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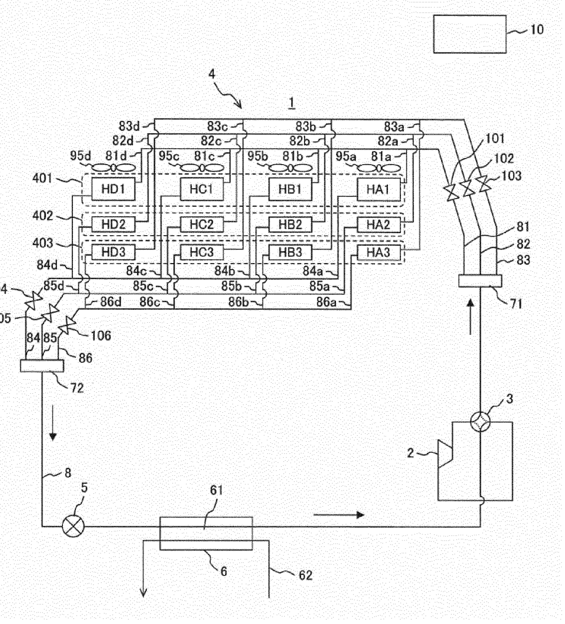
(54) **Refrigeration cycle apparatus and refrigeration unit and air-conditioning system equipped with the refrigeration cycle apparatus**

(57) A refrigeration cycle apparatus includes: a compressor; a fan (95a-95d) for heat source-side heat exchangers (4); multiple heat source-side heat exchangers (4) which exchange heat with air and are divided in the direction of height and grouped from a position close to the fan (95a-95d), including heat exchanger groups (401, 402, 403); an expansion valve (5); a use-side heat exchanger (6) which exchanges heat with a use-side heat conveying medium; a refrigerant pipe which sequentially connects the compressor (2), heat source-side heat exchangers (4), expansion valve (5), and use-side heat exchanger (6) and circulates refrigerant; and a controller (10) which controls the quantity of refrigerant flowing into each of the heat exchanger groups according to a load factor. As a result, the following can be implemented when the wind speed distribution of the heat source-side heat exchangers (4) is ununiform in the vertical direction: even in part load operation in which capacity requirement varies, refrigerant can be more appropriately distributed to the heat source-side heat exchangers and the period coefficient of performance (COP) for a refrigeration cycle apparatus can be enhanced.

FIG. 1



EP 2 693 139 A1

Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a refrigeration cycle apparatus and a refrigeration unit and an air-conditioning system equipped with the refrigeration cycle apparatus.

[0002] In (water) chilling units, generally, multiple heat source-side heat exchangers are placed so that they encircle the side faces thereof. A machine room is placed below the heat source-side heat exchangers and a fan for the heat source-side heat exchangers is placed above the heat source-side heat exchangers. Therefore, the wind speed distribution of the heat source-side heat exchangers is ununiform in the vertical direction. As a result, the ratio of the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers becomes ununiform. There used to be cases where the heat transfer area of each heat source-side heat exchanger cannot be effectively utilized.

[0003] Meanwhile, JP-A-2006-336936 discloses a heat exchange unit. It is formed by placing multiple series-connected heat transfer pipes in multiple stages so that they are orthogonal to multiple plate-like fins provided in parallel to form cores and placing two of the cores in V shape. In this heat exchange unit, each core is divided into three regions in the vertical direction and a refrigerant distribution flow path provided with a flow control means based on an orifice is provided in each region. A refrigerant flow rate is distributed according to the flow rate of air passing through each region to supply refrigerant to the heat transfer pipes.

[0004] In recent years, the following methods for calculating equipment performance have been introduced in place of the rated coefficient of performance COP (COP obtained when a heat source machine delivers rated capacity) representative of equipment performance up to now: methods for calculating equipment performance in conformity with the actual state of use such as APF (Annual Performance Factor) and IPLV (Integrated Part Load Value) as period coefficients of performance (COP). Thus performance increase is demanded not only under predetermined load conditions such as rated operation but also under operating conditions under which a load factor is low as in part load operation or a load factor fluctuates.

[0005] As the result of consideration by the present inventors, it was confirmed that the following takes place in a heat exchanger in which the wind speed distribution is ununiform in the vertical direction when operating conditions change: with the flow velocity of refrigerant in each region taken into account, the optimum ratio of refrigerant flow rates at which refrigerant should be supplied to each region according to a load factor varies. (An example of the above case is a case where such part load operation that capacity requirement varies is performed.) With the technology in JP-A-2006-336936, the ratio of refrigerant flow rate to air flow rate can be optimized under predetermined operating conditions under which the opening diameter of each orifice is set. However, the ratio of distribution of refrigerant quantity to each region is fixed by an orifice and no consideration is given to changing the ratio of refrigerant flow rate according to change in operating conditions.

SUMMARY OF THE INVENTION

[0006] It is an object of the invention to, when the wind speed distribution of heat source-side heat exchangers is uniform in the vertical direction, make it possible to more appropriately distribute refrigerant to the heat source-side heat exchangers even in part load operation in which capacity requirement varies and to increase the period coefficient of performance (COP) for a refrigeration cycle apparatus.

[0007] A refrigeration cycle apparatus of the invention includes: a compressor; a fan for a heat source-side heat exchanger; multiple heat source-side heat exchangers for heat exchange with air, divided in the direction of height and grouped from a position close to the fan to include heat exchanger groups; an expansion valve; a use-side heat exchanger for heat exchange with a use-side heat conveying medium; a refrigerant pipe which sequentially connects the compressor, heat source-side heat exchangers, expansion valve, and/or use-side heat exchanger and circulates refrigerant; and/or a controller which controls the quantity of refrigerant flowing into each of the heat exchanger groups according to a load factor.

