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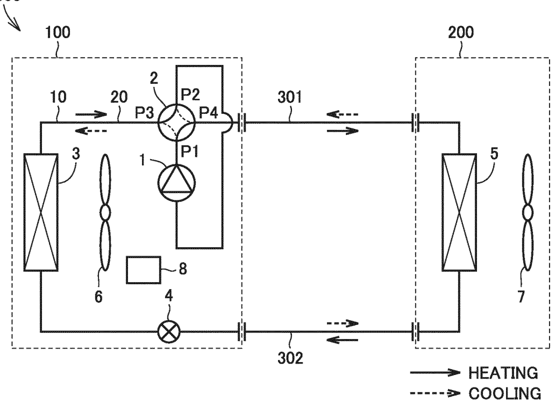
(54) OUTDOOR UNIT, AIR CONDITIONER, AND METHOD FOR DESIGNING OUTDOOR UNIT

(57) An outdoor unit (100) includes: a casing; and a heat exchanger (3) contained in the casing. The heat exchanger (3) includes a heat transfer tube that allows refrigerant to flow in the heat transfer tube. The refrigerant is R290. The heat transfer tube has an inside tube volume of more than or equal to 70% and less than 100%, relative to a heat transfer tube used to allow R32 to flow.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present disclosure relates to an outdoor unit, an air conditioner, and a method for designing an outdoor unit.

BACKGROUND ART

[0002] R32 is generally used as refrigerant in an air conditioner. Due to refrigerant regulations and the like in Europe, it is required to use refrigerant having a global warming potential (GWP) lower than that of R32 as refrigerant used in a refrigeration cycle of an air conditioner. Examples of the refrigerant having a GWP lower than that of R32 include R290 (propane). Since R290 is higher in evaporation latent heat than R32, R290 is higher in theoretical coefficient of performance (COP), which is a theoretical coefficient of performance of an air conditioner, than R32. Therefore, R290 is promising as alternative refrigerant to R32.

[0003] For example, Japanese Patent Laying-Open No. 2001-227822 (PTL 1) describes an air conditioner in which R290 is used as refrigerant.

CITATION LIST

PATENT LITERATURE

[0004] PTL 1: Japanese Patent Laying-Open No. 2001-227822

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0005] However, since R290 is lower in pressure than R32, R290 is larger in refrigerant pressure loss than R32. Therefore, when R290 is used in an air conditioner, a coefficient of performance decreases, as compared with when R32 is used in an air conditioner including a heat exchanger having the same inside tube volume. As a method for avoiding the decrease in coefficient of performance caused by the large refrigerant pressure loss, increasing a pipe diameter of the heat exchanger or increasing the number of paths (number of routes) in the heat exchanger is conceivable. However, increasing the pipe diameter of the heat exchanger or increasing the number of paths (number of routes) in the heat exchanger leads to an increase in cost of the heat exchanger.

[0006] In addition, R290 is lower in thermal conductivity of liquid refrigerant than R32. Therefore, R290 is lower in thermal conductivity of a supercooled liquid portion than R32, and thus, R290 tends to be lower in degree of supercooling than R32. Therefore, when R290 is used in an air conditioner, an enthalpy difference of an evaporator is small, as compared with when R32 is used in an air conditioner including a heat exchanger having the same inside tube volume, and thus, a coefficient of performance decreases. As a method for increasing the degree of supercooling, increasing an amount of the refrigerant, or decreasing a pipe diameter of the heat exchanger or decreasing the number of paths in the heat exchanger is conceivable. However, since a maximum refrigerant filling amount of R290 is defined by the international standards, increasing the amount of the refrigerant is difficult. In addition, since R290 is lower in pressure than R32, decreasing the pipe diameter of the heat exchanger or decreasing the number of paths in the heat exchanger leads to an increase in refrigerant flow velocity, which causes a higher rate of increase in refrigerant pressure loss. Therefore, a condensation temperature increases significantly, and thus, the coefficient of performance is not improved.

[0007] The present disclosure has been made in light of the above-described problems and an object thereof is to provide an outdoor unit, an air conditioner, and a method for designing an outdoor unit, which make it possible to keep the cost of a heat exchanger down and improve a coefficient of performance of the air conditioner while using R290.

SOLUTION TO PROBLEM

[0008] An outdoor unit of the present disclosure includes: a casing; and an outdoor heat exchanger contained in the casing. The outdoor heat exchanger includes a heat transfer tube that allows refrigerant to flow in the heat transfer tube. The refrigerant is R290. The heat transfer tube has an inside tube volume of more than or equal to 70% and less than 100%, relative to a heat transfer tube used to allow R32 to flow.

ADVANTAGEOUS EFFECTS OF INVENTION

[0009] According to the outdoor unit of the present disclosure, the refrigerant is R290. The heat transfer tube has an inside tube volume of more than or equal to 70% and less than 100%, relative to a heat transfer tube used to allow R32 to flow. Therefore, it is possible to keep the cost of the heat exchanger down and improve the coefficient of performance of the air conditioner while using R290.

BRIEF DESCRIPTION OF DRAWINGS

[0010]

Fig. 1 is a refrigerant circuit diagram of an air conditioner according to a first embodiment.

Fig. 2 is a perspective view schematically showing a configuration of an outdoor unit according to the first embodiment.

Fig. 3 is a perspective view schematically showing a state in which a portion of a perimeter wall portion that forms a blower chamber, a fan grill and a top plate portion of the outdoor unit according to the first embodiment are removed.

Fig. 4 is a schematic view schematically showing a configuration of an outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 5 is a graph showing a change in coefficient of performance (COP) of the air conditioner with respect to an inside tube volume of the outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 6 is a graph showing a change in degree of supercooling (SC) with respect to the inside tube volume of the outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 7 is a graph showing a change in amount of refrigerant circulation (Gr) with respect to the inside tube volume of the outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 8 is a graph showing a change in compressor frequency with respect to the inside tube volume of the outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 9 is a graph showing a change in discharge pressure of a compressor with respect to the inside tube volume of the outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 10 is a graph showing a change in compressor input ($Gr \times \Delta hcomp$) with respect to the inside tube volume of the outdoor heat exchanger of the outdoor unit according to the first embodiment.

Fig. 11 is a front view schematically showing a height of an indoor heat exchanger with respect to a height of a casing of the outdoor unit according to the first embodiment.

Fig. 12 is a flowchart of a method for designing the outdoor unit according to the first embodiment.

Fig. 13 is a top view schematically showing a stack width of an outdoor heat exchanger with respect to a lateral length of a casing of an outdoor unit according to a second embodiment.

Fig. 14 is a top view schematically showing a length of an L-shaped bent portion of the outdoor heat exchanger with respect to a length of the casing of the outdoor unit according to the second embodiment in a depth direction.

Fig. 15 is a front view schematically showing a height of an indoor heat exchanger with respect to a height of a casing of an outdoor unit according to a third embodiment.

Fig. 16 is a top view schematically showing a length of an L-shaped bent portion of an outdoor heat exchanger with respect to a length of the casing of the outdoor unit according to the third embodiment in a depth direction.

Fig. 17 is a front view schematically showing a height of an indoor heat exchanger with respect to a height of a casing of a modification of the outdoor unit according to the third embodiment.

Fig. 18 is a top view schematically showing a length of an L-shaped bent portion of an outdoor heat exchanger with respect to a length of the casing of the modification of the outdoor unit according to the third embodiment in a depth direction.

DESCRIPTION OF EMBODIMENTS

[0011] Embodiments will be described hereinafter with reference to the drawings, in which the same or corresponding portions are denoted by the same reference characters and description thereof will not be repeated.

First Embodiment

[0012] A configuration of an air conditioner 1000 according to a first embodiment will be described with reference to Fig. 1.

[0013] As shown in Fig. 1, air conditioner 1000 includes a compressor 1, a four-way valve 2, an outdoor heat exchanger 3, a decompressing valve 4, an indoor heat exchanger 5, an outdoor blower 6, an indoor blower 7, and a controller 8. Air conditioner 1000 includes an outdoor unit 100, and an indoor unit 200 connected to outdoor unit 100.

[0014] Although air conditioner 1000 includes four-way valve 2 in the present embodiment, air conditioner 1000 may be an air conditioner for cooling only that does not include four-way valve 2.

[0015] A refrigerant circuit 10 includes compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, and indoor heat exchanger 5. Compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, and indoor heat exchanger 5 are connected by a pipe 20. Refrigerant circuit 10 is configured to circulate refrigerant. The refrigerant is R290 (propane).

[0016] Compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, outdoor blower 6, and controller 8 are contained in outdoor unit 100. Indoor heat exchanger 5 and indoor blower 7 are contained in indoor unit 200. Outdoor unit 100 and indoor unit 200 are connected by a gas pipe 301 and a liquid pipe 302. A part of pipe 20 forms gas pipe 301 and liquid pipe 302.

[0017] Refrigerant circuit 10 is configured such that the refrigerant circulates in the order of compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, indoor heat exchanger 5, and four-way valve 2 during cooling operation. Refrigerant circuit 10 is also configured such that the refrigerant circulates in the order of compressor 1, four-way valve 2, indoor heat exchanger 5, decompressing valve 4, outdoor heat exchanger 3, and four-way valve 2 during heating operation.

[0018] Compressor 1 is configured to compress the refrigerant. Compressor 1 is configured to compress and discharge the suctioned refrigerant. Compressor 1 may be configured to be capacity-variable. Compressor 1 may be configured such that a capacity thereof varies by adjustment of the rotation speed of compressor 1 based on an instruction provided from controller 8.

[0019] Four-way valve 2 is configured to switch a flow of the refrigerant to allow the refrigerant compressed by compressor 1 to flow through outdoor heat exchanger 3 or indoor heat exchanger 5. Four-way valve 2 includes a first port P1 to a fourth port P4. First port P1 is connected to the discharge side of compressor 1. Second port P2 is connected to the suction side of compressor 1. Third port P3 is connected to outdoor heat exchanger 3. Fourth port P4 is connected to indoor heat exchanger 5. Four-way valve 2 is configured to allow the refrigerant discharged from compressor 1 to flow through outdoor heat exchanger 3 during the cooling operation. During the cooling operation, third port P3 is connected to first port P1 and fourth port P4 is connected to second port P2 in four-way valve 2. Four-way valve 2 is also configured to allow the refrigerant discharged from compressor 1 to flow through indoor heat exchanger 5 during the heating operation. During the heating operation, fourth port P4 is connected to first port P1 and third port P3 is connected to second port P2 in four-way valve 2.

[0020] Outdoor heat exchanger 3 is configured to perform heat exchange between the refrigerant flowing inside outdoor heat exchanger 3 and the air flowing outside outdoor heat exchanger 3. Outdoor heat exchanger 3 is configured to function as a condenser that condenses the refrigerant during the cooling operation, and function as an evaporator that evaporates the refrigerant during the heating operation. Outdoor heat exchanger 3 is a fin-and-tube-type heat exchanger including a plurality of fins and a heat transfer tube passing through the plurality of fins.

[0021] Decompressing valve 4 is configured to expand and thereby decompress the refrigerant condensed by the condenser. Decompressing valve 4 is configured to decompress the refrigerant condensed by outdoor heat exchanger 3 during the cooling operation, and decompress the refrigerant condensed by indoor heat exchanger 5 during the heating operation. Decompressing valve 4 is, for example, a solenoid expansion valve.

