of absolute humidity X_w of the air that has passed through the wet region 491 using the following Equation (4). The operation control device 80 can acquire the value of the occupancy ratio R_w of the wet region 491 through calculation of Equation (4).

$$X_w = (X_d - f_x(T_e, 100)) \times BF + f_x(T_e, 100) \quad (4)$$

The operation control device 80 calculates the value of absolute humidity X_m of the mixed air Ar7 using the following Equation (5). The operation control device 80 can acquire the value of the absolute humidity X_m of the mixed air Ar7 through calculation of Equation (5).

$$X_m = R_w \times X_w + (1 - R_w) \times X_d \quad (5)$$

Using dry-bulb temperature and relative humidity as parameters, the operation control device 80 uses the following Equation (6) to calculate the value of the dew point

temperature T_p of the mixed air Ar7 when a function for determining dew point temperature is expressed as f_p . The function f_p is, for example, a function in which an air calculation graph is approximated using a calculation formula. The operation control device 80 can acquire the value of the dew point temperature T_p of the mixed air Ar7 through calculation of
5 Equation (6).

$$T_p = f_p(T_m, X_m) \quad (6)$$

The operation control device 80 performs control such that fan rotor condensation is not generated downstream of the indoor heat exchanger 42 by preventing the temperature T_m of the mixed air Ar7 from falling below the dew point temperature T_p of the mixed air Ar7
10 determined using Equation (6).

(3-4-3) Device control for avoiding fan rotor condensation during low-capacity cooling operation

Device control for avoiding fan rotor condensation during the low-capacity cooling operation is performed using calculation results calculated on the basis of the size of the wet region (occupancy ratio of wet region) determined using the above-mentioned Equations (1) to (6). For example, the operation control device 80 controls the indoor expansion valve 41 and/or the indoor fan 43 by comparing the temperature T_m of the mixed air Ar7 (temperature detected by discharge temperature sensor 453) and the dew point temperature T_p of the mixed air Ar7 determined using the above-mentioned Equations (1) to (6).
15

FIG. 7 illustrates a limit line for fan rotor condensation in terms of mixed air temperature determined from the evaporation temperature and the intake temperature. The graph shown in FIG. 7 is a graph showing the relationships determined using the above-mentioned Equations (1) to (6) in graph form. Limit lines LN1, LN2, LN3 and LN4 are limit lines when the intake humidity H_i is 85%RH, 80%RH, 70%RH and 60%RH,
20 respectively. Condensation is not generated when the temperature T_m of the mixed air Ar7 is higher than the limit lines LN1 to LN4. Conversely, condensation is generated when the temperature T_m of the mixed air Ar7 is lower than the limit lines.

As evident from FIG. 7, fan rotor condensation can be avoided by increasing the temperature T_m of the mixed air Ar7 higher than approximately 17°C when, for example, the evaporation temperature T_e is approximately 7°C and the intake humidity H_i is 80%RH. In other words, the limit lines LN1 to LN4 represent the dew point temperature T_p of the mixed air Ar7 under different conditions.
25

In the operation control device 80, the indoor unit 40 is operated at the operation point OP1 in FIG. 7 and under the condition that the evaporation temperature T_e is

approximately 7°C, the intake humidity H_i is 80%RH and the dew point temperature T_p of the mixed air Ar7 is approximately 17°C. In this case, there is no risk that fan rotor condensation will be generated. In this case, control can be performed in which operation is continued without change if the temperature T_m of the mixed air Ar7 at the operation point OP1 of the indoor unit 40 is higher than 17°C. However, in order to effectively avoid fan rotor condensation, there is also considered changing the operating condition to an operation point at which fan rotor condensation is even less likely to be generated even when the temperature T_m of mixed air at the operation point OP2 of the indoor unit 40 is higher than 17°C so that the temperature T_m of mixed air does not fall below the dew point temperature T_p due to a sudden change in environment or set conditions.

In addition, the operation control device 80 may be configured to, for example, when a difference between the temperature T_m of the mixed air Ar7 and the limit line LN2 (dew point temperature T_p) falls below a first threshold in a case where the evaporation temperature T_e and the intake humidity H_i have not changed from approximately 7°C and 80%RH, respectively, under the above-mentioned condition, determine that $(T_m - T_p) < 7^\circ\text{C}$ when the temperature T_m of the mixed air Ar7 at the operation point OP1 is 23°C if the value of the first threshold is 7°C and perform control of decreasing the opening degree of the indoor expansion valve 41, which is a pressure reducing mechanism, and increasing the flow rate of the indoor fan 43. When the operation control device 80 performs control of decreasing the opening degree of the indoor expansion valve 41, less refrigerant circulates and the superheat region 492 in the indoor heat exchanger 42 increases. Because of this, the temperature T_m of mixed air can be reduced from decreasing and the generation of fan rotor condensation can be reduced. A reduction in cooling capacity due to less refrigerant circulating can be compensated by increasing the flow rate of the indoor fan 43.