[0008] According to the invention, the quantity of refrigerant flowing into each of heat exchanger groups grouped in the direction of height is controlled according to a load factor. Therefore, even in part load operation in which capacity requirement varies, it is possible to more appropriately distribute refrigerant to the heat source-side heat exchangers with the flow velocity of refrigerant in each region taken into account. Consequently, the period coefficient of performance (COP) for a refrigeration cycle apparatus can be enhanced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009]

FIG. 1 is a drawing illustrating a refrigerant circuit of a refrigeration unit showing an embodiment of the invention;

FIG. 2 is a schematic diagram of heat source-side heat exchangers illustrated in FIG. 1;

FIG. 3(1) is a drawing indicating the relation between the height position of a heat exchanger and the ratio of refrigerant flow rate at a load factor;

FIG. 3(2) is a drawing indicating the relation between the height position of the heat exchanger and the ratio of refrigerant flow rate at another load factor;

FIG. 3(3) is a drawing indicating the relation between the height position of the heat exchanger and the ratio of refrigerant flow rate at further another load factor;

FIG. 3(4) is a drawing indicating the relation between the height position of the heat exchanger and the ratio of refrigerant flow rate at further another load factor;

FIG. 4 is a sectional view of a unit; and

FIG. 5 is a drawing illustrating a refrigerant circuit of a refrigeration unit, explaining a third embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] First, a description will be given to the details of consideration by the present inventors. When a fan for heat source-side heat exchangers is placed above the heat source-side heat exchangers, the wind speed distribution of the heat source-side heat exchangers is ununiform in the vertical direction. Therefore, the ratio of the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers becomes ununiform and there used to be cases where the heat transfer area of each heat source-side heat exchanger cannot be effectively utilized. In this case, the refrigerant flow rate is distributed so as to implement the following to make equal the ratio of the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers: the distributed flow rate of refrigerant is made higher on the upper side of heat source-side heat exchangers high in air flow rate than on the lower side of heat source-side heat exchangers low in air flow rate. This makes it possible to bring the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers to the same level to enhance the heat exchange efficiency.

[0011] As the result of consideration by the present inventor, the following was confirmed: when operating conditions changes (in the case of such part load operation that capacity requirement changes), the optimum ratio of the flow rate of refrigerant to be supplied to each region according to a load factor differs. FIG. 3(1) to FIG. 3(4) indicate the relation between the position of the height of heat exchangers and the ratio of the flow rate of refrigerant for individual load factors and show the result of simulation carried out by the present inventors. Specifically, the drawings indicate the ratio of the flow rate of refrigerant flowing through each path when the refrigerant is let to flow in multiple paths (number of paths: 34) arranged at different heights under load factors of 100%, 75%, 50%, and 25%. The simulation was based on the premise that the higher a heat exchanger is positioned, the higher the wind speed is and the lower a heat exchanger is positioned, the lower the wind speed is. There are 34 paths and the average ratio of the flow rate of refrigerant is approximately 0.0294. The more the ratio is higher than the average, the more the quantity of refrigerant flowing in the relevant path per unit time is increased (that is, the flow velocity of refrigerant is increased). The more the ratio is lower than the average, the more the quantity of refrigerant flowing in the relevant path is reduced (the flow velocity of refrigerant is reduced.) Each horizontal axis of FIG. 3(1) to FIG. 3(4) represents the position of height of the path in a heat exchanger. Path 1 is the path placed in the uppermost portion and Path 34 is the path placed in the lowermost portion. Each vertical axis represents the ratio of the flow rate of refrigerant. In any of FIG. 3(1) to FIG. 3(4), the flow rate and flow velocity of flowing refrigerant are higher in an upper regions where the wind speed is higher. As the load factor is reduced, the flow rate and flow velocity of refrigerant are increased in upper regions where the wind speed is higher and the flow rate and flow velocity of flowing refrigerant are reduced in lower regions where the wind speed is lower.

[0012] According to this result, the flow velocity of refrigerant of the entire heat source-side heat exchangers can be increased by taking the following measure as the load factor is reduced: the ratio of the flow rate of refrigerant is increased in upper regions where the flow rate and flow velocity of refrigerant are increased more than in lower regions where the flow rate and flow velocity of refrigerant are reduced. As the result of the flow velocity of refrigerant of the entire heat source-side heat exchangers being increased, the heat transfer rate of the entire heat source-side heat exchangers is enhanced. Consequently, the heat exchange efficiency of the heat source-side heat exchangers can be further enhanced.

[0013] Therefore, for example, when the wind speed of heat source-side heat exchangers is higher on the upper side than on the lower side, the heat exchange efficiency can be enhanced by taking the following measure: the flow rate of refrigerant is distributed on the upper side of heat source-side heat exchangers higher in air flow rate more than on the lower side of heat source-side heat exchangers lower in air flow rate. The ratio of the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers is thereby brought to the same level. Further, the heat transfer rate of the entire heat source-side heat exchangers is enhanced by taking the following measure as the load factor is reduced: the ratio of the flow rate of refrigerant is increased in upper regions where the flow rate and flow velocity of refrigerant are higher more than in lower regions where the flow rate and flow velocity of refrigerant are lower. For this reason, the heat exchange efficiency of the heat source-side heat exchangers can be further enhanced.

[0014] In case of low load (FIG. 3(4) indicates a case of 25% load), as indicated by FIG. 3(4), the following takes place: the flow velocity of refrigerant remains low in proximity to the lowermost part of the heat source-side heat exchangers and refrigerant that flowed in does not contribute to heat exchange. In case of low load, therefore, the following measure is taken to cope with this: the ratio of the flow rate of refrigerant in upper regions where the flow rate and flow velocity of refrigerant are higher is increased; and further heat exchangers in lower regions where refrigerant is retained are disused. This makes it possible to use heat exchangers higher in the flow velocity of refrigerant to enhance a heat transfer rate and the heat exchange efficiency. Further, it is possible to avoid using heat exchangers on the lower side which are lower in the flow velocity of refrigerant and have refrigerant retained and do not contribute to heat exchange.

[0015] As mentioned above, refrigerant can be more appropriately distributed to heat source-side heat exchangers by taking the following measure even in part load operation in which capacity requirement changes: the quantity of refrigerant flowing into each region of heat exchangers is controlled according to a load factor.

[0016] For example, the ratio of refrigerant distributed to each region is fixed using an orifice or the like so that it is optimized under 100% load. Under 100% load, it is possible to bring the ratio of the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers to the same level to enhance the heat exchange efficiency. However, even when the load is caused to transition to 50% load, the ratio of refrigerant distribution to each region cannot be changed and the heat exchange efficiency cannot be further enhanced. When the load transitions from 100% to 25% load, refrigerant is retained and the refrigerant flows to heat exchangers on the lower side which do not contribute to heat exchange and the heat exchange efficiency is degraded. For example, the ratio of refrigerant distribution to each region is fixed using an orifice or the like so that it is optimized under 50% load. When the load is caused to transition to 100% load, in this case, the refrigerant flow velocity of heat exchangers on the upper side is reduced. For this reason, (when the heat source-side heat exchangers function as a condenser,) the following can take place in a refrigerant path so placed that the flow velocity of refrigerant is increased: the refrigerant is not completely condensed and arrives at the outlet of a heat source-side heat exchanger.