[0022] Indoor heat exchanger 5 is configured to perform heat exchange between the refrigerant flowing inside indoor heat exchanger 5 and the air flowing outside indoor heat exchanger 5. Indoor heat exchanger 5 is configured to function as an evaporator that evaporates the refrigerant during the cooling operation, and function as a condenser that condenses the refrigerant during the heating operation. Indoor heat exchanger 5 is a fin-and-tube-type heat exchanger including a plurality of fins and a heat transfer tube passing through the plurality of fins.

[0023] Outdoor blower 6 is configured to blow the outdoor air to outdoor heat exchanger 3. That is, outdoor blower 6 is configured to supply the air to outdoor heat exchanger 3.

[0024] Indoor blower 7 is configured to blow the indoor air to indoor heat exchanger 5. That is, indoor blower 7 is configured to supply the air to indoor heat exchanger 5.

[0025] Controller 8 is configured to perform computations, provide instructions, and the like to control the devices and the like of air conditioner 1000. Controller 8 is electrically connected to compressor 1, four-way valve 2, decompressing valve 4, outdoor blower 6, indoor blower 7 and the like, and is configured to control the operations thereof.

[0026] Next, the operation of air conditioner 1000 according to the first embodiment will be described. A broken arrow in Fig. 1 indicates a flow of the refrigerant during the cooling operation. A solid arrow in Fig. 1 indicates a flow of the refrigerant during the heating operation.

[0027] Air conditioner 1000 can selectively perform the cooling operation and the heating operation. During the cooling operation, the refrigerant circulates in refrigerant circuit 10 in the order of compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, indoor heat exchanger 5, and four-way valve 2. During the cooling operation, outdoor heat exchanger 3 functions as a condenser. Heat exchange is performed between the refrigerant flowing through outdoor heat exchanger 3 and the air blown by outdoor blower 6. During the cooling operation, indoor heat exchanger 5 functions as an evaporator. Heat exchange is performed between the refrigerant flowing through indoor heat exchanger 5 and the air blown by indoor blower 7.

[0028] During the heating operation, the refrigerant circulates in refrigerant circuit 10 in the order of compressor 1, four-way valve 2, indoor heat exchanger 5, decompressing valve 4, outdoor heat exchanger 3, and four-way valve 2. During the heating operation, indoor heat exchanger 5 functions as a condenser. Heat exchange is performed between the refrigerant flowing through indoor heat exchanger 5 and the air blown by indoor blower 7. During the heating operation, outdoor heat exchanger 3 functions as an evaporator. Heat exchange is performed between the refrigerant flowing through outdoor heat exchanger 3 and the air blown by outdoor blower 6.

[0029] Next, a configuration of outdoor unit 100 according to the first embodiment will be described in detail with reference to Figs. 2 and 3.

[0030] As shown in Figs. 2 and 3, outdoor unit 100 includes compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, outdoor blower 6, controller 8, and a casing 101. Compressor 1, four-way valve 2, outdoor heat exchanger 3, decompressing valve 4, outdoor blower 6, and controller 8 are contained in casing 101. Casing 101 includes a bottom portion 102, a perimeter wall portion 103, a fan grill 104, a top plate portion 105, and a separator 106. Perimeter wall portion 103 is arranged on bottom portion 102. A not-shown air outlet is provided in a front surface of perimeter wall portion 103. Fan grill 104 is configured to cover the air outlet. Top plate portion 105 is arranged on perimeter wall portion 103. Separator 106 is configured to separate a machine chamber 107 of outdoor unit 100 from a blower chamber 108 of outdoor unit 100. Compressor 1, four-way valve 2, decompressing valve 4, and controller 8 are placed in machine chamber 107. Outdoor heat exchanger 3 and outdoor blower 6 are placed in blower chamber 108.

[0031] Next, a configuration of outdoor heat exchanger 3 of outdoor unit 100 according to the first embodiment will be described in detail with reference to Figs. 3 and 4. Outdoor heat exchanger 3 according to the first embodiment may include one column or two columns. For the sake of convenience in description, Fig. 3 shows outdoor heat exchanger 3 including two columns. Fig. 4 is a schematic view schematically showing the configuration of outdoor heat exchanger 3. For the sake of convenience in description, Fig. 4 shows outdoor heat exchanger 3 including one column.

[0032] As shown in Figs. 3 and 4, outdoor heat exchanger 3 includes a heat transfer tube HP that allows the refrigerant to flow in heat transfer tube HP, and a plurality of fins FP. The plurality of fins FP are stacked with each other. Heat transfer tube HP is configured to pass through the plurality of fins FP. Heat transfer tube HP is configured to meander.

[0033] Next, a coefficient of performance of outdoor unit 100 according to the first embodiment will be described in detail, as compared with when R32 is used as refrigerant.

[0034] As for an air conditioner in which R32 is used as refrigerant, an outdoor heat exchanger and an outdoor blower are placed at a maximum size within a placeable range relative to a casing size of an outdoor unit, in order to enhance the performance (coefficient of performance) of the air conditioner. That is, in the Z direction and the X direction of the casing shown in Fig. 3, the outdoor heat exchanger is made as large as possible, as long as the outdoor heat exchanger is housed in the casing. The reasons for this are to increase a heat exchanger heat transfer area and enhance the heat transfer performance, and to decrease an input of the outdoor blower by increasing a front surface area of the heat exchanger and decreasing an air-side pressure loss of the heat exchanger. A blade diameter of the outdoor blower is also made as large as possible, as long as the outdoor blower is housed in the casing. This is because an amount of wind that can be blown at an equivalent rotation speed increases as the blade diameter increases, and thus, the performance (coefficient of performance) of the air conditioner is enhanced.

[0035] As described above, in the air conditioner in which R32 is used as refrigerant, the outdoor heat exchanger and the outdoor blower are placed at a maximum size within a placeable range relative to the casing size of the outdoor unit. However, when R290 is used as refrigerant instead of R32 in such outdoor unit, the optimum coefficient of performance cannot be obtained.

[0036] The reason why an optimum point of the coefficient of performance of the air conditioner in which R290 is used changes as compared with when R32 is used will be described. As a thermophysical characteristic of R290, R290 is lower in thermal conductivity of liquid refrigerant than R32. Specifically, the thermal conductivity of the liquid refrigerant when the condensation temperature is 40°C and the degree of supercooling (SC) is 5 deg(°C) is 0.1188 W/m•K for R32, while the thermal conductivity of the liquid refrigerant is 0.0893 W/m•K for R290, and thus, R290 is lower than R32 by 25%. Therefore, R290 is lower in thermal conductivity of a supercooled liquid portion than R32, and thus, R290 tends to be lower in degree of supercooling (SC) than R32. Therefore, when R290 is used, an enthalpy difference of the evaporator is small in the case of an inside tube volume (100%) of the current outdoor heat exchanger, and thus, the coefficient of performance does not become an optimum point. That is, when R290 is used in the air conditioner, the enthalpy difference of the evaporator is small, as compared with when R32 is used in the air conditioner including the heat exchanger having the same inside tube volume, and thus, the coefficient of performance decreases.

[0037] As a method for increasing the degree of supercooling (SC), the following methods are conceivable. A first method is to simply increase an amount of R290. A second method is to decrease a pipe diameter of the outdoor heat exchanger or decrease the number of paths (number of routes). However, the above-described methods have the following problems. As for the first method, since a maximum refrigerant filling amount of R290 is defined by the international standards, increasing the amount of the refrigerant is difficult. As for the second method, since R290 is lower in pressure than R32, a refrigerant flow velocity increases, which causes a higher rate of increase in refrigerant pressure loss. Therefore, the condensation temperature increases significantly, and thus, the coefficient of performance (performance) is not improved.

[0038] In the present embodiment, the coefficient of performance (performance) is improved by increasing the degree of supercooling (SC) with a method other than the above-described methods. Specifically, in the present embodiment, the coefficient of performance (performance) is improved by reducing the inside tube volume of the outdoor heat exchanger and increasing the degree of supercooling (SC).

[0039] Figs. 5 to 10 are graphs showing changes in coefficient of performance (COP) and the like of the air conditioner with respect to the inside tube volume of the outdoor heat exchanger. Figs. 5 to 10 show results of simulation. Since the outdoor heat exchanger is a fin-and-tube-type heat exchanger, the outdoor heat exchanger is designed such that the fins decrease as the inside tube volume decreases. In addition, the outdoor heat exchanger is designed such that the capacity is equivalent even when the inside tube volume decreases. The refrigerant is R290. Since each of a saturated gas density and a saturated liquid density of R290 is approximately 50% of each of those of R32, an amount of R290 is 50% of an amount of R32.

[0040] In the simulation, under the following conditions, the number of rows of outdoor heat exchanger 3 is reduced by two rows from the thirty-two rows and the changes in coefficient of performance (COP) and the like are calculated. That is, the thirty-two rows of outdoor heat exchanger 3 correspond to the outdoor heat exchanger inside tube volume of 100%, the thirty rows correspond to 94%, the twenty-eight rows correspond to 88%, the twenty-six rows correspond to 81%, the twenty-four rows correspond to 75%, the twenty-two rows correspond to 69%, and the twenty rows correspond to 63%.

[0041] The cooling rated conditions (outdoor dry bulb temperature of 35°C, outdoor wet bulb temperature of 24°C, indoor dry bulb temperature of 27°C, and indoor wet bulb temperature of 19°C) are applied. The cooling capacity is 2.5 kW. The amount of R290 is 0.33 kg. The maximum refrigerant filling amount of flammable refrigerant of the air conditioner is defined by the international standards, IEC60335-2-40. The gas pipe has a diameter of 12.7 mm. The liquid pipe has a diameter of 6.35 mm. The gas pipe has a length of 5 m. The liquid pipe has a length of 5 m. The amount of outdoor wind is 35.7 m^3/min. The amount of indoor wind is 13.2 m^3/min.

[0042] Specifications of the outdoor heat exchanger are as follows. The outdoor heat exchanger is a fin-and-tube-type heat exchanger. The heat transfer tube has an outer diameter of 5 mm. The heat transfer tube has a thickness of 0.21 mm. The number of columns is two. The number of rows is thirty-two. The stack width is 847 mm. The fin pitch (FP) is 1.5 mm. The row pitch (DP) is 21 mm. The column pitch (LP) is 22 mm. Each fin has a thickness of 0.11 mm. The number of paths is 8-2 paths. That is, an inlet has eight paths and an outlet has two paths during cooling.

[0043] Specifications of the indoor heat exchanger are as follows. The indoor heat exchanger is a fin-and-tube-type heat exchanger. The heat transfer tube has an outer diameter of 5 mm. The heat transfer tube has a thickness of 0.21 mm. The number of columns is two. The number of rows is thirty. The stack width is 789 mm. The fin pitch (FP) is 1.2 mm. The row pitch (DP) is 15.3 mm. The column pitch (LP) is 8.67 mm. Each fin has a thickness of 0.095 mm. The number of paths is 2-4 paths. That is, an inlet has two paths and an outlet has four paths during cooling.

[0044] As shown in Fig. 5, in the case of R290, the coefficient of performance (COP) is optimized, i.e., the coefficient of performance (COP) is 102.3% at 85% of the current outdoor heat exchanger volume (outdoor heat exchanger inside tube volume of 100%). The inside tube volume of the outdoor heat exchanger that allows the coefficient of performance to be more than or equal to the coefficient of performance (COP of 100%) at the current outdoor heat exchanger volume (outdoor heat exchanger inside tube volume of 100%) is more than or equal to 70% and less than 100%. In the present embodiment, the heat transfer tube has an inside tube volume of more than or equal to 70% and less than 100%, relative to a heat transfer tube used to allow R32 to flow.