The operation control device 80 may be configured to, for example, when a difference between the temperature T_m of the mixed air Ar7 and the limit line LN2 (dew point temperature T_p) falls below a second threshold in a case where the evaporation temperature T_e and the intake humidity H_i have not changed from approximately 7°C and 80%RH, respectively, under the above-mentioned condition, perform control of increasing the flow rate of the indoor fan 43. For example, if the value of the second threshold is 8°C, the operation control device 80 determines that $(T_m - T_p) < 8^\circ\text{C}$ when the temperature T_m of the mixed air Ar7 of the operation point OP1 is 24°C and performs control of increasing the flow rate of the indoor fan 43. When the operation control device 80 performs control of increasing the flow rate of the indoor fan 43, the increase in flow rate and cooling capacity

causes the direction of the indoor fan 43 to change to a direction in which the superheat region 492 of the indoor heat exchanger 42 increases, and hence the temperature T_m of mixed air can be reduced from decreasing and the generation of fan rotor condensation can be reduced.

5 In addition, the operation control device 80 may be configured to, for example, when a difference between the temperature T_m of the mixed air Ar7 and the limit line LN2 (dew point temperature T_p) falls below a third threshold in a case where the evaporation temperature T_e and the intake humidity H_i have not changed from approximately 7°C and 80%RH, respectively, under the above-mentioned condition, perform control of switching
10 from the low-capacity cooling operation mode to the normal cooling operation mode. For example, if the value of the third threshold is 0.5°C, the operation control device 80 determines that $(T_m - T_p) < 0.5^\circ\text{C}$ when the temperature T_m of the mixed air Ar7 at the operation point OP1 is 17°C and performs control of switching from the low-capacity cooling operation mode to the normal cooling operation mode. When the operation control device
15 80 performs control of switching from the low-capacity cooling operation mode to the normal cooling operation mode, the state changes from the state illustrated in FIG. 5 to the state illustrated in FIG. 4 and substantially all of the indoor heat exchanger 42 can be made the wet region 491. Because of this, air passing through the superheat region 492 of the indoor heat exchanger 42 can be eliminated, and hence rotor condensation can be reduced while ensuring
20 necessary cooling capacity.

(3-4-4)

The graph shown in FIG. 8 expresses the relationships determined using the above-mentioned Equations (1) to (6) in the form of a graph. The limit lines LN11, LN12, LN13 and LN14 are limit lines when the intake humidity H_i is 85%RH, 80%RH, 70%RH and
25 60%RH, respectively. Condensation is not generated when the occupancy ratio R_w of the wet region 491 is smaller than the limit lines LN11 to LN14. Conversely, condensation is generated when the occupancy ratio R_w of the wet region 491 is larger than the limit lines LN11 to LN14.

As evident from FIG. 8, fan rotor condensation can be avoided by decreasing the
30 occupancy ratio R_w of the wet region 491 lower than approximately 50% when, for example, the evaporation temperature T_e is approximately 7°C and the intake humidity H_i is 80%RH.

In the operation control device 80, the indoor unit 40 is operated at the operation point OP2 in FIG. 8 and under the condition that the evaporation temperature T_e is approximately 7°C, the intake humidity H_i is 80%RH and a limit occupancy ratio R_{mw} of

the wet region 491 is approximately 50°C. In this case, there is no risk that fan rotor condensation will be generated. In this case, control can be performed in which operation of the indoor unit 40 is continued without change if the occupancy ratio R_w of the wet region 491 at the operation point OP2 of the indoor unit 40 is smaller than 50%. However, in order to effectively avoid fan rotor condensation, there is also considered changing the operating condition to an operation point at which fan rotor condensation is even less likely to be generated, even when the occupancy ratio R_w of the indoor unit 40 at the operation point OP2 is smaller than 50%.

The operation control device 80 may be configured to, for example, when a difference between the occupancy ratio R_w of the wet region 491 and the limit line LN12 falls below a fourth threshold in a case where the evaporation temperature T_e and the intake humidity H_i have not changed from approximately 7°C and 80%RH, respectively, under the above-mentioned condition, perform control of decreasing the opening degree of the indoor expansion valve 41, which is a pressure reducing mechanism, and increasing the flow rate of the indoor fan 43. For example, if the value of the fourth threshold is 15%, the operation control device 80 determines that $(R_{mw} - R_w) < 15$ when the occupancy ratio R_w of the wet region 491 at the operation point OP2 is 40% and performs control of reducing the opening degree of the indoor expansion valve 41 and increasing the flow rate of the indoor fan 43. A reduction in cooling capacity due to less refrigerant circulating can be compensated by increasing the flow rate of the indoor fan 43.

