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(54) **Heat pump system**

Wärmepumpensystem

Système de pompe à chaleur

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(73) Proprietor: **Mitsubishi Heavy Industries**
Tokyo 108-8215 (JP)

(72) Inventors:
- **Mori, Takachika**
  Tokyo, 108-8215 (JP)
- **Yamaguchi, Toru**
  Tokyo, 108-8215 (JP)
- **Akatsuka, Kei**
  Tokyo, 108-8215 (JP)
- **Fuchimoto, Takeshi**
  Tokyo, 108-8215 (JP)

(74) Representative: **Intès, Didier Gérard André et al**
Cabinet Beau de Loménie
158 rue de l'Université
75340 Paris Cedex 07 (FR)

(56) References cited:
WO-A1-2008/053959
JP-A- 2002 048 359
JP-A- 2008 267 722
JP-A- 2008 267 729

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Description

{Technical Field}

[0001] The present invention relates to a heat pump system in which a plurality of heat pump chillers are connected to a single cold/hot water circuit.

{Background Art}

[0002] In a heat pump system in which a plurality of heat pump chillers are connected to a single cold/hot water circuit to produce cold water or hot water, the plurality of heat pump chillers are connected in series to the single cold/hot water circuit, as disclosed in PTLs 1 and 2, or the plurality of heat pump chillers are connected in parallel to the single cold/hot water circuit, as disclosed in PTL 3.

{Citation List}

{Patent Literature}

[0003]

{PTL 1} Japanese Unexamined Patent Application, Publication No. HEI 4-350468
{PTL 2} Japanese Unexamined Patent Application, Publication No. 2007-198693
{PTL 3} Japanese Unexamined Patent Application, Publication No. 2002-195684

[0004] JP2008267722 (A) discloses a refrigerating air conditioner including a plurality of parallel circuits each comprising a plurality of compressors.

{Summary of Invention}

{Technical Problem}

[0005] In a system in which a plurality of heat pump chillers are connected in series to a cold/hot water circuit, as disclosed in PTLs 1 and 2 described above, the pipe length of the cold/hot water circuit for the plurality of heat pump chillers connected in series is long. Accordingly, when a large amount of water is made to flow, the water sometimes cannot be made to completely flow out due to the insufficient head of the water pump. This requires using a pump with a higher head than is necessary or a pump with a larger capacity than is necessary, thus causing a problem in that the motive power of the pump is increased, which increases the running costs, etc.

[0006] On the other hand, in a system in which a plurality of heat pump chillers are connected in parallel to a cold/hot water circuit, as disclosed in PTL 3 described above, the water is diverted by a parallel circuit to the heat pump chillers connected in parallel when the flow rate is low. Accordingly, this reduces the amount of water flowing in the water circuits of the individual heat pump chillers. This therefore poses a problem in that, for example, the heat transfer coefficients of water in refrigerant/water heat exchangers decrease, and hence the efficiency is reduced.

[0007] The present invention is made in consideration of such circumstances, and an object thereof is to provide a heat pump system that can eliminate an insufficient pump head when the flow rate is high, a decrease in efficiency when the flow rate is low, and so on, so that the heat pump system can be operated constantly at high efficiency.

{Solution to Problem}

[0008] The invention refers to a heat pump system according to claim 1.
To solve the foregoing problems, a heat pump system of the present invention employs the following solutions.

[0009] That is, a heat pump system according to an aspect of the present invention is a heat pump system in which a plurality of heat pump chillers are connected to a single cold/hot water circuit equipped with a water pump, wherein the plurality of heat pump chillers are divided into a plurality of series, the heat pump system comprising a parallel circuit in which the heat pump chillers of the individual series are connected in parallel to the single cold/hot water circuit; and a series circuit in which the heat pump chillers of the individual series are connected in series to the single cold/hot water circuit, wherein the parallel circuit and the series circuit are switchable to each other via a switching means.