[0045] As shown in Fig. 6, as the inside tube volume of the outdoor heat exchanger decreases, the degree of supercooling (SC) increases. That is, because of the fixed amount of the refrigerant, as the inside tube volume of the outdoor heat exchanger decreases, a refrigerant average density increases, and thus, the degree of supercooling (SC) increases. Since the degree of supercooling (SC) increases, the enthalpy difference of the evaporator increases, and thus, the compressor frequency can be decreased and the amount of refrigerant circulation (Gr) decreases as shown in Figs. 7 and 8. As a result, as shown in Figs. 5, 9 and 10, the compressor input ($W=Gr\times\Delta hcomp$) decreases and the coefficient of performance (COP) is improved. As the inside tube volume of the outdoor heat exchanger is further decreased, the degree of supercooling (SC) increases. However, the discharge pressure of the compressor increases more than the increase in degree of supercooling (SC) and a compressor enthalpy difference $\Delta hcomp$ increases. Therefore, the compressor input ($W=Gr\times\Delta hcomp$) increases and the coefficient of performance (COP) decreases.

[0046] Fig. 11 shows a height ZL2 of outdoor heat exchanger 3 with respect to a height ZL1 of casing 101 of outdoor unit 100. As described above, the height of outdoor heat exchanger 3 in the current outdoor unit is made as great as possible, i.e., more than or equal to 89% and less than or equal to 95% of the height of casing 101 of outdoor unit 100. Specifically, for example, height ZL1 of casing 101 of outdoor unit 100 of a room air conditioner is 530 mm, while height ZL2 of outdoor heat exchanger 3 is more than or equal to 472 mm and less than or equal to 504 mm.

[0047] As shown in Fig. 5, the inside tube volume of the outdoor heat exchanger according to the present embodiment that allows the COP to be more than or equal to the COP (100%) at the current outdoor heat exchanger volume (100%) is more than or equal to 70% and less than 100%. Therefore, as shown in Fig. 11, when height ZL2 of outdoor heat exchanger 3 in a row direction (Z direction) is more than or equal to 62% and less than 95% (= (89% to 95%)×(70% to 100%)) of height ZL1 of casing 101 of outdoor unit 100, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance (COP) of the air conditioner in which R290 is used. In the present embodiment, height ZL2 of outdoor heat exchanger 3 is more than or equal to 62% and less than 95% of height ZL1 of casing 101.

[0048] In addition, as shown in Fig. 5, the inside tube volume of the outdoor heat exchanger that allows the coefficient of performance (COP) of the air conditioner to be within a more preferable range from 102.3%, which is the optimum coefficient of performance, to the coefficient of performance reduced by 1% is more than or equal to 75% and less than or equal to 95%. Therefore, as shown in Fig. 11, when height ZL2 of outdoor heat exchanger 3 in the row direction (Z direction) is more than or equal to 67% and less than or equal to 90% (= (89% to 95%)×(75% to 95%)) of height ZL1 of casing 101 of outdoor unit 100, it is possible to keep the cost of outdoor heat exchanger 3 down and further improve the coefficient of performance (COP) of the air conditioner in which R290 is used.

[0049] Next, a method for designing the outdoor unit according to the first embodiment will be described with reference to Figs. 5, 11 and 12.

[0050] The method for designing the outdoor unit according to the first embodiment includes a first step S1 and a second step S2. In first step S1, an inside tube volume of an outdoor heat exchanger when R32 is used is set. That is, a current outdoor heat exchange volume (100%) when R32 is used is set. In second step S2, the inside tube volume of the outdoor heat exchanger in which R290 is used is set by reducing the inside tube volume of the outdoor heat exchanger in which R290 is used so as to exceed a coefficient of performance when R32 is used. That is, the inside tube volume of the outdoor heat exchanger in which R290 is used is set by reducing the inside tube volume of the outdoor heat exchanger in which R290 is used so as to exceed the coefficient of performance (100%) when R32 is used at the current outdoor heat exchange volume (100%).

[0051] Next, a function and effect of the first embodiment will be described.

[0052] In outdoor unit 100 according to the first embodiment, the refrigerant is R290. The heat transfer tube has an inside tube volume of more than or equal to 70% and less than 100%, relative to a heat transfer tube used to allow R32 to flow. The inside tube volume of outdoor heat exchanger 3 that allows the coefficient of performance to be more than or equal to the coefficient of performance when R32 is used as refrigerant is more than or equal to 70% and less than 100% of the inside tube volume when R32 is used as refrigerant. Therefore, it is possible to keep the cost of the heat exchanger down and improve the coefficient of performance of air conditioner 1000 while using R290.

[0053] In outdoor unit 100 according to the first embodiment, height ZL2 of outdoor heat exchanger 3 is more than or equal to 62% and less than 95% of height ZL1 of casing 101. Therefore, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance of air conditioner 1000 in which R290 is used.

[0054] In outdoor unit 100 according to the first embodiment, heat transfer tube HP is configured to pass through the plurality of fins FP. Therefore, a fin-and-tube-type heat exchanger can be used as outdoor heat exchanger 3.

[0055] Air conditioner 1000 according to the first embodiment includes above-described outdoor unit 100, and indoor unit 200 connected to outdoor unit 100. Therefore, it is possible to keep the cost of the heat exchanger down and improve the coefficient of performance of air conditioner 1000 while using R290.

[0056] In the method for designing outdoor unit 100 according to the first embodiment, the inside tube volume of the outdoor heat exchanger in which R290 is used is set by reducing the inside tube volume of the outdoor heat exchanger in which R290 is used so as to exceed the coefficient of performance when R32 is used. Therefore, it is possible to keep the cost of the heat exchanger down and improve the coefficient of performance of air conditioner 1000 while using R290.

Second Embodiment

[0057] Air conditioner 1000 according to a second embodiment has the same configuration, operation, and function and effect as those of air conditioner 1000 according to the first embodiment, unless otherwise specified.

[0058] In the first embodiment, the size of the outdoor heat exchanger in the row direction (Z direction) is reduced. However, even when the size of the outdoor heat exchanger in a stack width direction (X direction) is reduced, a similar effect is obtained.

[0059] Fig. 13 shows a stack width XL2 of outdoor heat exchanger 3 with respect to a lateral length XL1 of casing 101 of outdoor unit 100. As described above, stack width XL2 of outdoor heat exchanger 3 in the current outdoor unit is made as great as possible, i.e., more than or equal to 80% and less than or equal to 85% of lateral length XL1 of casing 101 of outdoor unit 100. Stack width XL2 of outdoor heat exchanger 3 is smaller as compared with the Z direction due to a distributor, a connection pipe and the like for outdoor heat exchanger 3. Specifically, for example, lateral length XL1 of casing 101 of outdoor unit 100 of a room air conditioner is 699 mm, while the stack width of outdoor heat exchanger 3 is more than or equal to 560 mm and less than or equal to 593 mm.

[0060] As shown in Fig. 5, the inside tube volume of the outdoor heat exchanger according to the present embodiment that allows the COP to be more than or equal to the COP (100%) at the current outdoor heat exchanger volume (100%) is more than or equal to 70% and less than 100%. Therefore, as shown in Fig. 13, when stack width XL2 of outdoor heat exchanger 3 is more than or equal to 56% and less than 85% (= (80% to 85%)×(70% to 100%)) of lateral length XL1 of casing 101 of outdoor unit 100, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance (COP) of the air conditioner in which R290 is used. In the present embodiment, stack width XL2 of outdoor heat exchanger 3 is more than or equal to 56% and less than 85% of lateral length XL1 of casing 101.

[0061] In addition, as shown in Fig. 5, the inside tube volume of the outdoor heat exchanger that allows the coefficient of performance (COP) of the air conditioner to be within the more preferable range from 102.3%, which is the optimum coefficient of performance, to the coefficient of performance reduced by 1% is more than or equal to 75% and less than or equal to 95%. Therefore, as shown in Fig. 13, when stack width XL2 of outdoor heat exchanger 3 is more than or equal to 60% and less than 81% (= (80% to 85%)×(75% to 95%)) of lateral length XL1 of casing 101 of outdoor unit 100, it is possible to keep the cost of outdoor heat exchanger 3 down and further improve the coefficient of performance (COP) of the air conditioner in which R290 is used.

[0062] Fig. 14 shows a length YL2 of an L-shaped bent portion of outdoor heat exchanger 3 with respect to a length YL1 of casing 101 of outdoor unit 100 in a depth direction (Y direction). Length YL2 of the L-shaped bent portion of outdoor heat exchanger 3 is more than or equal to 60% and less than 66% of length YL1 of casing 101 in the depth direction (Y direction). Due to a length of outdoor heat exchanger 3 in the depth direction (Y direction) other than the L-shaped bent portion, length YL2 of the L-shaped bent portion has a small value. Specifically, for example, length YL1 of casing 101 of outdoor unit 100 of a room air conditioner in the depth direction (Y direction) is 249 mm, while length YL2 of the L-shaped bent portion of outdoor heat exchanger 3 is more than or equal to 150 mm and less than or equal to 164 mm.

[0063] Therefore, a total length (X direction + Y direction) of outdoor heat exchanger 3 bent in an L-shape is more than or equal to 710 mm and less than or equal to 757 mm. As shown in Fig. 5, the inside tube volume of the outdoor heat exchanger according to the present embodiment that allows the COP to be more than or equal to the COP (100%) at the current outdoor heat exchanger volume (100%) is more than or equal to 70% and less than 100%. Therefore, when R290 is used, the length of outdoor heat exchanger 3 is more than or equal to 497 mm and equal to 757 mm. When the length of outdoor heat exchanger 3 is more than or equal to 497 mm and less than or equal to 593 mm, the length of outdoor heat exchanger 3 is less than or equal to the current outdoor heat exchanger stack width, and thus, the L-shaped bent portion of outdoor heat exchanger 3 can be eliminated. When the blade diameter or bellmouth diameter of outdoor blower 6 cannot be increased due to the L-shaped bent portion of outdoor heat exchanger 3, the elimination of the L-shaped bent portion of outdoor heat exchanger 3 makes it possible to increase the blade diameter and the bellmouth diameter of the outdoor blower. As a result, the aerodynamic performance can also be improved, and thus, the performance can be further improved.

[0064] Next, a function and effect of the second embodiment will be described.

[0065] In outdoor unit 100 according to the second embodiment, stack width XL2 of outdoor heat exchanger 3 is more than or equal to 56% and less than 85% of lateral length XL1 of casing 101. Therefore, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance of air conditioner 1000 in which R290 is used.

Third Embodiment

[0066] Air conditioner 1000 according to a third embodiment has the same configuration, operation, and function and effect as those of air conditioner 1000 according to the first embodiment, unless otherwise specified.

[0067] Unlike the first and second embodiments, in the third embodiment, a length of outdoor heat exchanger 3 in the Y direction (number of columns), not in the Z direction or in the X direction, is reduced. In the present embodiment, outdoor heat exchanger 3 includes two or more columns.