In addition, the operation control device 80 may be configured to, for example, when a difference between the occupancy ratio R_w of the wet region 491 and the limit line LN12 falls below a fifth threshold in a case where the evaporation temperature T_e and the intake humidity H_i have not changed from approximately 7°C and 80%RH, respectively, under the above-mentioned condition, perform control of increasing the flow rate of the indoor fan 43. For example, if the value of the fifth threshold is 25%, the operation control device 80 determines that $(R_{mw} - R_w) < 25\%$ when the occupancy ratio of the wet region 491 at the operation point OP2 is 30% and performs control of increasing the flow rate of the indoor fan 43.

The operation control device 80 can also be configured to, for example, when a difference between the occupancy ratio R_w of the wet region 491 and the limit line LN12 falls below a sixth threshold in a case where the evaporation temperature T_e and the intake humidity H_i have not changed from approximately 7°C and 80%RH, respectively, under the above-mentioned condition, perform control of switching from the low-capacity cooling

operation mode to the normal cooling operation mode. For example, if the value of the sixth threshold is 1%, the operation control device 80 determines that $(R_{mw}-R_w) < 1\%$ when the occupancy ratio of the wet region 491 at the operation point OP2 is 50% and performs control of switching from the low-capacity cooling operation mode to the normal cooling operation mode.

(3-4-5)

There has been described above a case where, with the above-described control, in the low-capacity cooling operation in which the superheat region 492 of the indoor heat exchanger 42 is increased more than in the normal cooling operation, the operation control device 80 performs the avoidance control for fan rotor condensation as described with reference to, for example, FIG. 7 is performed using the intake temperature T_i , the intake humidity H_i , the temperature T_m of the mixed air Ar7 and the evaporation temperature T_e and performs control such that fan rotor condensation is not generated downstream of the indoor heat exchanger 42 due to the temperature T_m of the mixed air Ar7 exceeding the dew point temperature T_p . However, the operation control device 80 may perform the avoidance control for fan rotor condensation using the intake temperature T_i , the intake humidity H_i , the humidity of the mixed air Ar7 and the evaporation temperature T_e instead of the intake temperature T_i , the intake humidity H_i , the temperature T_m of the mixed air Ar7 and the evaporation temperature T_e and perform control such that fan rotor condensation is not generated downstream of the indoor heat exchanger 42 due to humidity of the mixed air Ar7 exceeding a saturation humidity of mixed air. As illustrated in FIG. 2, for example, the discharge humidity sensor 454 may be provided in the discharge space S3 to this end.

(3-5) Avoidance control for fan rotor condensation during low-capacity cooling operation

(3-5-1) Outline of avoidance control for fan rotor condensation

During the low-capacity cooling operation, the operation control device 80 uses detection results output from two or more of the indoor heat exchanger temperature sensors 455 to determine the size of the wet region 491 and performs control of preventing a state where fan rotor condensation is generated downstream of the indoor heat exchanger 42 due to the temperature of the mixed air Ar7 illustrated in FIG. 5 exceeding the dew point temperature of the mixed air Ar7. More specifically, the operation control device 80 uses the intake temperature and intake humidity (relative humidity) of the sucked-in air Ar6, evaporation temperature, and detection results output from two or more of the indoor heat exchanger temperature sensors 455 to determine the size of the wet region 491 and perform control on the basis of the result of determining the size of the wet region 491.

(3-5-2) Calculation in operation control device 80

The operation control device 80 inputs the temperatures of U-shaped pipes 485 output from a plurality of indoor heat exchanger temperature sensors 455 attached to the U-shaped pipes 485. The temperatures of the U-shaped pipes 485 are the temperatures of refrigerant that flows through the U-shaped pipes 485. The temperature of the heat transfer tube 482 in the wet region 491 is substantially the evaporation temperature T_e , which is temperature of a liquid-gas two phase refrigerant. In contrast, the temperature of the heat transfer tube 482 in the superheat region 492 is higher than the evaporation temperature T_e . For example, if it is assumed that there are 10 heat transfer tubes 482 and 11 indoor heat exchanger temperature sensors 455, an indoor heat exchanger temperature sensor 455 can be disposed at the front and back of each heat transfer tube 482. For example, if there is a difference equal to or greater than a predetermined threshold between the temperatures detected by two indoor heat exchanger temperature sensors 455 at the front and back of any heat transfer tube 482, the operation control device 80 can be configured to determine that the region until those heat transfer tubes 482 is the wet region 491. For example, the operation control device 80 determines that the occupancy ratio R_w of the wet region 491 is 100% if the indoor heat exchanger temperature sensor 455 on a side near the outlet of the tenth heat transfer tube 482 near the outlet of the indoor heat exchanger 42 detects the evaporation temperature T_e . For example, if there is a difference equal to or greater than a predetermined threshold between temperatures detected by two indoor heat exchanger temperature sensors 455 on each end of the sixth heat transfer tube 482, the operation control device 80 determines that the region until the sixth heat transfer tube 482 is the superheat region 492 and can acquire a value indicating that the occupancy ratio R_w of the wet region 491 is 50%.