[0017] A refrigeration cycle apparatus of the invention includes: a compressor; a fan for heat source-side heat exchangers; multiple heat source-side heat exchangers for heat exchange with air, divided in the direction of height and grouped from a position close to the fan to include heat exchanger groups; an expansion valve; a use-side heat exchanger for heat exchange with a use-side heat conveying medium; a refrigerant pipe which sequentially connects the compressor, heat source-side heat exchangers, expansion valve, and use-side heat exchanger and circulates refrigerant; and a controller which controls the quantity of refrigerant flowing into each of the heat exchanger groups according to a load factor. According to the invention, the quantity of refrigerant flowing into each of the heat exchanger groups grouped in the direction of height is controlled according to a load factor. Therefore, even in part load operation in which capacity requirement varies, it is possible to more appropriately distribute refrigerant to the heat source-side heat exchangers with the flow velocity of refrigerant in each region taken into account. Therefore, it is possible to enhance the period coefficient of performance (COP) for a refrigeration cycle apparatus.

[0018] Hereafter, a description will be given to a first embodiment of the invention. FIG. 1 is a block diagram illustrating the configuration of the refrigerant circuit of arefrigerationunit. As illustrated in FIG. 1, a refrigeration unit 1 includes a compressor 2, a four way valve 3 (refrigerant flow path change-over apparatus), heat source-side heat exchangers 4, an expansion valve 5 (pressure reducing device), and a use-side heat exchanger 6. These devices are sequentially connected through a refrigerant circuit 8 to form a refrigeration cycle apparatus.

[0019] Refrigerant is filled in the refrigerant circuit 8. For the refrigerant,HFCsingle refrigerant,HFC mixed refrigerant, HFO-1234yf, HFO-1234ze, natural refrigerant (e.g. CO_2 refrigerant), and the like can be used.

[0020] Cooling operation/heating operation is performed by refrigerant being circulated in the refrigeration cycle flow path by the compressor 2. For the compressor 2, a variable discharge compressor whose discharge is controllable is used. For the compressor, piston type, rotary type, scroll type, screw type, centrifugal type, and the like can be used. The rotational speed thereof is variable from low speed to high speed by capacity control based on inverter control.

[0021] The heat source-side heat exchangers 4 including heat source-side heat exchanger units 90A (Refer to FIG. 2) cause heat exchange between air on the heat source side and a primary-side fluid flow path 61. For the heat source-side heat exchangers 4, as illustrated in FIG. 2, fin tube-type heat exchangers comprised of a large number of laminated plate-like fins 41 and multiple heat transfer pipes 42 penetrating the fins, provided in multiple stages are used. The open ends of the heat transfer pipes 42 are connected by a bend pipe or the like to form a large number of refrigerant paths. Refrigerant flows in the refrigerant paths (primary-side fluid flow path 61) and air is blown by a fan (air blower) and flows between the laminated plate-like fins 41. In the heat source-side heat exchangers 4, air and refrigerant exchange heat through the fins 41 and the heat transfer pipes 42. The heat source-side heat exchangers function as a condenser in cooling operation and function as an evaporator in heating operation.

[0022] As illustrated in FIG. 1, the heat source-side heat exchangers 4 are provided with multiple fans 95a, 95b, 95c, 95d in correspondence with the multiple heat source-side heat exchangers.

[0023] The use-side heat exchanger 6 causes heat exchange between refrigerant flowing in the primary-side fluid flow path 61 and a heat conveying medium flowing in a secondary-side fluid flow path 62. For the use-side heat exchanger 6, the following heat exchangers can be used: a plate-type heat exchanger in which heat exchange is carried out by refrigerant and a heating medium flowing in multiple flow channels alternately partitioned by plates; a shell-and-tube-type heat exchanger; and the like. Though not shown in the drawing, the heat conveying medium is circulated between a load-side heat exchanger (e.g. air-conditioning system) and a use-side heat exchanger by a circulating means such as a pump and thereby gives and receives heat. The use-side heat exchanger functions as an evaporator in cooling operation and functions as a condenser in heating operation.

[0024] The refrigeration unit 1 is equipped with a temperature sensor for detecting outdoor air temperature, refrigerant temperature, and the temperature of the heating medium. A detection signal of the temperature detected by the temperature sensor is inputted to the controller. In addition, the refrigeration unit 1 is equipped with a pressure sensor for detecting the refrigerant pressure of the refrigeration cycle. A detection signal of the pressure detected by the pressure sensor is inputted to a controller 10.

[0025] The controller 10 determines an operation mode of the refrigeration unit 1 according to a required load and controls the following in accordance with the determined operation mode: the state (opening) of each of various valves (four way valve 3, expansion valve 5, refrigerant flow rate control valves 101 to 103 and 104 to 106), the rotational speed of the compressor 2, the rotational speed of each of the fans 95a, 95b, 95c, 95d of the heat source-side heat exchangers. In addition, the controller 10 is inputted with the detection amounts detected by the temperature sensor and the pressure sensor and controls various types of operation of the refrigeration unit 1. The refrigeration unit 1 controls the operating state of the refrigeration unit according to a required load and controls the number of revolutions and the number of operated units of the fans 95a, 95b, 95c, 95d in accordance with a command from the controller.

[0026] A description will be given with a case where cooling operation is performed by the refrigeration unit 1 taken as an example. High-temperature and high-pressure gas refrigerant discharged from the compressor 2 goes through the four way valve 3 and a header 71 and flows into the heat source-side heat exchangers 4 which function as a condenser. The refrigerant which flowed into the heat source-side heat exchangers 4 radiates heat to the outside air and is thereby condensed and liquefied. The liquefied refrigerant is depressurized by the expansion valve 5 adjusted to a predetermined opening and is turned into a low-temperature and low-pressure two-phase state of gas and liquid, flowing into the primary-side flow path 61 of the use-side heat exchanger 6. The refrigerant flowing in the use-side heat exchanger 6 absorbs heat from the heat conveying medium flowing in the secondary-side flow path 62 and is thereby evaporated and gasified. The gasified refrigerant goes through the four way valve 3 and is sucked into the compressor 2 and it is then compressed again by the compressor 2 and is turned into high-temperature and high-pressure gas refrigerant. Thus the refrigeration cycle apparatus of the refrigeration unit 1 is formed. The refrigeration cycle apparatus can also be caused to function in heating operation by taking the following measure: the setting of the four way valve 3 is changed and high-temperature and high-pressure gas refrigerant discharged from the compressor 2 is circulated in the direction opposite the direction in cooling operation.