[0068] When outdoor heat exchanger 3 includes two columns in the Y direction, one column is sized to be equivalent (100%) to the current heat exchanger in the X direction and the Z direction, and only the other column is reduced in size. This is because when both of the two columns are equally reduced in size, the front surface area of outdoor heat exchanger 3 decreases, which leads to an increase in input of outdoor blower 6. The one column reduced in size may have a size of more than or equal to 40% and less than 100% of the current heat exchanger. Assuming that the inside tube volume of one column of the current heat exchanger is 100%, the inside tube volume of two columns is 200%. The inside tube volume of the outdoor heat exchanger according to the present embodiment that allows the coefficient of performance to be more than or equal to the coefficient of performance (COP of 100%) at the inside tube volume (inside tube volume of 100%) of the current heat exchanger is more than or equal to 70% and less than 100% of the inside tube volume of the current heat exchanger. Therefore, the inside tube volume of two columns of the heat exchanger according to the present embodiment that allows the coefficient of performance to be more than or equal to the coefficient of performance (COP of 100%) at the inside tube volume (inside tube volume of 100%) of the current heat exchanger is more than or equal to 140% and less than 200% (= 200%×(70% to 100%)) of the inside tube volume of two columns of the current heat exchanger. When the inside tube volume is reduced in only one column on the rear surface side so as not to reduce the front surface area of outdoor heat exchanger 3, the inside tube volume of the one column is more than or equal to 40% and less than 100% (= (140% to 200%)-100%) of the inside tube volume of the current heat exchanger. In the more preferable range (from the optimum COP to the COP reduced by 1%), the inside tube volume of the outdoor heat exchanger according to the present embodiment is more than or equal to 75% and less than or equal to 95% of the inside tube volume of the current heat exchanger. Therefore, the inside tube volume of two columns of the heat exchanger according to the present embodiment that achieves the more preferable range (from the optimum COP to the COP reduced by 1%) is more than or equal to 150% and less than or equal to 190% (= 200%×(75% to 95%)) of the inside tube volume of two columns of the current heat exchanger. When the inside tube volume is reduced in only one column on the rear surface side so as not to reduce the front surface area of outdoor heat exchanger 3, the inside tube volume of the one column is more than or equal to 50% and less than or equal to 90% (= (150% to 190%)-100%) of the inside tube volume of the current heat exchanger. Therefore, the inside tube volume of the one column is more than or equal to 50% and less than or equal to 90% of the current heat exchanger. The one column reduced in size may be one on the windward side (one that is away from outdoor blower 6). The reason for this is that by sizing the heat exchanger on the leeward side, which is the condenser inlet side, to be 100% of the current heat exchanger, easier handling of the paths in the multipath portion is achieved. Another reason is that by arranging the heat exchanger reduced in size on the windward side, the degree of supercooling is obtained more easily.

[0069] In addition, when outdoor heat exchanger 3 is bent in an L-shape, the heat exchanger on the windward side is formed linearly without being bent in an L-shape and the heat exchanger on the leeward side is bent in an L-shape, which makes it possible to reduce the volume of the outdoor heat exchanger on the windward side. Nevertheless, the front surface area is not reduced, and thus, the aerodynamic performance is also enhanced.

[0070] Referring to Figs. 15 and 16, outdoor heat exchanger 3 according to the third embodiment includes a first column 31 and a second column 32. A height of first column 31 is more than or equal to 89% and less than or equal to 95% of the height of casing 101. As described above, the inside tube volume of the one column reduced in size is more than or equal to 40% and less than 100% of the inside tube volume of the current heat exchanger. Therefore, a height of second column 32 is more than or equal to 36% and less than or equal to 95% (= (89% to 95%)×(40% to 100%)) of the height of casing 101. In the more preferable range (from the optimum COP to the COP reduced by 1%), the inside tube volume of the one column is more than or equal to 50% and less than or equal to 90% of the inside tube volume of the current heat exchanger. Therefore, the height of second column 32 is more than or equal to 45% and less than or equal to 86% (= (89% to 95%)×(50% to 90%)) of the height of casing 101. A stack width of first column 31 is more than or equal to 80% and less than or equal to 85% of the lateral length of casing 101. As described above, the inside tube volume of the one column is more than or equal to 40% and less than 100% of the inside tube volume of the current heat exchanger. Therefore, a stack width of second column 32 is more than or equal to 32% and less than or equal to 85% (= (80% to 85%)×(40% to 100%)) of the lateral length of casing 101. In the more preferable range (from the optimum COP to the COP reduced by 1%), the inside tube volume of the one column is more than or equal to 50% and less than or equal to 90% of the inside tube volume of the current heat exchanger. Therefore, the stack width of second column 32 is more than or equal to 40% and less than or equal to 77% (= (80% to 85%)×(50% to 90%)) of the lateral length of casing 101.

[0071] Second column 32 is arranged on the windward side relative to first column 31 in a wind flow F generated by outdoor blower 6.

[0072] First column 31 is bent in an L-shape, and second column 32 is formed linearly.

[0073] Similarly, when the outdoor heat exchanger includes three columns in the Y direction, only one column is reduced in size. The one column reduced in size may have a size of more than or equal to 10% and less than 100% of the current heat exchanger. Assuming that the inside tube volume of one column of the current heat exchanger is 100%, the inside tube volume of three columns is 300%. The inside tube volume of the outdoor heat exchanger according to the present embodiment that allows the coefficient of performance to be more than or equal to the coefficient of performance (COP of 100%) at the inside tube volume (inside tube volume of 100%) of the current heat exchanger is more than or equal to 70% and less than 100% of the inside tube volume of the current heat exchanger. Therefore, the inside tube volume of three columns of the heat exchanger according to the present embodiment that allows the coefficient of performance to be more than or equal to the coefficient of performance (COP of 100%) at the inside tube volume (inside tube volume of 100%) of the current heat exchanger is more than or equal to 210% and less than 300% (= 300%×(70% to 100%)) of the inside tube volume of three columns of the current heat exchanger. When the inside tube volume is reduced in only one column on the rear surface side so as not to reduce the front surface area of outdoor heat exchanger 3, the inside tube volume of the one column is more than or equal to 10% and less than 100% (= (210% to 300%)-200%) of the inside tube volume of the current heat exchanger. In the more preferable range (from the optimum COP to the COP reduced by 1%), the inside tube volume of the outdoor heat exchanger according to the present embodiment is more than or equal to 75% and less than or equal to 95% of the inside tube volume of the current heat exchanger. Therefore, the inside tube volume of three columns of the heat exchanger according to the present embodiment that achieves the more preferable range (from the optimum COP to the COP reduced by 1%) is more than or equal to 225% and less than or equal to 285% (= 300%×(75% to 95%)) of the inside tube volume of three columns of the current heat exchanger. When the inside tube volume is reduced in only one column on the rear surface side so as not to reduce the front surface area of outdoor heat exchanger 3, the inside tube volume of the one column is more than or equal to 25% and less than or equal to 85% (= (225% to 285%)-200%) of the inside tube volume of the current heat exchanger. Therefore, the inside tube volume of the one column is more than or equal to 25% and less than or equal to 85% of the current heat exchanger.

[0074] Referring to Figs. 17 and 18, a modification of outdoor heat exchanger 3 according to the third embodiment includes first column 31, second column 32 and a third column 33. Heights of first column 31 and second column 32 are more than or equal to 89% and less than or equal to 95% of the height of casing 101. As described above, the inside tube volume of the one column reduced in size is more than or equal to 10% and less than 100% of the inside tube volume of the current heat exchanger. Therefore, a height of third column 33 is more than or equal to 9% and less than or equal to 95% (= (89% to 95%)×(10% to 100%)) of the height of casing 101. In the more preferable range (from the optimum COP to the COP reduced by 1%), the inside tube volume of the one column is more than or equal to 25% and less than or equal to 85% of the inside tube volume of the current heat exchanger. Therefore, the height of third column 33 is more than or equal to 22% and less than or equal to 81% (= (89% to 95%)×(25% to 85%)) of the height of casing 101. Stack widths of first column 31 and second column 32 are more than or equal to 80% and less than or equal to 85% of the lateral length of casing 101. As described above, the inside tube volume of the one column reduced in size is more than or equal to 10% and less than 100% of the inside tube volume of the current heat exchanger. Therefore, a stack width of third column 33 is more than or equal to 8% and less than or equal to 85% (= (80% to 85%)×(10% to 100%)) of the lateral length of casing 101. In the more preferable range (from the optimum COP to the COP reduced by 1%), the inside tube volume of the one column is more than or equal to 25% and less than or equal to 85% of the inside tube volume of the current heat exchanger. Therefore, the stack width of third column 33 is more than or equal to 20% and less than or equal to 72% (= (80% to 85%)×(25% to 85%)) of the lateral length of casing 101.

[0075] Third column 33 is arranged on the windward side relative to first column 31 and second column 32 in wind flow F generated by outdoor blower 6.

[0076] First column 31 and second column 32 are bent in an L-shape, and third column 33 is formed linearly.

[0077] Next, a function and effect of the third embodiment will be described.

[0078] In outdoor unit 100 according to the third embodiment, the height of first column 31 is more than or equal to 89% and less than or equal to 95% of the height of casing 101. The height of second column 32 is more than or equal to 45% and less than or equal to 86% of the height of casing 101. Therefore, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance of air conditioner 1000 in which R290 is used.

[0079] In outdoor unit 100 according to the third embodiment, the stack width of first column 31 is more than or equal to 80% and less than or equal to 85% of the lateral length of casing 101. The stack width of second column 32 is more than or equal to 40% and less than or equal to 77% of the lateral length of the casing. Therefore, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance of air conditioner 1000 in which R290 is used.

[0080] In outdoor unit 100 according to the third embodiment, second column 32 is arranged on the windward side relative to first column 31 in the wind flow generated by outdoor blower 6. Thus, by sizing the heat exchanger on the leeward side, which is the condenser inlet side, to be 100% of the current heat exchanger, easier handling of the paths in the multipath portion is achieved. In addition, by arranging the heat exchanger reduced in size on the windward side, the degree of supercooling is obtained more easily.

[0081] In outdoor unit 100 according to the third embodiment, first column 31 is bent in an L-shape, and second column 32 is formed linearly. Therefore, the heat exchanger on the leeward side is bent in an L-shape, which makes it possible to reduce the volume of the outdoor heat exchanger on the windward side. Nevertheless, the front surface area is not reduced, and thus, the aerodynamic performance is also enhanced.

[0082] In the modification of outdoor unit 100 according to the third embodiment, the heights of first column 31 and second column 32 are more than or equal to 89% and less than or equal to 95% of the height of casing 101. The height of third column 33 is more than or equal to 22% and less than or equal to 81% of the height of casing 101. Therefore, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance of air conditioner 1000 in which R290 is used.

[0083] In the modification of outdoor unit 100 according to the third embodiment, the stack widths of first column 31 and second column 32 are more than or equal to 80% and less than or equal to 85% of the lateral length of casing 101. The stack width of third column 33 is more than or equal to 20% and less than or equal to 72% of the lateral length of casing 101. Therefore, it is possible to keep the cost of outdoor heat exchanger 3 down and improve the coefficient of performance of air conditioner 1000 in which R290 is used.

[0084] In the modification of outdoor unit 100 according to the third embodiment, third column 33 is arranged on the windward side relative to first column 31 and second column 32 in the wind flow generated by outdoor blower 6. Thus, by sizing the heat exchanger on the leeward side, which is the condenser inlet side, to be 100% of the current heat exchanger, easier handling of the paths in the multipath portion is achieved. In addition, by arranging the heat exchanger reduced in size on the windward side, the degree of supercooling is obtained more easily.

[0085] In the modification of outdoor unit 100 according to the third embodiment, first column 31 and second column 32 are bent in an L-shape, and third column 33 is formed linearly. Therefore, the heat exchanger on the leeward side is bent in an L-shape, which makes it possible to reduce the volume of the outdoor heat exchanger on the windward side. Nevertheless, the front surface area is not reduced, and thus, the aerodynamic performance is also enhanced.

[0086] It should be understood that the embodiments disclosed herein are illustrative and non-restrictive in every respect. The scope of the present disclosure is defined by the terms of the claims, rather than the description above, and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.