Note that the indoor heat exchanger temperature sensors 455 may be disposed evenly or disposed concentrated in one area. For example, because the indoor heat exchanger 42 in FIG. 2 includes eight heat transfer tubes 482 in the upper front heat exchange portion 426, the indoor heat exchanger temperature sensors 455 can be disposed at the front and back of the eight heat transfer tubes 482 of the upper front heat exchange portion 426. If the indoor heat exchanger temperature sensors 455 are disposed in this way, it is possible to determine that the occupancy ratio R_w is approximately 50% in detail with a small number of sensors.

The operation control device 80 is configured to acquire the values of the temperature T_w of air that passes through the wet region 491, the absolute humidity

Xwkg/kgDA of the air that passes through the wet region 491 and the absolute humidity Xdkg/kgDA of the air that passes through the superheat region 492. For example, the operation control device 80 can calculate using the following Equations (14), (15) and (16) to acquire the temperature Tw of air that passes through the wet region 491, the absolute humidity Xw of the air that passes through the wet region 491 and the absolute humidity Xd of the air that passes through the superheat region 492.

The operation control device 80 uses the occupancy ratio Rw of the wet region 491 acquired from detection results output from the indoor heat exchanger temperature sensor 455, the acquired temperature Tm of the mixed air Ar7, the absolute humidity Xw of the air that passes through the wet region 491 and the absolute humidity Xd of the air that passes through the superheat region 492 to determine the temperature Tm of the mixed air Ar7 using the following Equation (11).

$$T_m = R_w \times T_w + (1 - R_w) \times T_i \quad (11)$$

The operation control device 80 determines the absolute humidity Xm of the mixed air Ar7 using the following Equation (12).

$$X_m = R_w \times X_w + (1 - R_w) \times X_d \quad (12)$$

Then, the operation control device 80 uses the values of the temperature Tm and the absolute humidity Xm of the mixed air Ar7 determined using Equations (11) and (12) to determine the dew point temperature Tp of the mixed air using the following Equation (13).

Here, fp is a function for determining dew point temperature with dry-bulb temperature and absolute humidity as parameters. The function fp is a function where, for example, a psychrometric chart is approximated using a calculation formula.

$$T_p = fp(T_m, X_m) \quad (13)$$

The operation control device 80 performs control such that fan rotor condensation is not generated downstream of the indoor heat exchanger 42 by using the results of Equation (13) to ensure that the temperature Tm of the mixed air Ar7 does not fall below the dew point temperature Tp of the mixed air Ar.

Next, one aspect is described in which the operation control device 80 acquires the values of the temperature Tm of the mixed air Ar7, the absolute humidity Xw of the air that passes through the wet region 491 and the absolute humidity Xd of the air that passes through the superheat region 492. As described above, the operation control device 80 is configured to read out and acquire the necessary bypass factor BF from, for example, an internal memory, acquire the value of the intake temperature Ti detected by the indoor temperature sensor 451 from the indoor temperature sensor 451, acquire the value of the intake humidity

Hi detected by the indoor humidity sensor 452 from the indoor humidity sensor 452 and acquire the value of the evaporation temperature Te detected by the liquid-side temperature sensor 44 from the liquid-side temperature sensor 44.

5 The operation control device 80 determines the temperature Tw of the air that passes through the wet region 491 using the following Equation (14).

$$Tw = (Ti - Te) \times BF + Te \quad (14)$$

In addition, the operation control device 80 acquires the absolute humidity Xd of the air that passes through the superheat region 492 using the following Equation (15). Here, fx is a function for determining absolute humidity with dry-bulb temperature and absolute
10 humidity as parameters.

$$Xd = fx(Ti, Hi) \quad (15)$$

The operation control device 80 uses the absolute humidity Xd of the air that passes through the superheat region 492 determined using the Equation (15) to determine the absolute humidity Xw of the air that passes through the wet region using the following
15 Equation (16).

$$Xw = (Xd - fx(Te, 100)) \times BF + fx(Te, 100) \quad (16)$$

The operation control device 80 can acquire the temperature Tm of the mixed air Ar7 and the values of the absolute humidity Xw of the air that passes through the wet region 491 and the absolute humidity Xd of the air that passes through the superheat region 492 by
20 calculating the above Equations (14), (15) and (16).