[0027] In this embodiment, as illustrated in FIG. 1, the heat source-side heat exchangers 4 include heat exchanger groups by taking the following measure: the multiple heat source-side heat exchangers are divided in the direction of height and the heat source-side heat exchangers divided in the direction of height are grouped from the upper side. That is, the heat source-side heat exchangers 4 include heat exchanger groups 401, 402, 403 formed by grouping heat exchangers substantially identical in height. The heat exchanger groups respectively include refrigerant distribution flow paths 81, 82, 83 and refrigerant merging flowpaths 84, 85, 86. The flow rate control valves 101 to 106 are provided at both ends of the heat exchanger groups. A description will be given with the uppermost heat exchanger group 401 taken as an example. The heat exchanger group 401 is comprised of four heat source-side heat exchangers (HA1, HB1, HC1, HD1). It is provided with the refrigerant distribution flow path 81 and the flow rate control valve 101 on the upstream side and the refrigerant merging flow path 84 and the flow rate control valve 104 on the downstream side.

[0028] In this embodiment, the heat source-side heat exchangers 4 are divided into multiple heat source-side heat exchangers in the direction of height. The heat transfer area obtained after the division may be changed from height to height of the heat exchangers. For example, the front face area of the heat exchangers (HA1, HB1, HC1, HD1) including the uppermost heat exchanger group 401 is set to at least 50% of the front face area of the entire heat exchangers or above. Thus the following takes place by supplying refrigerant only to upper heat exchanger groups (e.g. 401 and 402) when the required cooling capacity is low (under low load): the quantity of refrigerant flowing into the heat transfer pipes of the heat exchangers including the heat exchanger groups 401, 402 is increased. For this reason, the flow velocity in the pipes is increased and the heat transfer rate on the refrigerant side is enhanced. As a result, favorable heat exchange is carried out and the required capacity can be obtained.

[0029] The opening of each of the flow rate control valves 101 to 106 is controlled by the controller 10 according to the operating state of the refrigeration unit and an optimumquantity of refrigerant is distributed. In heat exchangers including a heat exchanger group, for example, the heat exchanger group 401, refrigerant is distributed from the refrigerant distribution flow path 81 to HA1, HB1, HC1, HD1 through 81a, 81b, 81c, 81d, respectively. The heat exchangers in an identical heat exchanger group are positioned at substantially the same height and the place of installation of a branch portion 171a is located at the same height. Therefore, refrigerant can be distributed to the heat exchangers without the influence of head difference. In addition, the effective heat transfer area of the heat exchangers is ensured and the operation efficiency can be enhanced by adjusting the opening of each of the flow rate control valves 101 to 106 so that a favorable quantity of refrigerant is distributed to the heating surface of each heat exchanger.

[0030] FIG. 2 is a schematic diagram of a heat source-side heat exchanger unit 90A of a refrigeration unit. The multiple refrigerant paths of heat source-side heat exchangers 4 are branched from branch portions 171a, 172a, 173a through branch pipes 81a, 82a, 83a on the refrigerant inlet side of the heat exchangers and refrigerant flows into the heat source-side heat exchangers 4. Multiple refrigerant paths meet at merging portions 181a, 182a, 183a and are connected to merging pipes 84a, 85a, 86a on the refrigerant outlet side of the heat source-side heat exchangers 4.

[0031] FIG. 4 is a sectional view of a unit 94 in which a fan 95 is installed above heat source-side heat exchangers 4. Air flows from outside the enclosure into the heat exchanger groups 401, 402, 403 of heat source-side heat exchangers 4 vertically installed in the unit enclosure. The air exchanges heat with refrigerant through the fins of heat source-side heat exchangers and heat transfer pipes and it then sent by a fan 95 installed at the upper part of the enclosure and flows out of the unit. The flow velocity of air passing through heat exchangers is distributed from an upper position to a lower position. More specific description will be given. In air courses 91, 92 in the upper position close to the fan 95, the flow velocity is higher than an average air flow velocity and heat exchange is accelerated. In the lower position 93, the air flow velocity is lower than the average flow velocity and heat exchange is reduced.

[0032] To cope with this, more flowing refrigerant is distributed on the upper side of heat source-side heat exchangers high in air flow rate than on the lower side of heat source-side heat exchangers low in air flow rate. This makes it possible to bring the ratio of the flow rate of air and the flow rate of refrigerant passing through the heat source-side heat exchangers to the same level and enhance the heat exchange efficiency. In addition, the ratio of refrigerant flow rate is increased in upper regions more than in lower regions. In the upper regions, the flow rate and flow velocity of refrigerant are increased with reduction in the load factor and in the lower regions, the flow rate and flow velocity of refrigerant are reduced. As a result, the heat transfer rate of the entire heat source-side heat exchangers is enhanced and thus the heat exchange efficiency of the heat source-side heat exchangers can be further enhanced.

[0033] Under low load, the flow velocity of refrigerant remains low in proximity to the lowermost part of the heat source-side heat exchangers and refrigerant which flowed in does not contribute to heat exchange. Therefore, the following measure may be taken: the ratio of refrigerant flow rate is increased in upper regions where the flow rate and flow velocity of refrigerant are high and heat exchangers in lower regions where refrigerant are retained are disused. This makes it possible to use heat exchangers high in refrigerant flow velocity to increase a heat transfer rate and enhance the heat exchange efficiency. In addition, it is possible to avoid using lower heat exchangers which are low in refrigerant flow velocity and do not contribute to heat exchange because of the retention of refrigerant.

[0034] As described up to this point, the following measure is taken in a refrigeration cycle apparatus (refrigeration unit) in this embodiment: multiple heat source-side heat exchangers are divided in the direction of height and the heat source-side heat exchangers divided in the direction of height are grouped from the upper side to include heat exchanger groups; and according to the load on the use-side heat exchanger, the quantity of refrigerant flowing into each of the heat exchanger groups is controlled. As a result, the quantity of refrigerant flowing into each of the heat exchanger groups grouped in the direction of height is controlled according to the load on the use-side heat exchanger. For this reason, even in part load operation in which capacity requirement varies, refrigerant can be more appropriately distributed to the heat source-side heat exchangers with the flow velocity of refrigerant in each region taken into account. Therefore, the period coefficient of performance (COP) for a refrigeration cycle apparatus can be enhanced.

[0035] A description will be given to a second embodiment of the invention. In this embodiment, the heat exchanger groups are used as follows according to the load factor of the refrigeration cycle apparatus: they are used from the heat exchanger group 401 placed in the uppermost position among the heat exchanger groups grouped in the direction of height in the first embodiment. In the heat exchanger group 403 which is not used, refrigerant is discharged from the heat exchanger group 403 and the other heat exchanger groups 401, 402 are used to operate the refrigeration cycle apparatus.

[0036] As indicated in FIGS. 3(1) to 3(4), the following takes place when the wind speed distribution of the heat source-side heat exchangers is higher on the upper side than on the lower side: the flow velocity of refrigerant is higher in upper heat source-side heat exchangers. In case of 25% load, the flow velocity of refrigerant is low in proximity to the lowermost part of the heat source-side heat exchangers and refrigerant is retained. The refrigerant which flowed in does not contribute to heat exchange.