[0010] According to the aspect of the present invention, the plurality of heat pump chillers connected to the single cold/hot water circuit are divided into a plurality of series, and the heat pump system includes a parallel circuit in which the heat pump chillers of the individual series are connected in parallel to the single cold/hot water circuit; and a series circuit in which the heat pump chillers of the individual series are connected in series to the single cold/hot water circuit, wherein the parallel circuit and the series circuit are switchable to each other via a switching means. Therefore, if there is a possibility of an increase in the flow rate of water flowing in the single cold/hot water circuit, so that the water pump cannot make the water completely flow out due to the insufficient head, the cold/hot water circuit leading to the plurality of heat pump chillers is switched to the parallel circuit formed of the individual series to decrease the pipe length of the cold/hot water circuit leading to the plurality of heat pump chillers, thereby ensuring a sufficient pump head to allow the water to be made to completely flow out. On the other hand, in the case where the water flow rate is low, so that there is some excess pump head, the cold/hot water circuit leading to the plurality of heat pump chillers is switched to the series circuit to make the water flow in series in the plurality of heat pump chillers, thereby preventing a decrease in the water flow rates of the refrig-

erant/water heat exchangers to suppress a decrease in the water-side heat transfer coefficients, so that the individual heat pump chillers can be operated at high efficiency. Accordingly, as the water pump, there is no need to employ a higher head pump or a larger capacity pump than is necessary, which can reduce the cost of the water pump and save power, and allows the heat pump chillers to be individually operated constantly at high efficiency, thus enhancing the COPs (coefficients of performance).

[0011] Furthermore, in the foregoing heat pump system, the heat pump chillers in each series are constituted by a plurality of the heat pump chillers connected in series.

[0012] According to the aspect of the present invention, the -heat pump chillers in each series are constituted by a plurality of the heat pump chillers connected in series. This can increase or decrease the number of heat pump chillers to be connected by connecting two or three heat pump chillers in series in each series or by increasing the number of series to two or three. This can make it easy to adjust the performance of the heat pump system and can optimize the COPs of the water pump and the individual heat pump chillers.

[0013] Furthermore, in the foregoing heat pump system, the plurality of heat pump chillers in each series are modularized into a single unit and are connectable in parallel or in series for each of the modules via the parallel circuit or the series circuit.

[0014] According to the aspect of the present invention, the plurality of heat pump chillers in each series are modularized into a single unit and are connectable in parallel or in series for each of the modules via the parallel circuit or the series circuit. This allows the plurality of heat pump chillers in each series to be modularized and to be installed as a single unit. Accordingly, the higher the number of heat pump chillers to be connected, the better the ease-of-installation and the lower the cost that can be achieved.

[0015] Furthermore, in one of the foregoing heat pump systems, the parallel circuit is a circuit that connects the heat pump chillers of the individual series in parallel with each other to the single cold/hot water circuit, and the series circuit is a circuit that connects the cold/hot water circuit outlet side of the heat pump chillers in a first series to the cold/hot water circuit inlet side of the heat pump chillers in a second series.

[0016] According to the aspect of the present invention, the parallel circuit is a circuit in which the heat pump chillers of the individual series are connected in parallel with each other to the single cold/hot water circuit, and the series circuit is a circuit in which the cold/hot water circuit outlet side of the heat pump chillers in the first series is connected to the cold/hot water circuit inlet side of the heat pump chillers in the second series. This allows the cold/hot water circuit leading to the plurality of heat pump chillers to be easily switched to one of the parallel circuit and the series circuit by making the circuits that are connected in parallel for each series communicate with the single cold/hot water circuit or by closing the cold/hot water circuit outlet side in the first series and the cold/hot water circuit inlet side in the second series to bring the series circuit that connects them into a communicating state with the switching means. Accordingly, optimum operation depending on the circumstances can be achieved by switching the plurality of heat pump chillers to serial connection or parallel connection depending on the operation mode.