REFERENCE SIGNS LIST

[0087] 1 compressor; 2 four-way valve; 3 outdoor heat exchanger; 4 decompressing valve; 5 indoor heat exchanger; 6 outdoor blower; 7 indoor blower; 8 controller; 10 refrigerant circuit; 31 first column; 32 second column; 33 third column; 100 outdoor unit; 101 casing; 200 indoor unit; 1000 air conditioner; FP fin; HP heat transfer tube.

Claims

1. An outdoor unit comprising:

a casing; and
an outdoor heat exchanger contained in the casing,
the outdoor heat exchanger comprising a heat transfer tube that allows refrigerant to flow in the heat transfer tube,
the refrigerant being R290,
and
the heat transfer tube having an inside tube volume of more than or equal to 70% and less than 100%, relative to a heat transfer tube used to allow R32 to flow.

2. The outdoor unit according to claim 1, wherein a height of the outdoor heat exchanger is more than or equal to 62% and less than 95% of a height of the casing.

3. The outdoor unit according to claim 1, wherein a stack width of the outdoor heat exchanger is more than or equal to 56% and less than 85% of a lateral length of the casing.

4. The outdoor unit according to claim 1, wherein

the outdoor heat exchanger comprises a first column and a second column,
a height of the first column is more than or equal to 89% and less than or equal to 95% of a height of the casing, and
a height of the second column is more than or equal to 45% and less than or equal to 86% of the height of the casing.

5. The outdoor unit according to claim 1, wherein

the outdoor heat exchanger comprises a first column and a second column,
a stack width of the first column is more than or equal to 80% and less than or equal to 85% of a lateral length of the casing, and
a stack width of the second column is more than or equal to 40% and less than or equal to 77% of the lateral length of the casing.

6. The outdoor unit according to claim 4 or 5, further comprising

an outdoor blower, wherein
the second column is arranged on a windward side relative to the first column in a wind flow generated by the outdoor blower.

7. The outdoor unit according to claim 6, wherein

the first column is bent in an L-shape, and
the second column is formed linearly.

8. The outdoor unit according to claim 1, wherein

the outdoor heat exchanger comprises a first column, a second column and a third column,
heights of the first column and the second column are more than or equal to 89% and less than or equal to 95% of a height of the casing, and
a height of the third column is more than or equal to 22% and less than or equal to 81% of the height of the casing.

9. The outdoor unit according to claim 1, wherein

the outdoor heat exchanger comprises a first column, a second column and a third column,
stack widths of the first column and the second column are more than or equal to 80% and less than or equal to 85% of a lateral length of the casing, and
a stack width of the third column is more than or equal to 20% and less than or equal to 72% of the lateral length of the casing.

10. The outdoor unit according to claim 8 or 9, further comprising

an outdoor blower, wherein
the third column is arranged on a windward side relative to the first column and the second column in a wind flow generated by the outdoor blower.

11. The outdoor unit according to claim 10, wherein

the first column and the second column are bent in an L-shape, and
the third column is formed linearly.

12. The outdoor unit according to any one of claims 1 to 11, wherein

the outdoor heat exchanger further comprises a plurality of fins stacked with each other, and
the heat transfer tube is configured to pass through the plurality of fins.

13. An air conditioner comprising:

the outdoor unit as recited in any one of claims 1 to 12; and
an indoor unit connected to the outdoor unit.

14. A method for designing an outdoor unit, the method comprising:

setting an inside tube volume of an outdoor heat exchanger when R32 is used; and
setting the inside tube volume of the outdoor heat exchanger in which R290 is used, by reducing the inside tube volume of the outdoor heat exchanger in which the R290 is used so as to exceed a coefficient of performance when the R32 is used.