[0037] Therefore, the following measure is taken in a refrigeration cycle apparatus in this embodiment: according to the load factor of the refrigeration cycle apparatus, the heat exchanger groups grouped in the direction of height are selectively and sequentially used from the heat exchanger group 401 placed in the uppermost position. As mentioned above, the heat exchanger groups grouped in the direction of height are sequentially used from the heat exchanger group placed in the uppermost position. When this is done in operating conditions in which the load factor of the refrigeration cycle apparatus is low, the following advantages are brought: a heat exchanger high in refrigerant flow velocity can be used to increase a heat transfer rate and enhance the heat exchange efficiency. In addition, it is possible to avoid using a heat exchanger group which is low in refrigerant flow velocity and does not contribute to heat exchange because of the retention of refrigerant.

[0038] In a refrigeration cycle apparatus in this embodiment, with respect to a heat exchanger group which is not used, refrigerant is discharged from the heat exchanger group and the other heat exchanger groups are used to operate the refrigeration cycle apparatus. In a heat exchanger group low in refrigerant flow velocity, refrigerant is retained and it does not contribute to heat exchange. If refrigerant is left retained in this heat exchanger group which does not contribute to heat exchange, the quantity of refrigerant circulating in the other heat exchanger groups that contribute to operation is reduced and the heat exchange efficiency will be degraded. If the quantity of filled refrigerant in advance to avoid this, it will be necessary to fill the refrigeration cycle apparatus with unnecessary refrigerant in excess of essentially necessary refrigerant. When refrigerant is discharged from a heat exchanger group which is not used and the other heat exchanger groups are used to operate a refrigeration cycle apparatus as in this embodiment, the following advantages are brought: the quantity of refrigerant filled in the refrigeration cycle apparatus can be optimized and degradation in heat exchange efficiency can be avoided.

[0039] A concrete description will be given with reference to FIG. 1. In the refrigeration unit 1, the flow rate control valve 103 of the refrigerant distribution flow path 83 is closed and the opening of the expansion valve 5 is reduced and operation is performed for a certain time. The pressure in the heat exchangers including the heat exchanger group 403 is reduced and made lower than the pressure obtained when capacity requirement is met. The quantity of refrigerant remaining in the heat exchangers is thereby reduced. Subsequently, the flow rate control valve 106 of the refrigerant merging flow path 86 is closed to stop the supply of refrigerant to the heat exchanger group 403. Thereafter, cooling operation in accordance with capacity requirement is performed. The refrigerant flows into the heat exchanger groups 401, 402 and carries out heat exchange. However, the distribution of refrigerant to the heat exchanger group 401 and the heat exchanger group 402 is carried out by adjusting the opening of each of the flow rate control valves 101, 102.

[0040] As mentioned above, the following can be implemented by disusing the heat exchangers (HA3, HB3, HC3, HD3) at the lower part: the quantity of refrigerant flowing into the heat transfer pipes of the heat exchangers including the heat exchanger groups 401, 402 is increased; consequently, the flow velocity in the pipes is increased and a refrigerant-side heat transfer rate is enhanced and favorable heat exchange is performed.

[0041] Disusing the heat exchangers (HA3, HB3, HC3, HD3) at the lower part makes it possible to prevent refrigerant from being retained in the heat exchangers at the lower part and optimize the quantity of refrigerant filled in the refrigeration unit system. In general, the quantity of refrigerant filled in a refrigeration unit is based on the volumetric capacity of the refrigeration cycle so that the capacity required of the system in cooling operation and in heating operation is met. In cooling operation, an air heat exchanger (heat source-side heat exchanger) acts as a condenser and cools and liquefies refrigerant in a superheated gas state. At the outlet of the heat exchanger, multiple refrigerant pipes going out of each path merge with the merging portions 181a, 182a, 183a. (Refer to FIG. 2.) For example, when the merging portion 181a is positioned higher than the path outlet of the relevant heat exchanger, liquid refrigerant is sometimes retained in the pipe from the path outlet of the heat exchanger to the merging portion and refrigerant becomes hard to flow. Since the quantity of refrigerant flowing through one path is reduced, this state is prominent under low load conditions. Refrigerant is retained in a path at the lower part of a heat exchanger and a heat transfer area is not effectively used anymore. The retained refrigerant does not circulate in the refrigeration cycle and remains in the heat exchanger. For this reason, it is required to increase the quantity of filled refrigerant to achieve cycle conditions in correspondence with the capacity requirement. This leads to an excessive quantity of filled refrigerant and this is a minus element in terms of cost and environmental load.

[0042] Disusing the heat exchangers (HA3, HB3, HC3, HD3) at the lower part as in this embodiment makes it possible to implement the following: refrigerant is prevented from being retained in a heat exchanger and a favorable heat transfer area is ensured under operating conditions corresponding to a load factor. Therefore, the efficiency of heat exchange under low load is enhanced and the operating efficiency can be enhanced.

[0043] A description will be given to a third embodiment of the invention with reference to FIG. 5. Unlike the refrigerant distribution circuit in the first embodiment illustrated in FIG. 1, the following measure is taken: each of the refrigerant distribution flow paths 81, 82, 82 is branched into two flow paths at branch portions A, B, C; and thereafter, each flow path is further branched into two at a branch portion D and a branch portion G, a branch portion E and a branch portion H, and a branch portion F and a branch portion I. Providing a flow rate regulating valve in each branched flow path makes it possible to control the refrigerant flow rate to a specific heat exchanger among the refrigerant flow rates distributed to heat exchanger groups.

[0044] In each above embodiment, the following measure may be taken with respect to the pipe diameter of the refrigerant distribution flow paths 81, 82, 83 to the heat exchange groups 401, 402, 403: the pipe diameter of the refrigerant distribution flow path 81 to the heat exchanger group 401 in the upper position is set to a large value; the pipe diameter of the refrigerant distribution flow path 81 to the heat exchanger group 402 in the middle position is set to amediumvalue; and the pipe diameter of the refrigerant distribution flow path 83 to the heat exchanger group 403 in the lower position is set to a small value. With this configuration, pressure loss differs depending on pipe diameter when refrigerant flows. Therefore, it is possible to make large the quantity of refrigerant supplied to the heat exchanger group 401 in the upper position and make small the quantity of refrigerant supplied to the heat exchanger group 403 in the lower position. The upper heat exchanger group large in pipe diameter is supplied with more refrigerant than the lower heat exchanger group is. For this reason, when the wind speed distribution of the heat source-side heat exchangers is higher on the upper side than on the lower side, refrigerant is supplied in accordance with wind speed distribution. This makes it possible to suppress reduction in exchange heat quantity caused by the ununiformity of wind speed distribution and contribute to the enhancement of coefficient of performance (COP).