[0017] Furthermore, in the foregoing heat pump system, the switching means is constituted by a first solenoid valve provided at the cold/hot water circuit outlet side of the heat pump chillers in the first series, a second solenoid valve provided at the cold/hot water circuit inlet side of the heat pump chillers in the second series, and a third solenoid valve provided in the series circuit.

[0018] According to the aspect of the present invention, the switching means is constituted by a first solenoid valve provided at the cold/hot water circuit outlet side of the heat pump chillers in the first series, a second solenoid valve provided at the cold/hot water circuit inlet side of the heat pump chillers in the second series, and a third solenoid valve provided in the series circuit. Therefore, by opening the first solenoid valve and the second solenoid valve and closing the third solenoid valve, the parallel circuit in which the cold/hot water circuits of the individual series are connected in parallel is formed, and by closing the first solenoid valve and the second solenoid valve and opening the third solenoid valve, the series circuit in which the cold/hot water circuits of the individual series are connected in series can be formed. This allows simple switching to the parallel circuit or the series circuit by turning on and off the inexpensive solenoid valves, thus ensuring reliable circuit switching.

[0019] Furthermore, in the foregoing heat pump system, the first solenoid valve and the third solenoid valve are replaced with a single three-way switching valve provided at a joint portion of the series circuit to the first series cold/hot water circuit.

[0020] According to the aspect of the present invention, the first solenoid valve and the third solenoid valve are replaced with a three-way switching valve provided at a joint portion of the series circuit to the first series cold/hot water circuit. This can reduce the number of valves that constitute a switching means to simplify the cold/hot water circuit. This can decrease the number of components and man-hours for installing the pipe of the cold/hot water circuit to reduce the cost.

[0021] Furthermore, one of the foregoing heat pump systems further comprises a control unit that detects a flow rate of water flowing in the cold/hot water circuit, wherein when the flow rate is equal to or higher than a set value, the control unit switches the cold/hot water circuit of the heat pump chillers to the parallel circuit via the switching means and, when the flow rate is equal to or lower than the set value, the control unit switches the cold/hot water circuit of the heat pump chillers to the series circuit via the switching means.

[0022] According to the aspect of the present invention, the heat pump system further comprises a control unit that detects a flow rate of water flowing in the cold/hot water circuit, wherein when the flow rate is equal to or higher than a set value, the control unit switches the cold/hot water circuit of the heat pump chillers to the parallel circuit via the switching means and, when the flow rate of water is equal to or lower than the set value, the control unit switches the cold/hot water circuit of the heat pump chillers to the series circuit via the switching means. Therefore, the control unit detects the flow rate of the water in the cold/hot water circuit with a flowmeter or the like; when the water flow rate becomes equal to or higher than a set value, exceeding a flow rate at which the head of the water pump becomes insufficient, the cold/hot water circuit for the heat pump chillers can be switched from the series circuit to the parallel circuit via the switching means. Accordingly, the flow rate of the cold/hot water circuit is monitored; when the water flow rate is equal to or higher than the set value, the cold/hot water circuit is automatically switched to the parallel circuit, and when it is equal to or lower than the set value, the cold/hot water circuit is automatically switched to the series circuit, so that insufficient head of the water pump and a decrease in the efficiency of the heat pump chillers can be eliminated.

[0023] Furthermore, in one of the foregoing heat pump systems, the parallel circuit and the series circuit are switchable by a manual operation switch via the switching means.

[0024] According to the aspect of the present invention, it is possible to switch between the parallel circuit and the series circuit by a manual operation switch via the switching means. Therefore, in the case where it is desired to use the cold/hot water circuit after being set to one of the parallel circuit and the series circuit in advance in accordance with the use of the heat pump system, required specifications at the load side, and so on, the cold/hot water circuit can be used after being set to one of the parallel circuit and the series circuit with the manual operation switch. Accordingly, providing the manual operation switch allows various uses of the heat pump system.