FIG.1

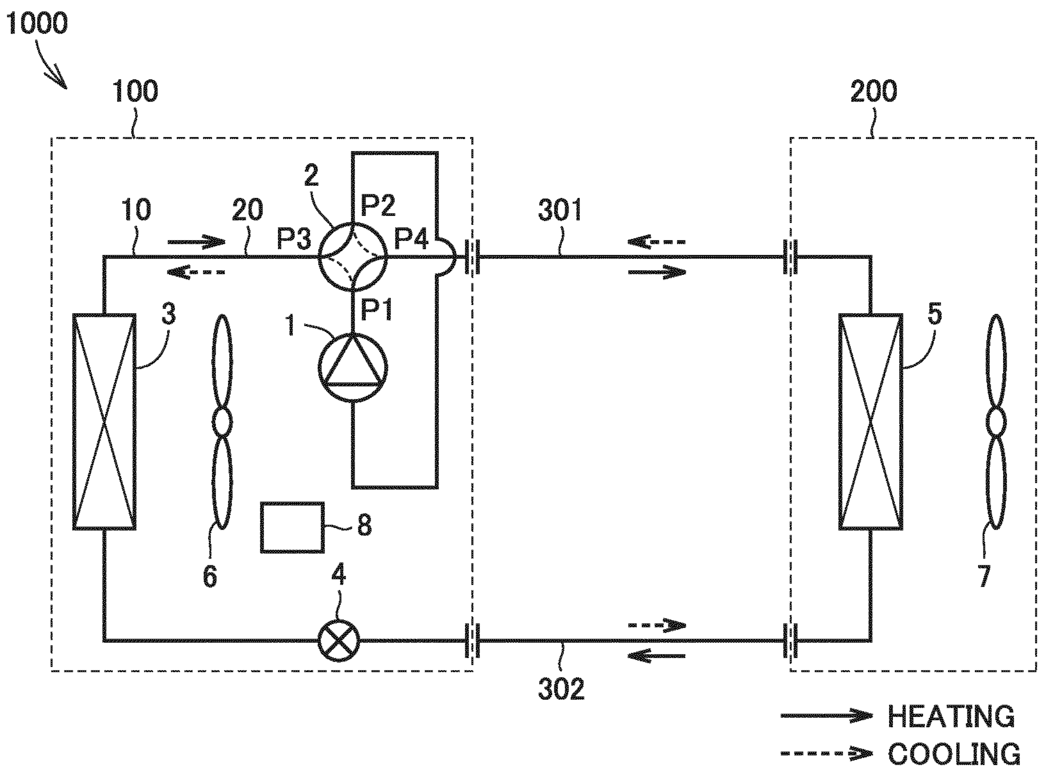

1000
100
200
2
10
20
P2
301
P3
P4
P1
1
3
5
8
6
4
7
302
HEATING
COOLING

FIG.2

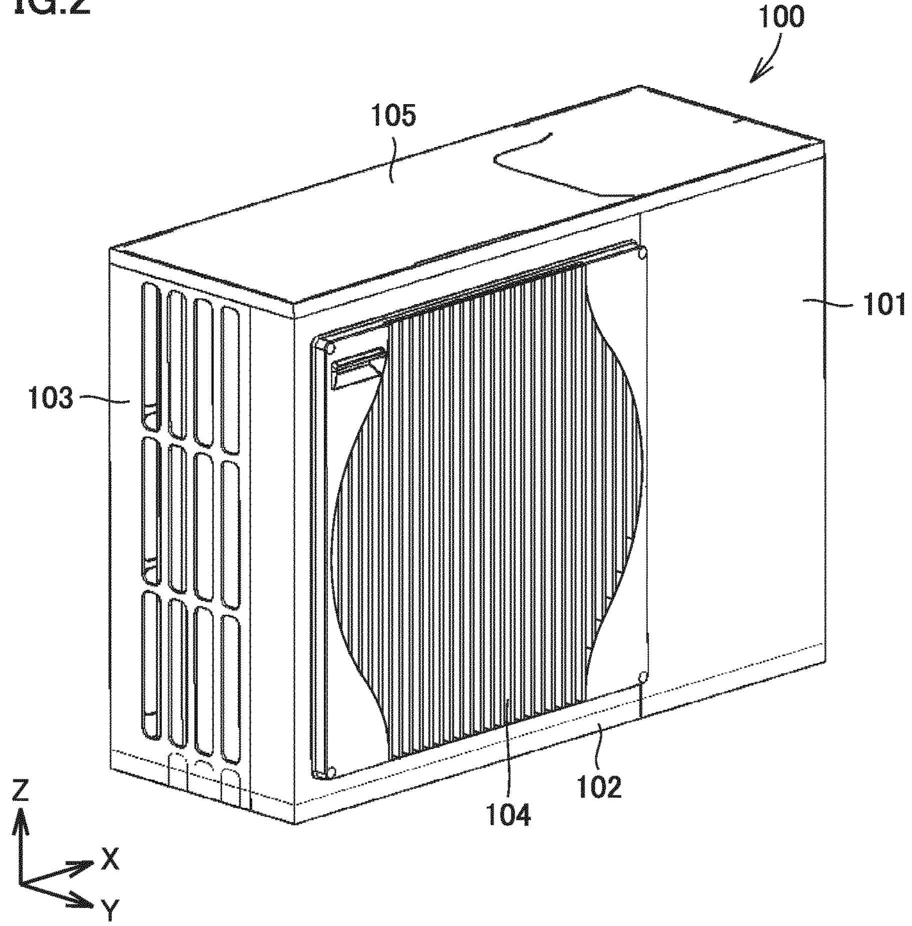


FIG.3

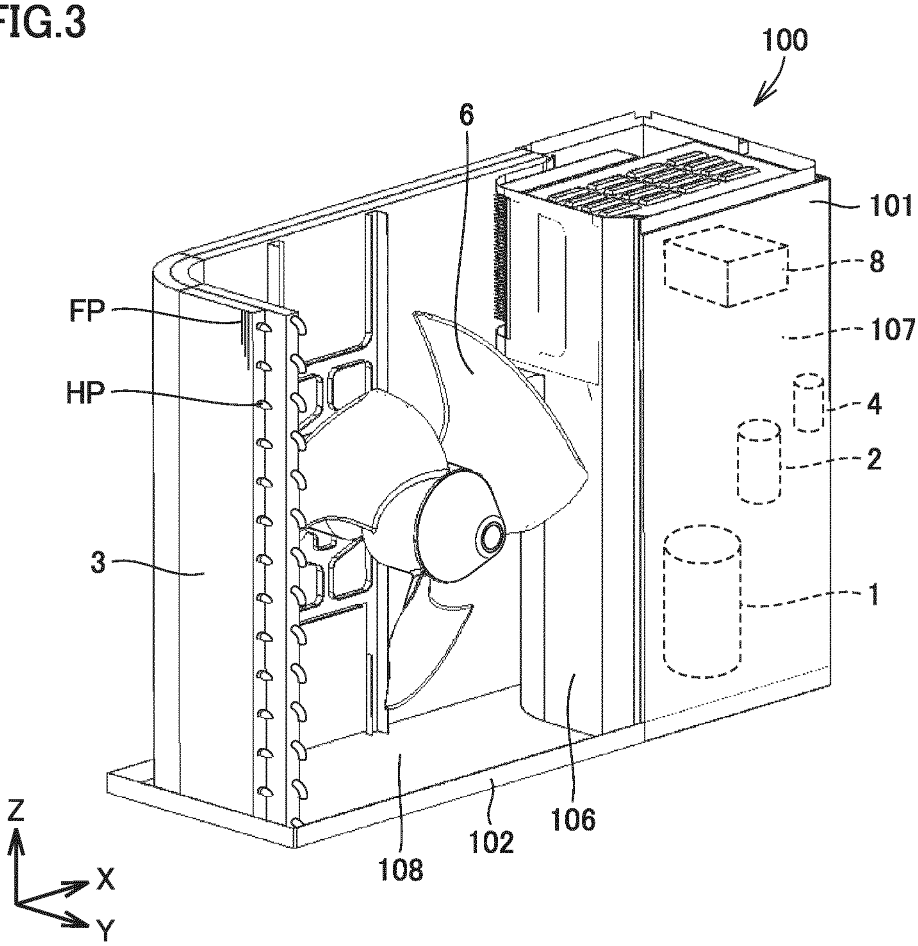


FIG.4

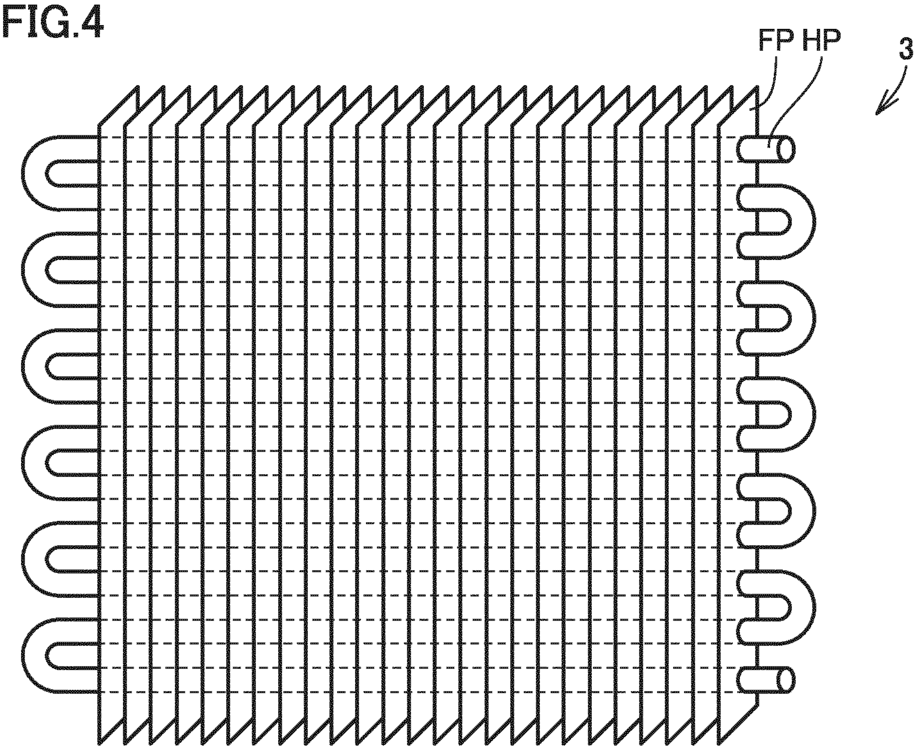
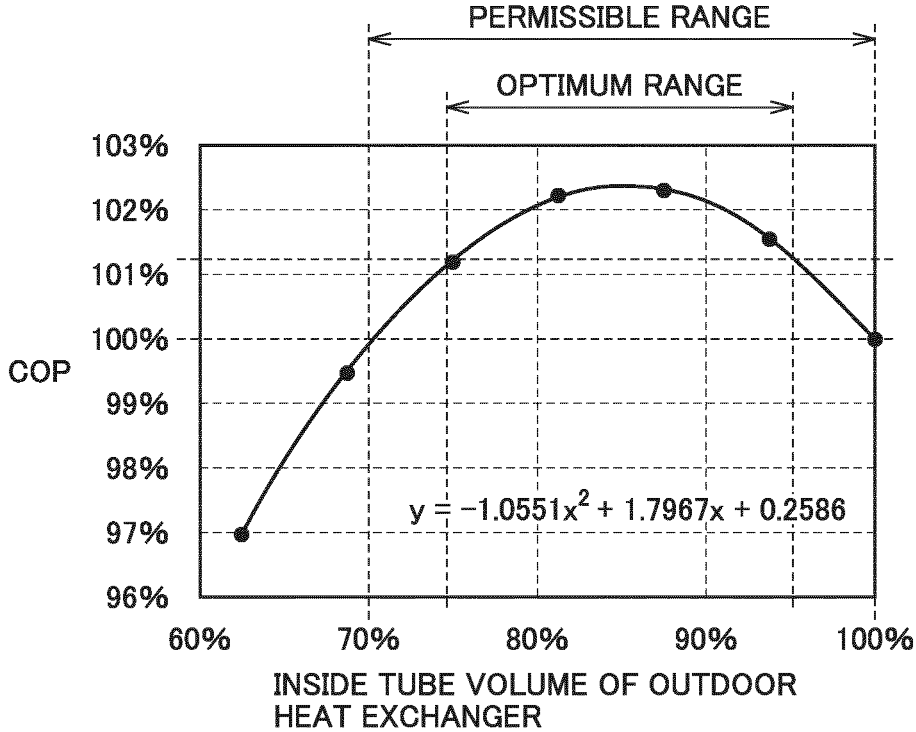


FIG.5


PERMISSIBLE RANGE
OPTIMUM RANGE
103%
102%
101%
100%
COP
99%
98%
97%
96%
y = −1.0551x2 + 1.7967x + 0.2586
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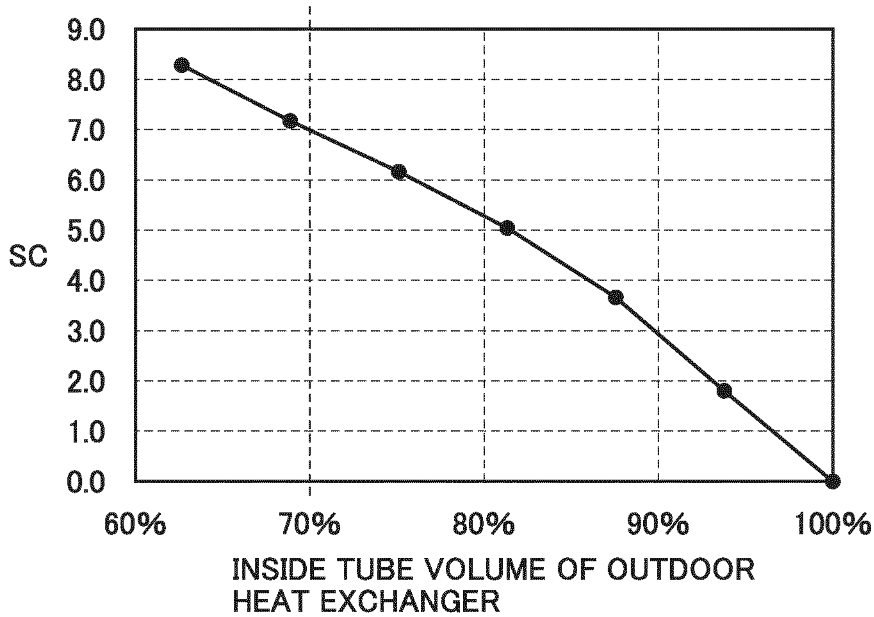
70%
80%
90%
100%
INSIDE TUBE VOLUME OF OUTDOOR HEAT EXCHANGER

FIG.6


SC
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7.0
6.0
5.0
4.0
3.0
2.0
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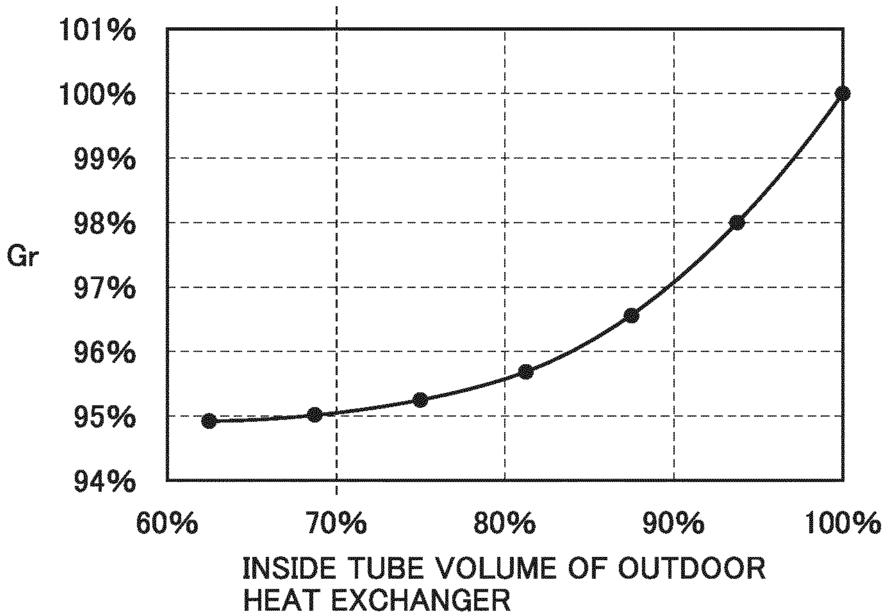
80%
90%
100%
INSIDE TUBE VOLUME OF OUTDOOR HEAT EXCHANGER

FIG.7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99%
98%
Gr
97%
96%
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70%
80%
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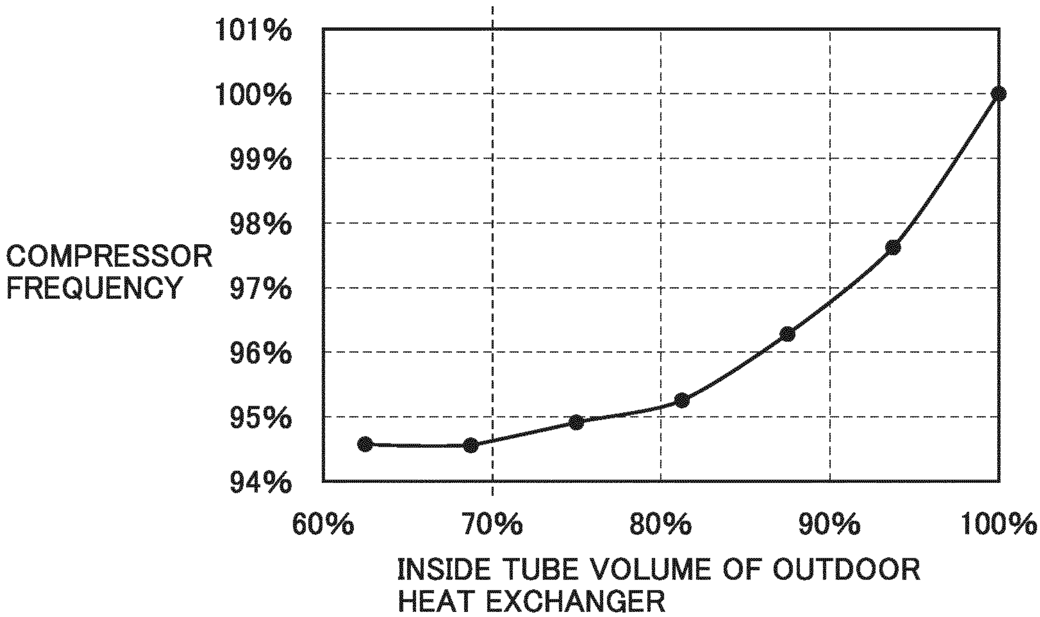
100%
INSIDE TUBE VOLUME OF OUTDOOR HEAT EXCHANGER