[0045] In the description of each above embodiment, a refrigeration cycle apparatus in this embodiment is applied to the refrigeration unit 1 ((water) chilling unit) which supplies a heating medium whose heat is exchanged by a use-side heat exchanger 6 to load-side equipment (not shown). Instead, the refrigeration cycle apparatus in this embodiment can also be applied to an air-conditioner or the like.

Features, components and specific details of the structures of the above-described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are apparent for an expert skilled in the art they shall be disclosed implicitly by the above description without specifying explicitly every possible combination.

Claims

1. A refrigeration cycle apparatus comprising:

a compressor (2);
a fan (95a-95d) for heat source-side heat exchangers;
a plurality of heat source-side heat exchangers (4) which exchange heat with air and are divided in the direction of height and grouped from a position close to the fan (95a-95d), including heat exchanger groups (401, 402, 403);
an expansion valve (5);
a use-side heat exchanger (6) which exchanges heat with a use-side heat conveying medium;
a refrigerant pipe which sequentially connects the compressor (2), the heat source-side heat exchangers (4), the expansion valve (5), and the use-side heat exchanger (6) and circulates refrigerant; and
a controller (10) which controls the quantity of refrigerant flowing into each of the heat exchanger groups (401, 402, 403) in accordance with a load factor.

2. The refrigeration cycle apparatus according to Claim 1,
wherein the controller (10) increases the ratio of refrigerant flowing into the heat exchanger group (401, 402, 403) higher in wind speed with reduction in the load factor.

3. The refrigeration cycle apparatus according to Claim 1,
wherein the controller (10) increases the ratio of refrigerant flowing into the heat exchanger group (401, 402, 403) higher in wind speed and increases the ratio of refrigerant flowing into the heat exchanger group (401, 402, 403) higher in wind speed with reduction in the load factor.

4. The refrigeration cycle apparatus according to Claim 1,
wherein the fan (95a-95d) is placed above the heat source-side heat exchangers (4), and
wherein the controller (10) increases the ratio of refrigerant flowing into the heat exchanger group (401, 402, 403) placed in an upper position with reduction in the load factor.

5. The refrigeration cycle apparatus according to Claim 1,
wherein the fan (95a-95d) is placed above the heat source-side heat exchangers (4), and
wherein the controller (10) increases the ratio of refrigerant flowing into the heat exchanger group (401, 402, 403) placed in an upper position and increases the ratio of refrigerant flowing into the heat exchanger group (401, 402, 403) placed in an upper position with reduction in the load factor;

6. The refrigeration cycle apparatus according to any of Claims 1 to 5,
wherein the heat exchanger groups (401, 402, 403) are each provided on the refrigerant inflow side with an inflow controller, and
wherein the controller (10) controls the inflow controllers to control the quantity of refrigerant flowing into each of the heat exchanger groups (401, 402, 403).

7. The refrigeration cycle apparatus according to any of Claims 1 to 6,
wherein as the load factor is increased, the heat exchanger groups (401, 402, 403) are sequentially

used from the heat exchanger group (401, 402, 403) placed in the uppermost position to operate the refrigeration cycle apparatus.

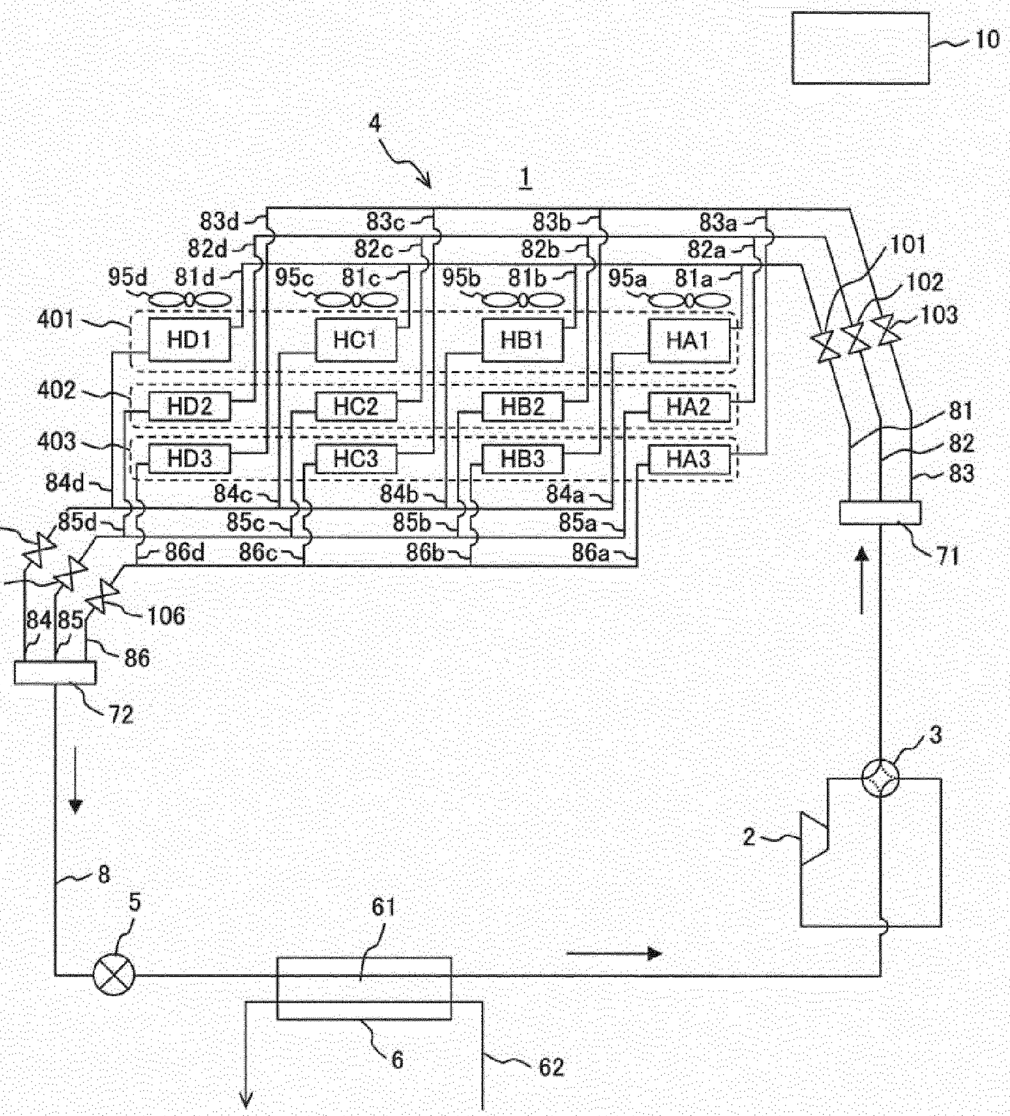
8. The refrigeration cycle apparatus according to at least one of Claims 1 to 7,
wherein the refrigeration cycle apparatus is operated with refrigerant discharged from the heat exchanger group (401, 402, 403) which is not used.