(3-5-3) Device control for avoiding fan rotor condensation during low-capacity cooling operation

FIG. 7 illustrates limit lines for fan rotor condensation for temperature of mixed air determined from the evaporation temperature and the intake temperature and the intake
25 humidity. The graph shown in FIG. 7 expresses the relationships determined using the Equations (11) to (16) in the form of a graph. Because the graph in FIG. 7 also expresses the relationships determined using the Equations (1) to (6), device control can be performed for avoiding fan rotor condensation during the low-capacity cooling operation using the relationships determined with the Equations (1) to (6), similar to that described in the section
30 "(3-4-3) Device control for avoiding fan rotor condensation during low-capacity cooling operation" which uses the relationships determined using the Equations (11) to (16).

(3-5-4)

The graph shown in FIG. 8 expresses the relationships determined using the Equations (11) to (16) in the form of a graph. Because the graph in FIG. 8 also expresses

the relationships determined using the Equations (1) to (6), device control can be performed for avoiding fan rotor condensation during the low-capacity cooling operation using the relationships determined with the Equations (11) to (16), similar to that described in the section "(3-4-4) Device control for avoiding fan rotor condensation during low-capacity cooling operation" which uses the relationships determined using the Equations (11) to (16).

(4) Features

(4-1)

As described above, in the multi-split air conditioning apparatus 10, although cooling capacity increases by increasing the wet region 491 of the indoor heat exchanger 42 by increasing the opening degree of the indoor expansion valve 41 (example of pressure reducing mechanism), the temperature of mixed air which is a mix of the air that passes through the superheat region 492 of the indoor heat exchanger 42 and the air that passes through the wet region 491 decreases when the wet region 491 expands. Because of this, in order that condensation in the fan rotor 43a is not generated due to the temperature T_m of the mixed air $Ar7$ falling too far below the dew point temperature T_p of the mixed air $Ar7$, necessary cooling capacity can be guaranteed by controlling the opening degree of the indoor expansion valve 41 such that the opening degree does not exceed an upper limit at which condensation occurs in the fan rotor 43a, so as to reduce an increase in size of the wet region 491. Further improvement of cooling capacity can be ensured by increasing the flow rate of the indoor fan 43 and necessary cooling capacity can be guaranteed. As a result, when the multi-split air conditioning apparatus 10 performs the low-capacity cooling operation, condensation in the fan rotor 43a of the indoor fan 43 can be avoided while ensuring necessary cooling capacity.

(4-2)

When the indoor temperature $Tr1$ is lower than the set temperature $Ts1$ during the low-capacity cooling operation while cooling, cooling capacity is decreased by decreasing the opening degree of the indoor expansion valve 41 and/or decreasing the flow rate of the indoor fan 43. Cooling capacity can be reduced while maintaining the state in which condensation in the fan rotor 43a is not generated because the wet region 491 can be narrowed and/or flow rate can be reduced from the state in which expansion of the wet region 491 is restricted to the upper limit at which condensation in the fan rotor 43a in the indoor fan 43 is not generated. At this time, an increase in load on the operation control device 80 can be reduced because the operation control device 80 does not perform avoidance control for fan rotor condensation.

(4-3)

If the indoor unit 40 is provided with the discharge temperature sensor 453 or the discharge humidity sensor 454 configured to measure the temperature T_m of the mixed air Ar7 or the humidity of the mixed air Ar7, the occupancy ratio R_w of the wet region 491 can be determined using the temperature T_m of the mixed air Ar7 or the humidity of the mixed air Ar7. As a result, the temperature T_m of the mixed air Ar7 or the humidity of the mixed air Ar7 can be used to easily determine whether or not expansion of the wet region 491 has been restricted to the upper limit at which condensation in the fan rotor 43a is not generated and condensation in the fan rotor 43a is more reliably avoided.

(4-4)

If the indoor heat exchanger 42 is provided with two or more indoor heat exchanger temperature sensors 455, the results of detection by the indoor heat exchanger temperature sensors 455 can be used to determine the occupancy ratio R_w of the wet region 491. As a result, the detection results of two or more indoor heat exchanger temperature sensors 455 can be used to easily determine whether or not expansion of the wet region 491 has been restricted until the upper limit at which condensation is not generated in the fan rotor 43a, and the condensation in the fan rotor 43a can be more reliably reduced.