FIG.8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97%
96%
95%
94%
COMPRESSOR
FREQUENCY
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70%
80%
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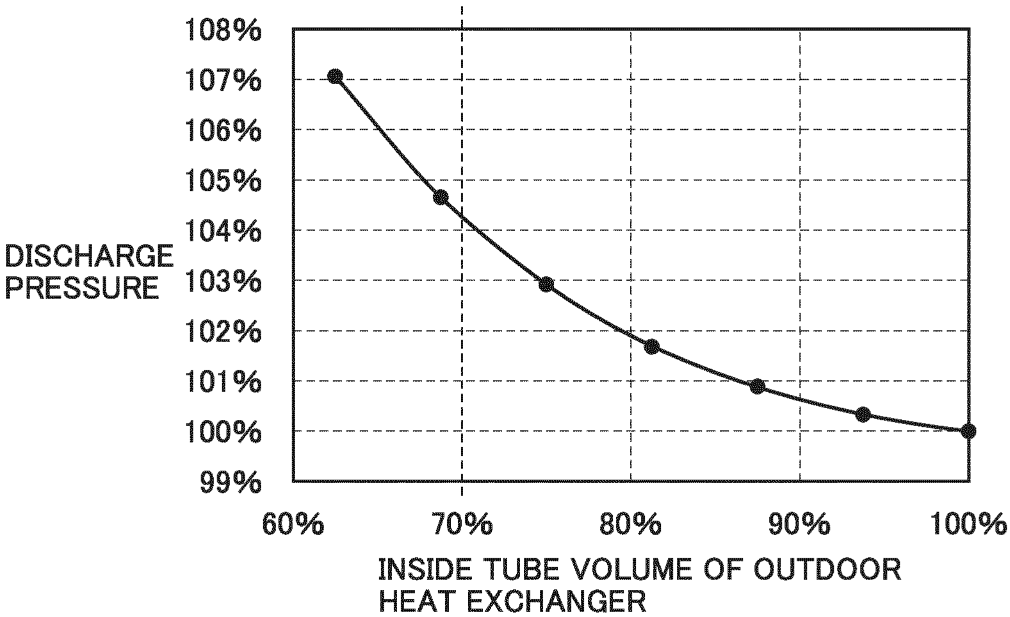
100%
INSIDE TUBE VOLUME OF OUTDOOR
HEAT EXCHANGER

FIG.9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107%
106%
105%
104%
103%
102%
101%
100%
99%
DISCHARGE PRESSURE
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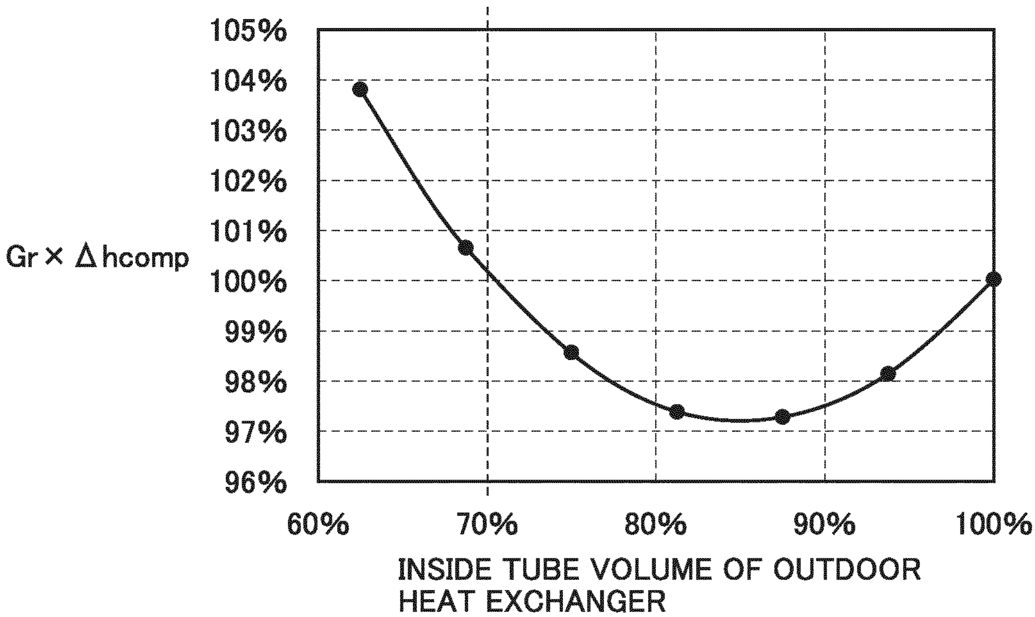
70%
80%
90%
100%
INSIDE TUBE VOLUME OF OUTDOOR HEAT EXCHANGER

FIG.10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104%
103%
102%
101%
Gr × Δhcomp
100%
99%
98%
97%
96%
60%
70%
80%
90%
100%
INSIDE TUBE VOLUME OF OUTDOOR HEAT EXCHANGER