9. The refrigeration cycle apparatus according to at least one of Claims 1 to 8,
wherein the heat exchanger groups (401, 402, 403) are eachprovidedwith an inflow controller on the refrigerant inflow side and an outflow controller on the refrigerant outflow side, and
wherein with the compressor driven, the inflow controller is brought into a closed state and then the outflow controller is brought into a closed state, refrigerant being thereby discharged from the heat exchanger groups (401, 402, 403) which are not used.

10. A refrigeration unit equipped with the refrigeration cycle apparatus according to any of Claims 1 to 9.

11. An air-conditioner equipped with the refrigeration cycle apparatus according to any of Claims 1 to 9.

FIG. 1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401
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HC1
HB1
HA1
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HC2
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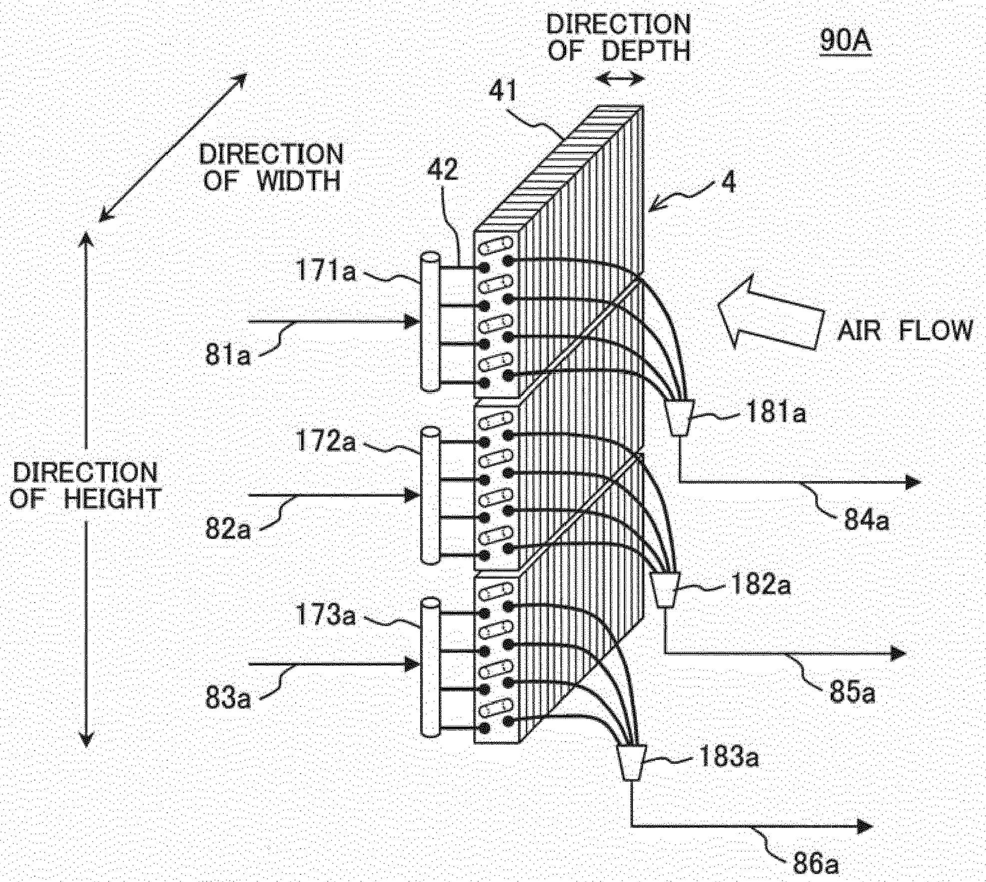
FIG. 2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86a

FIG. 3(1)

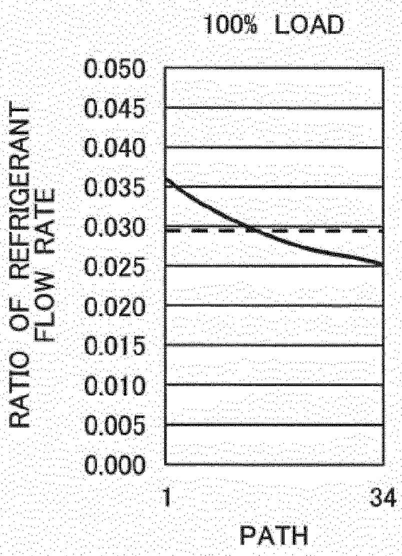


FIG. 3(2)

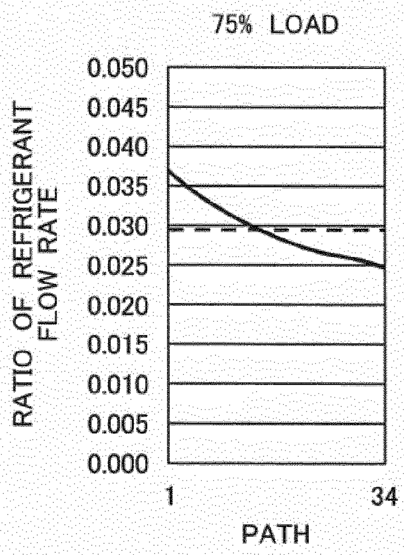


FIG. 3(3)

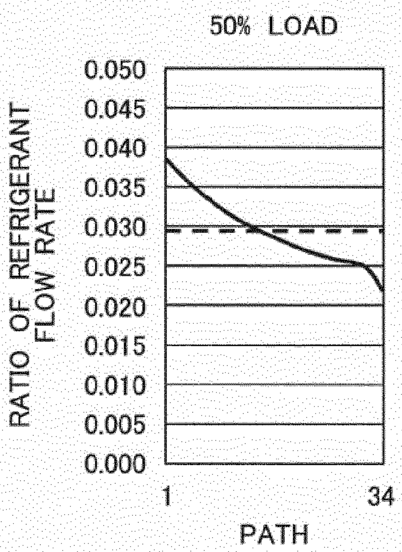


FIG. 3(4)