(4-5)

In order to achieve the necessary cooling capacity, the operation control device 80 switches from the low-capacity cooling operation mode to the normal cooling operation mode when expansion of the wet region cannot be restricted to the upper limit at which condensation is not generated in the fan rotor 43a even when the flow rate of the indoor fan 43 is increased. Thereby, substantially entire the indoor heat exchanger 42 can be made a wet region. As a result, the air that passes through the superheat region 492 of the indoor heat exchanger 42 can be eliminated and condensation in the fan rotor 43a can be reduced while ensuring the necessary cooling capability.

(4-6)

Note that, as seen from one viewpoint, the multi-split air conditioning apparatus 10 may include an outdoor unit (20) including a compressor (21) configured to compress refrigerant which circulates for executing a refrigeration cycle; and a plurality of indoor units (40, 50, 60) including a plurality of indoor heat exchangers (42, 52, 62) through which refrigerant discharged from the compressor circulates, a plurality of pressure reducing mechanisms (41, 51, 61, 41a, 51a, 61a) and a plurality of indoor fans (43, 53, 63) through which passes air that passes through the plurality of indoor heat exchangers, wherein at least

one indoor unit among the plurality of indoor units is configured to, when an indoor temperature is higher than a set temperature during the low-capacity cooling operation which increases the superheat region more than during the normal cooling operation, increase an opening degree of the pressure reducing mechanism, to thereby narrow the superheat region so as to expand a wet region of the indoor heat exchanger and increase flow rate of the indoor fan. The multi-split air conditioning apparatus 10 is configured to reduce expansion of the wet region until the upper limit at which condensation in the multi-split air conditioning apparatus has not been generated at the downstream of the indoor heat exchanger.

(5) Modification examples

10 (5-1) Modification example 1A

In the above-described embodiment, the avoidance control for fan rotor condensation for the indoor unit 40 is described, but the operation control device 80 can be made to perform the avoidance control for fan rotor condensation in the same manner as the indoor unit 40 for the indoor units 50, 60 as well. In this case, each indoor expansion valve 15 51, 61 functions as a pressure reducing mechanism for each indoor unit 50, 60. In addition, the indoor fan 53, 63 includes a fan rotor similar to the fan rotor 43a of the indoor fan 43 through which mixed air passes.

(5-2) Modification example 1B

In the above-described embodiment, the indoor unit 40 is provided with the discharge temperature sensor 453, the discharge humidity sensor 454 and two or more indoor heat exchanger temperature sensors 455, but the operation control device 80 can determine the size of the wet region when provided with any of the sensors. Therefore, it suffices that any of the discharge temperature sensor 453, the discharge humidity sensor 454 and the two or more indoor heat exchanger temperature sensors 455 is provided.

25 (5-3) Modification example 1C

In the above-described embodiment, the multi-split air conditioning apparatus 10 is described such that each indoor unit 40, 50, 60 is provided with the indoor expansion valve 41, 51, 61, the liquid-side temperature sensor 44, 54, 64 and the gas-side temperature sensor 45, 55, 65, respectively. However, as illustrated in FIGS. 9 and 10, these components may be provided in the outdoor unit 20. The outdoor unit 20 is provided with the expansion valves 41a, 51a, 61a, which each function as pressure reducing mechanisms for reducing pressure of refrigerant that flows through each of the indoor heat exchangers 42, 52, 62.

(5-3-1) Outdoor unit 20

The outdoor unit 20 illustrated in FIGS. 9 and 10 differs from the outdoor unit 20

illustrated in FIG. 1 in that, as described above, the outdoor unit 20 includes the expansion valves 41a, 51a, 61a, the liquid-side temperature sensors 44, 54, 64 and the gas-side temperature sensors 45, 55, 65. In terms of connection between the compressor 21, the four-way valve 22, the outdoor heat exchanger 23 and the accumulator 24, the outdoor unit 20 illustrated in FIGS. 9 and 10 is the same as the outdoor unit 20 illustrated in FIG. 1.

In the outdoor unit 20 illustrated in FIGS. 9 and 10, a liquid side of the outdoor heat exchanger 23 is connected to one end of a liquid pipe 271 inside the outdoor unit 20. The other end of the liquid pipe 271 is divided into three sections and each end of each section is connected to one end of each expansion valves 41a, 51a, 61a, respectively. The other ends of the expansion valves 41a, 51a, 61a are connected to three liquid-side connection ports 222 in the outdoor unit 20, respectively. Liquid-side temperature sensors 44, 54, 64 are attached between the other ends of the expansion valves 41a, 51a, 61a and the three liquid-side connection ports 222. The three liquid-side connection ports 222 are connected to liquid sides of the indoor heat exchangers 42, 52, 62 of the indoor units 40, 50, 60.