FIG.11

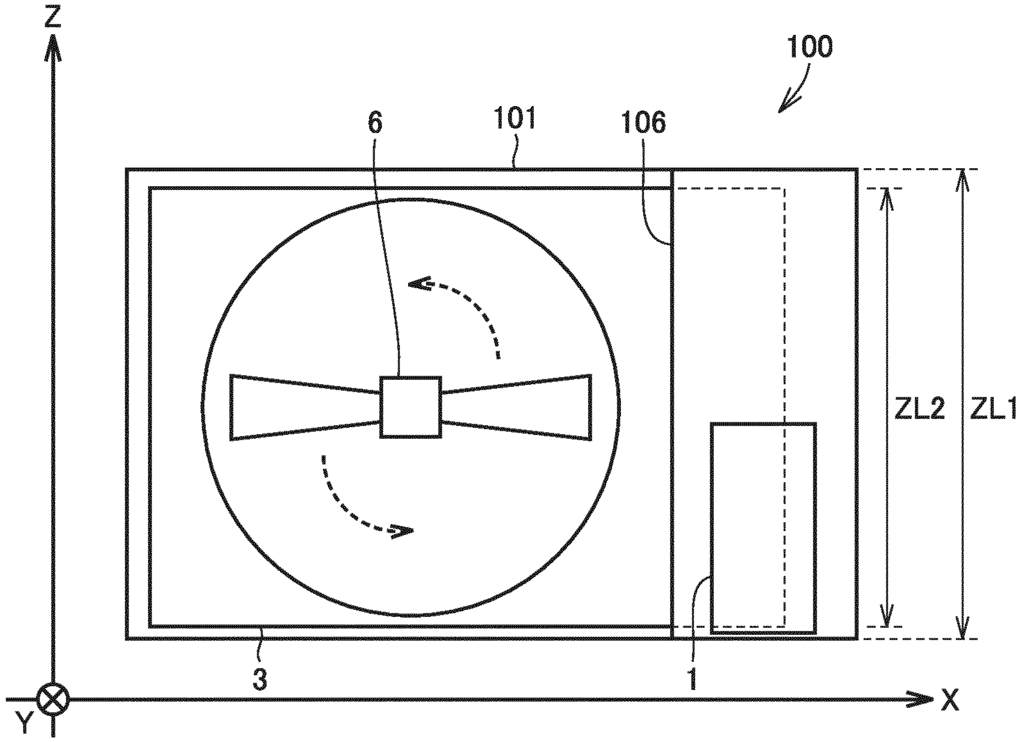


FIG.12

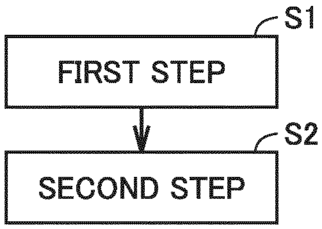


FIG.13

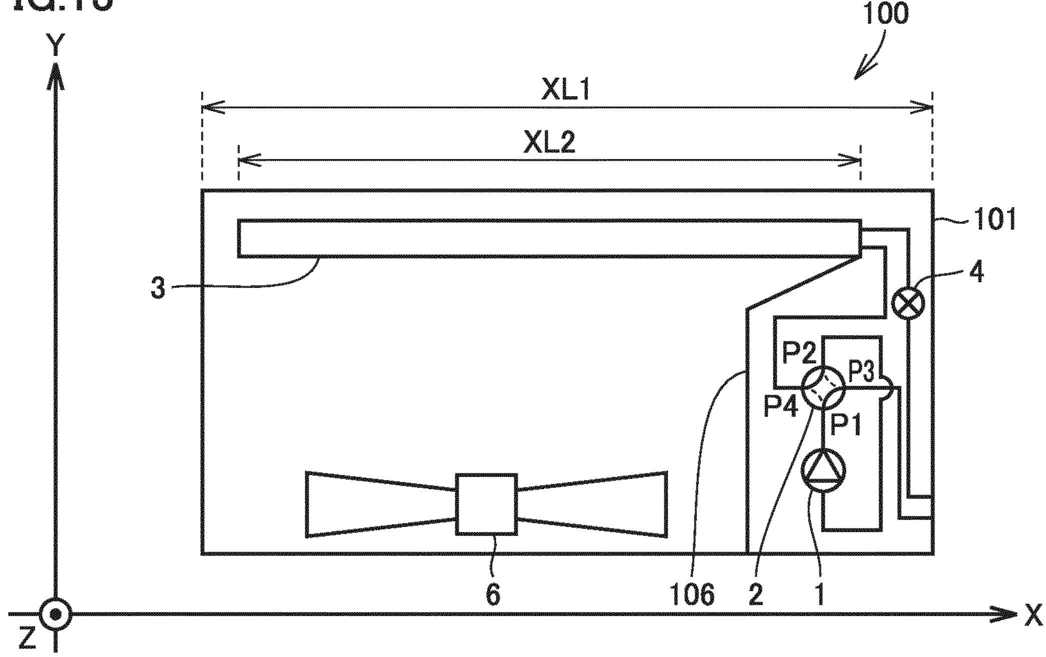


FIG.14

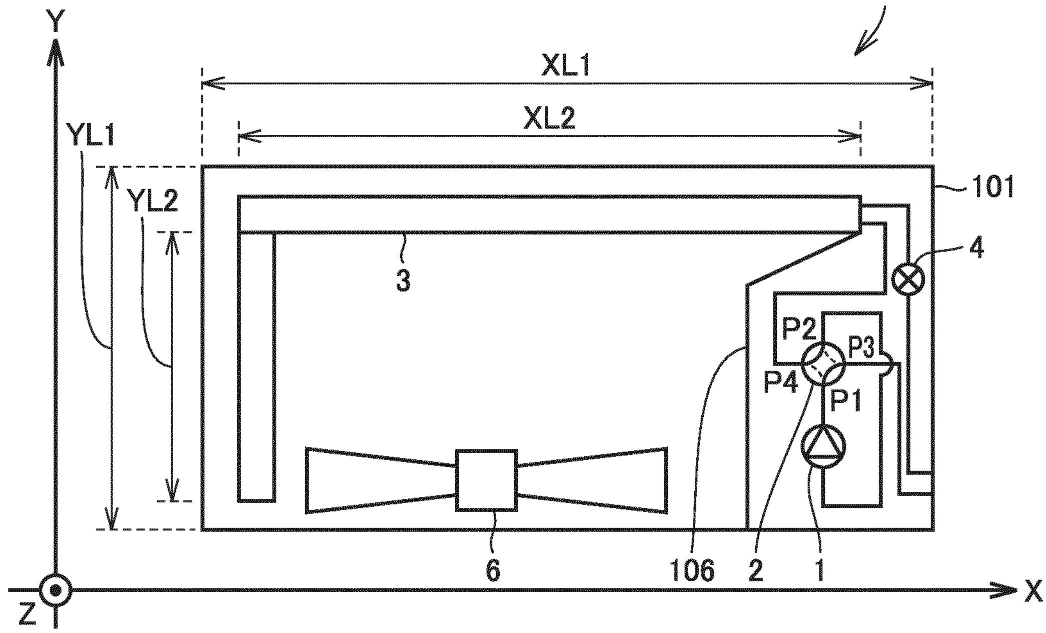


FIG.15

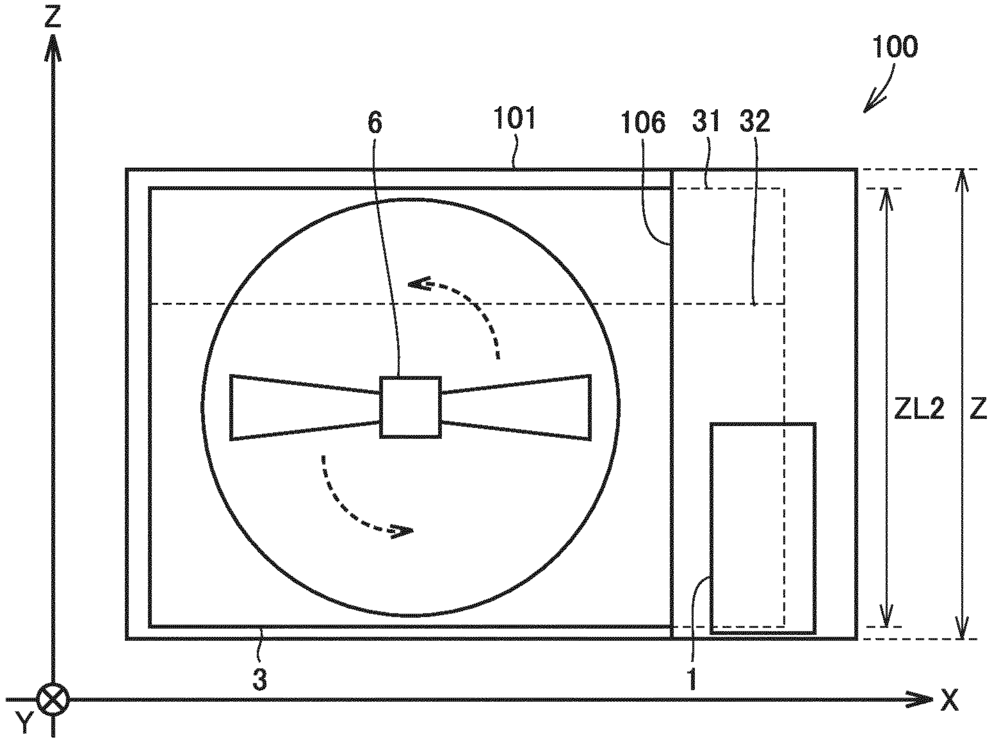


FIG.16

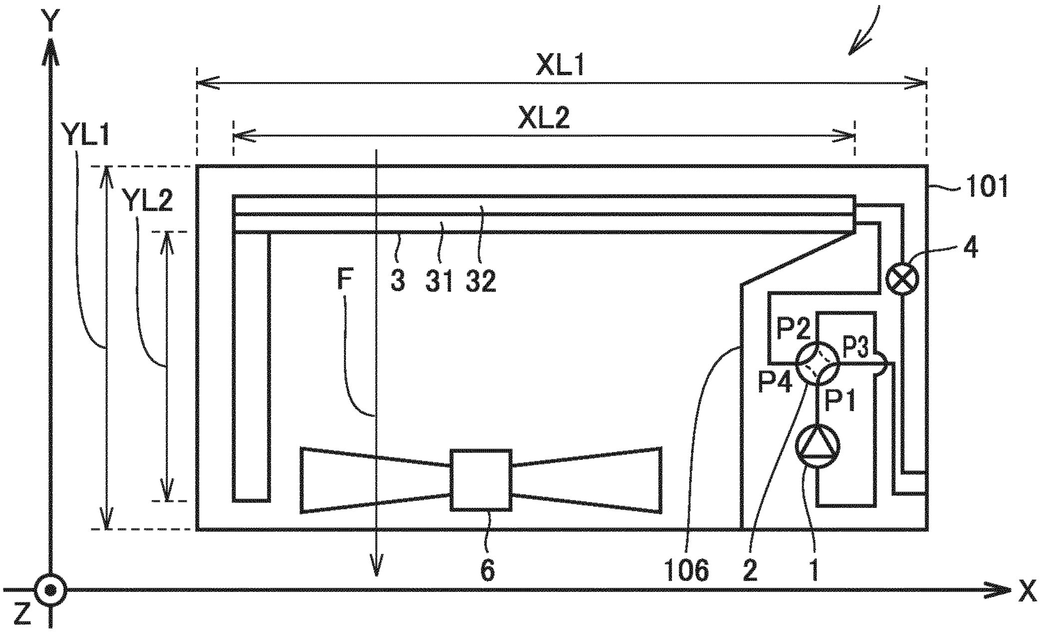


FIG.17

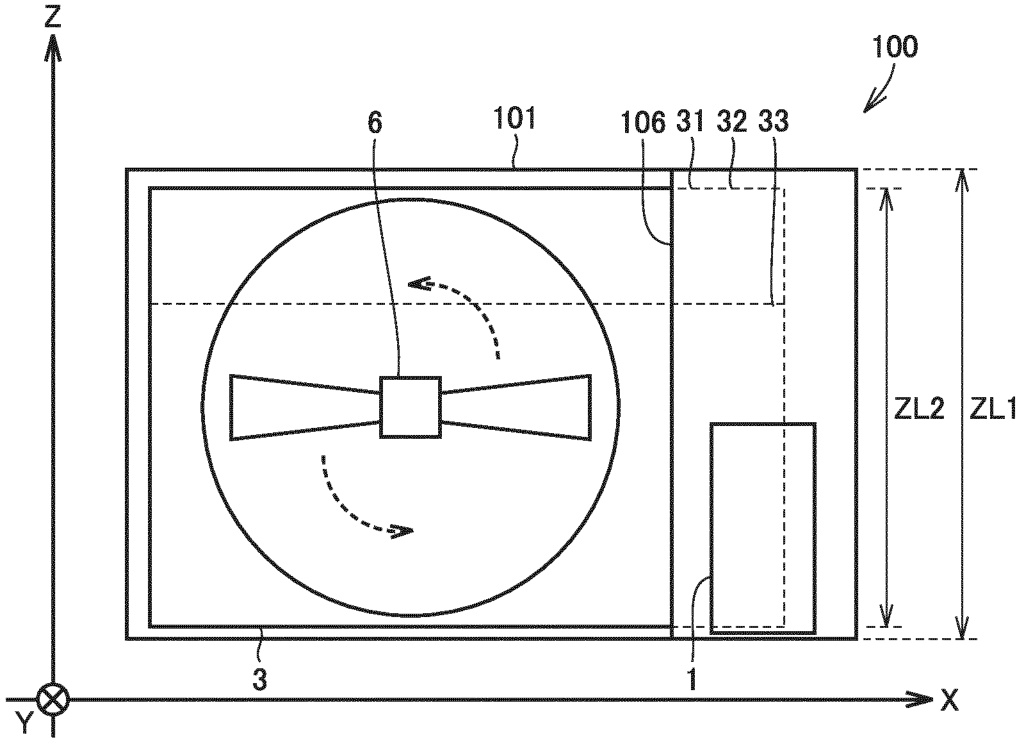
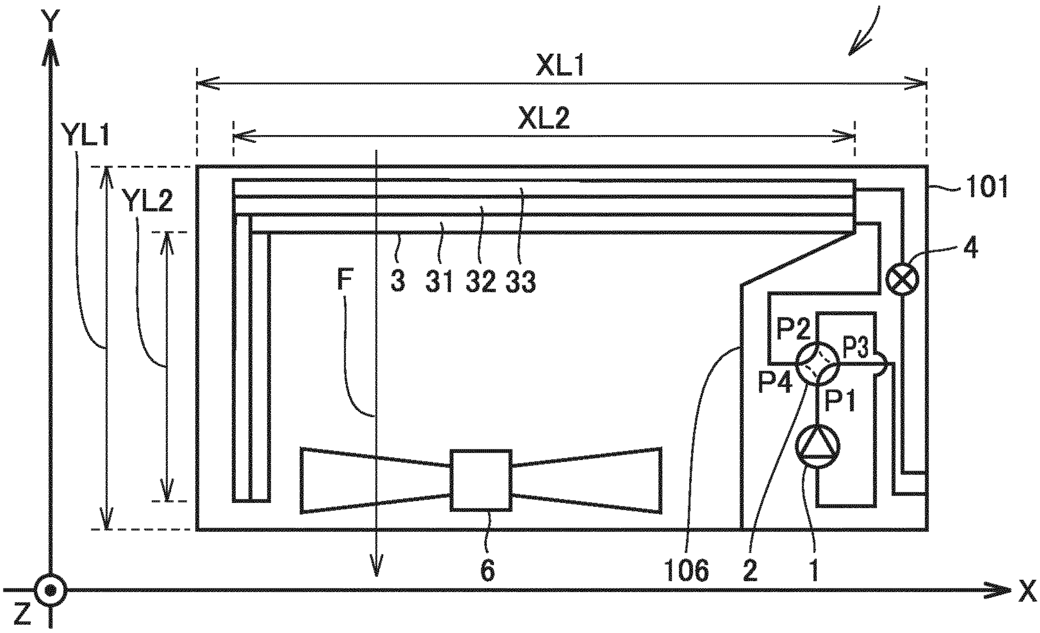


FIG.18



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2021/002459

A. CLASSIFICATION OF SUBJECT MATTER
F25B 39/00(2006.01)i; F25B 1/00(2006.01)i
FI: F25B39/00 Z; F25B1/00 396G
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F25B39/00; F25B1/00

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2001-227822 A (MITSUBISHI ELECTRIC CORP.) 24 August 2001 (2001-08-24) paragraphs [0032]-[0040]	1-14
Y	WO 2017/183068 A1 (MITSUBISHI ELECTRIC CORP.) 26 October 2017 (2017-10-26) paragraphs [0072]-[0074]	1-14
Y	JP 2017-53515 A (JOHNSON CONTROLS HITACHI AIR CONDITIONING TECHNOLOGY (HONGKONG) LTD.) 16 March 2017 (2017-03-16) paragraph [0023]	2, 12-13
Y	JP 2004-205106 A (SANYO ELECTRIC CO., LTD.) 22 July 2004 (2004-07-22) paragraph [0023]	3, 12-13
Y	JP 2019-215118 A (DAIKIN INDUSTRIES, LTD.) 19 December 2019 (2019-12-19) paragraph [0132]	4-7, 12-13

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

* Special categories of cited documents:
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 February 2021 (04.02.2021)	22 February 20021 (22.02.2021)

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

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2021/002459

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 63-299830 A (SHOWA ALUMINUM CORP.) 07 December 1988 (1988-12-07) page 2, lower left column, line 11 to page 3, upper right column, line 14, fig. 8-10	7, 11-13
Y	JP 2020-153599 A (FUJITSU GENERAL LTD.) 24 September 2020 (2020-09-24) paragraph [0037]	8-13

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

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2021/002459

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
JP 2001-227822 A	24 Aug. 2001	(Family: none)	
WO 2017/183068 A1	26 Oct. 2017	(Family: none)	
JP 2017-53515 A	16 Mar. 2017	US 2017/0067697 A1 paragraph [0035]	
JP 2004-205106 A	22 Jul. 2004	(Family: none)	
JP 2019-215118 A	19 Dec. 2019	(Family: none)	
JP 63-299830 A	07 Dec. 1988	(Family: none)	
JP 2020-153599 A	24 Sep. 2020	(Family: none)	

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2001227822 A **[0003] [0004]**