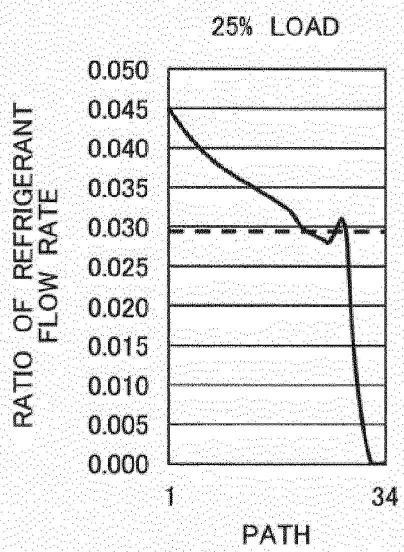


FIG. 4

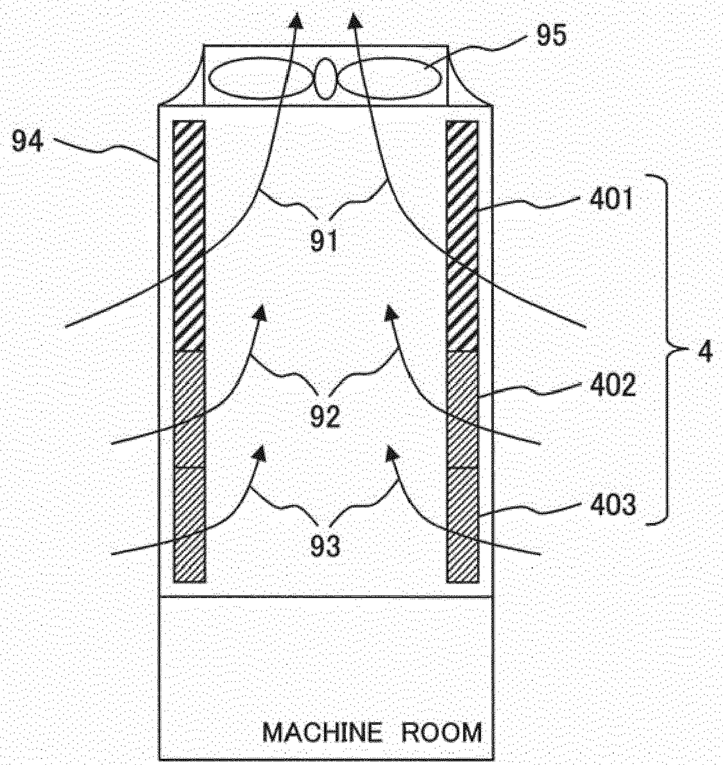
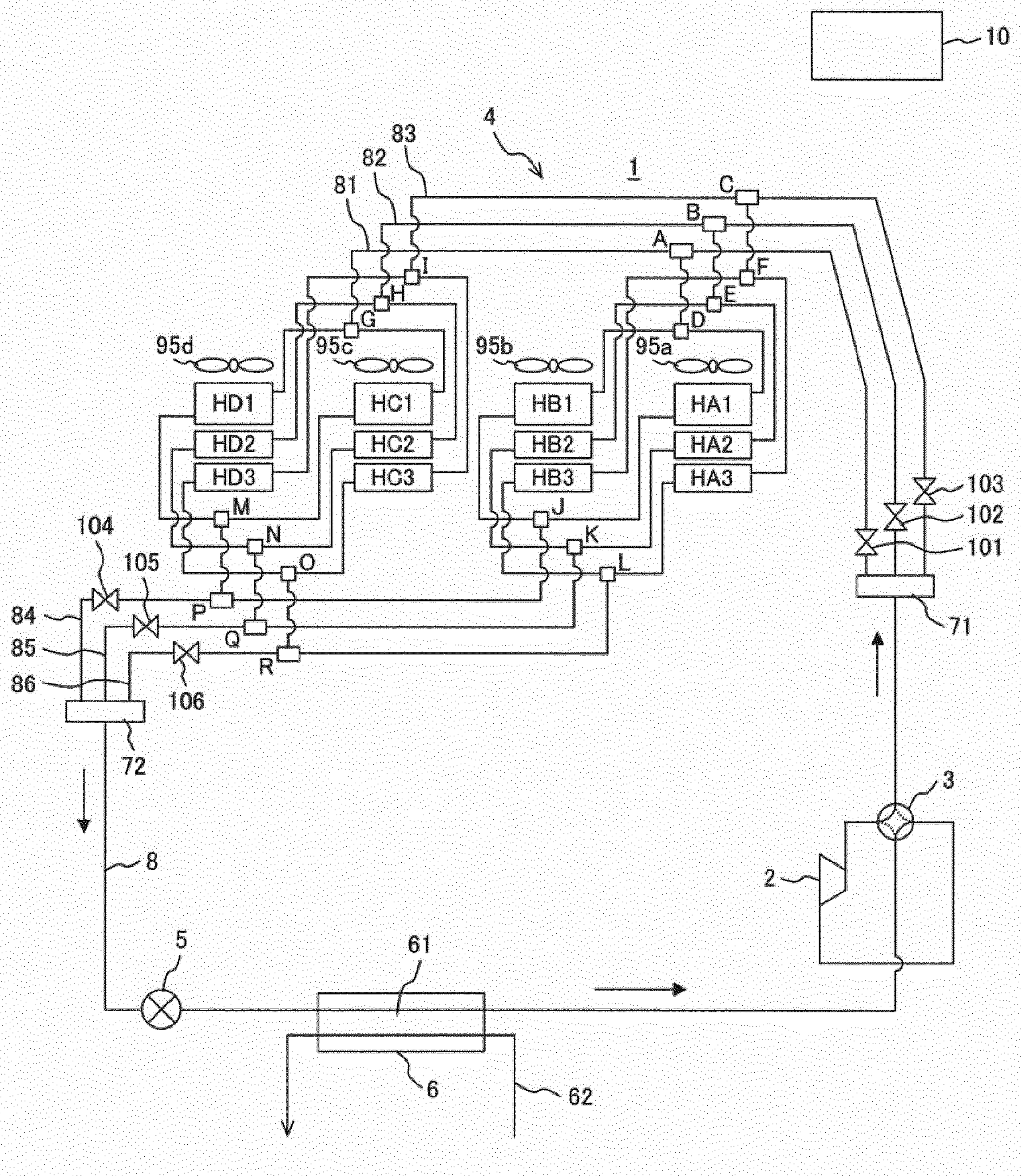


FIG. 5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EUROPEAN SEARCH REPORT

Application Number
EP 13 17 8031

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X	EP 1 793 179 A1 (TOSHIBA CARRIER CORP [JP]) 6 June 2007 (2007-06-06) * paragraphs [0018] - [0039]; figures 1-5 * -----	1-11	INV. F25B6/02 F25B5/02
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F25B

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	7 October 2013	Amous, Moez

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