The outdoor unit 20 illustrated in FIGS. 9 and 10 includes three gas-side connection ports 221 connected to gas-sides of the indoor heat exchangers 42, 52, 62 of the indoor units 40, 50, 60, respectively. A gas pipe 272 has one end and three other ends. The three gas-side connection ports 221 are connected to the three other ends of a gas pipe 272 which have been divided into three, respectively. Refrigerant that flows through the three other ends flows through the one end of the gas pipe 272. The one end of the gas pipe 272 is connected to the four-way valve 22. The one end of the gas pipe 272 is connected to the accumulator 24 during the cooling operation and connected to a discharge side of the compressor 21 during the heating operation. In order to detect the temperature of refrigerant that flows through the three other ends of the gas pipe 272, gas-side temperature sensors 45, 55, 65 are respectively provided at the three other ends.

(5-3-2) Indoor unit 40, 50, 60

The indoor units 40, 50, 60 illustrated in FIG. 9 have the same configuration as the indoor unit 40, 50, 60 illustrated in FIG. 1 except for the expansion valves 41a, 51a, 61a, the liquid-side temperature sensors 44, 54, 64 and the gas-side temperature sensors 45, 55, 65. Therefore, a description of the configuration of the indoor units 40, 50, 60 illustrated in FIG. 9 is omitted.

(5-3-3) Operation of multi-split air conditioning apparatus 10

In the outdoor unit 20 illustrated in FIGS. 9 and 10, the opening degrees of the expansion valves 41a, 51a, 61a are controlled by the outdoor-side control apparatus 37. In

addition, the temperature values detected by the liquid-side temperature sensors 44, 54, 64 and the gas-side temperature sensors 45, 55, 65 are acquired by the outdoor-side control apparatus 37.

In the multi-split air conditioning apparatus 10 illustrated in FIG. 1, the operation control device 80 acquires the temperature values detected by the liquid-side temperature sensor 44, 54, 64 and the gas-side temperature sensor 45, 55, 65 via the indoor-side control apparatus 47, 57, 67 and controls the expansion valve 41a, 51a, 61a via the indoor-side control apparatus 47, 57, 67. However, in the multi-split air conditioning apparatus 10 illustrated in FIG. 9, the operation control device 80 acquires the temperature values detected by the liquid-side temperature sensors 44, 54, 64 and the gas-side temperature sensors 45, 55, 65 via the outdoor-side control apparatus 37 and controls the expansion valves 41a, 51a, 61a via the outdoor-side control apparatus 37. However, the operation control device 80 acquiring the temperature values detected by the liquid-side temperature sensors 44, 54, 64 and the gas-side temperature sensors 45, 55, 65 and controlling the expansion valves 41a, 51a, 61a is the same for both the multi-split air conditioning apparatus 10 illustrated in FIG. 1 and the multi-split air conditioning apparatus 10 illustrated in FIG. 9, and the multi-split air conditioning apparatus 10 illustrated in FIG. 9 can perform the same control as described in the above-described embodiment, similar to the multi-split air conditioning apparatus 10 illustrated in FIG. 1.

Further, while the outdoor expansion valve 38 is omitted from the multi-split air conditioning apparatus 10 illustrated in FIG. 9, in the multi-split air conditioning apparatus 10 illustrated in FIG. 1, the outdoor expansion valve 38 is fully opened during the cooling operation and does not contribute to the cooling operation, and hence operations of components other than the outdoor expansion valve 38 during the cooling operation are the same for both the multi-split air conditioning apparatus 10 illustrated in FIG. 9 and the multi-split air conditioning apparatus 10 illustrated in FIG. 1.

(5-4) Modification example 1D

In the above-described embodiment, there is described a case where any one of the discharge temperature sensor 453, the discharge humidity sensor 454 and the indoor heat exchanger temperature sensor 455 provided to the indoor unit 40 is used to determine the size of the wet region, but these sensors may be used in combination to improve accuracy.

(5-5) Modification example 1E

In the above-described embodiment, condensation in the fan rotor 43a of the indoor fan 43 is taken as an example of condensation in the multi-split air conditioning apparatus

downstream of the indoor heat exchanger 42, but condensation in the multi-split air conditioning apparatus is not limited to condensation in the fan rotor 43a. Condensation in the multi-split air conditioning apparatus also includes, for example, condensation in the perpendicular blade 416 and/or the horizontal blade 417 downstream of the indoor heat exchanger 42.

(5-6) Modification example 1F

In the above-described embodiment, there is described a case where the occupancy ratio R_w of the wet region 491 at an upper limit at which condensation in the multi-split air conditioning apparatus downstream of the indoor heat exchanger 42 in the indoor unit 40 is not generated is calculated using two or more indoor heat exchanger temperature sensors 455. However, there can also be adopted a configuration in which one indoor heat exchanger temperature sensor 455 is used to restrict expansion of the wet region 491 to the upper limit at which condensation in the multi-split air conditioning apparatus downstream of the indoor heat exchanger 42 is not generated. For example, when an occupancy ratio of the wet region 491 in which condensation in the multi-split air conditioning apparatus downstream of the indoor heat exchanger 42 cannot be generated within a specified operation range of a particular indoor unit 40 is to be determined, the indoor heat exchanger temperature sensor 455 is disposed at such location that the occupancy ratio of the wet region 491 in which condensation in the multi-split air conditioning apparatus cannot be generated can be determined and, during the low-capacity cooling operation, the indoor heat exchanger temperature sensor 455 at that location detects a temperature indicating the superheat region 492. With this configuration, expansion of the wet region 491 to the upper limit at which condensation in the multi-split air conditioning apparatus downstream of the indoor heat exchanger 42 is not generated can be restricted during the low-capacity cooling operation. Note that this control is performed in the same way for all the indoor units 40, 50, 60.

REFERENCE SIGNS LIST

10 air conditioning apparatus

20 outdoor unit

21 compressor

40, 50, 60 indoor unit

41, 51, 61 indoor expansion valve (example of pressure reducing mechanism)

41a, 51a, 61a expansion valve (example of pressure reducing mechanism)

42, 52, 62 indoor heat exchanger

43, 53, 63 indoor fan

80 operation control device

CITATION LIST

PATENT LITERATURE

[Patent Literature 1] Japanese Patent Unexamined Publication S56-122864

CLAIMS

1. A multi-split air conditioning apparatus comprising:

an outdoor unit (20) including a compressor (21) configured to compress refrigerant that circulates and executes a refrigeration cycle; and

a plurality of indoor units (40, 50, 60) including:

a plurality of indoor heat exchangers (42, 52, 62) through which refrigerant discharged from the compressor circulates;

a plurality of pressure reducing mechanisms (41, 51, 61, 41a, 51a, 61a) through which refrigerant discharged from the compressor circulates; and

a plurality of indoor fans (43, 53, 63) through which passes air that passes through the plurality of indoor heat exchangers,

wherein at least one indoor unit among the plurality of indoor units is configured to, when an indoor temperature is higher than a set temperature during a low-capacity cooling operation which increases an superheat region more than during a normal cooling operation, increase an opening degree of the pressure reducing mechanism, to thereby narrow the superheat region of the indoor heat exchanger so as to expand a wet region of the indoor heat exchanger and is configured to increase flow rate of the indoor fan so as to restrict expansion of the wet region to an upper limit at which condensation in the apparatus is not generated at a downstream of the indoor heat exchanger, and

wherein the at least one indoor unit is configured to perform cooling with mixed air that has passed through the wet region and the superheat region during the low-capacity cooling operation.

2. The multi-split air conditioning apparatus according to claim 1, wherein

the at least one indoor unit is configured to, when the indoor temperature is lower than the set temperature during the low-capacity cooling operation, decrease cooling capacity by reducing the opening degree of the pressure reducing mechanism and/or reducing the flow rate of the indoor fan.

3. The multi-split air conditioning apparatus according to claim 1 or 2, wherein
- the at least one indoor unit is configured to determine that expansion of the wet region is restricted to an upper limit at which condensation in the apparatus is not generated at a downstream of the indoor heat exchanger using a temperature of the mixed air or a humidity of the mixed air.
4. The multi-split air conditioning apparatus according to any one of claims 1 to 3, wherein
- the at least one indoor unit further includes an indoor heat exchanger temperature sensor (455) provided to the indoor heat exchanger,
- and wherein the at least one indoor unit is configured to determine that expansion of the wet region is restricted to the upper limit at which condensation in the apparatus downstream of the indoor heat exchanger is not generated using detection results of the indoor heat exchanger temperature sensor during the low-capacity cooling operation.
5. The multi-split air conditioning apparatus according to any one of claims 1 to 4, wherein
- the at least one indoor unit switches from a low-capacity cooling operation mode to a normal cooling operation mode to obtain necessary cooling capacity when expansion of the wet region cannot be restricted to the upper limit at which condensation in the apparatus is not generated at the downstream of the indoor heat exchanger by increasing the flow rate of the indoor fan.