{Advantageous Effects of Invention}

[0025] According to the present invention, when there is a possibility of the flow rate of water flowing in a single cold/hot water circuit increasing, so that the water pump cannot make the water completely flow out due to insufficient head, the cold/hot water circuit leading to the plurality of heat pump chillers is switched to the parallel circuit formed of the individual series to decrease the pipe length of the cold/hot water circuit leading to the plurality of heat pump chillers, thereby ensuring a sufficient pump head to allow the water to be made to completely flow out. On the other hand, in the case where the water flow rate is low, so that there is some excess pump head, the cold/hot water circuit leading to the plurality of heat pump chillers is switched to the series circuit to cause the water to flow in series in the plurality of heat pump chillers, thereby preventing a decrease in the water flow rates of the refrigerant/water heat exchangers to suppress a decrease in water-side heat transfer coefficients, which allows the individual heat pump chillers to be operated at high efficiency. Therefore, as the water pump, there is no need to employ a higher head pump or a larger capacity pump than is necessary, which can reduce the cost of the water pump and save power and allows the individual heat pump chillers to be operated constantly at high efficiency, thus enhancing the COPs (coefficients of performance).

{Brief Description of Drawings}

[0026]

{Fig. 1} Fig. 1 is a system diagram of a cold/hot water circuit of a heat pump system according to a first embodiment of the present invention.

{Fig. 2} Fig. 2 is a refrigerant circuit diagram of an air-cooled heat pump chiller used in the heat pump system shown in Fig. 1.

{Fig. 3} Fig. 3 is a performance characteristic diagram of a pump provided in a cold/hot water circuit of the heat pump system shown in Fig. 1.

{Fig. 4} Fig. 4 is a COP characteristic diagram of the air-cooled heat pump chillers used in the heat pump system shown in Fig. 1.

{Fig. 5} Fig. 5(A) and Fig. 5(B) are characteristic diagrams showing the relationship between the water flow rate, and comp input and pump input for deriving the input characteristics of COP characteristics shown in Fig. 4.

{Description of Embodiments}

[0027] Embodiments according to the present invention will be described with reference to the drawings.

{First Embodiment}

[0028] A first embodiment of the present invention will be described hereinbelow using Figs. 1 to 5.

[0029] Fig. 1 shows a system diagram of a cold/hot water circuit of a heat pump system according to the first embodiment of the present invention. Fig. 2 shows a refrigerant circuit diagram of an air-cooled heat pump chiller used in the heat pump system.

[0030] A heat pump system 1 of this embodiment is configured such that a plurality of (four, in.this embodiment) air-cooled heat pump chillers (heat pump chillers) 4A to 4D are connected to a single cold/hot water circuit 2 equipped with a water pump 3.

[0031] The plurality of (four) air-cooled heat pump chillers 4A to 4D are divided into a plurality of series (two

series, in this embodiment); the air-cooled heat pump chillers 4A and 4B are connected in series to a first series cold/hot water circuit 2A, and the air-cooled heat pump chillers 4C and 4D are connected in series to a second series cold/hot water circuit 2B. Furthermore, the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B are connected in parallel with each other to the single cold/hot water circuit 2 to form a parallel circuit 5 in which the plurality of heat pump chillers 4A to 4D are connected in parallel to the single cold/hot water circuit 2.

[0032] Furthermore, the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B are connected in series between the outlet side of the air-cooled heat pump chillers 4A and 4B in the first series cold/hot water circuit 2A and the inlet side of the air-cooled heat pump chillers 4C and 4D in the second series cold/hot water circuit 2B to allow a series circuit 6 in which the plurality of (four) air-cooled heat pump chillers 4A to 4D are connected in series to the single cold/hot water circuit 2 to be formed.

[0033] It is possible to switch the parallel circuit 5 and the series circuit 6 described above via switching means constituted by three solenoid valves 7, 8, and 9, that is, a first solenoid valve 7 provided at the outlet side of the first series cold/hot water circuit 2A, a second solenoid valve 8 provided at the inlet side of the second series cold/hot water circuit 2B, and a third solenoid valve 9 provided in the series circuit 6. In other words, by opening the first solenoid valve 7 and the second solenoid valve 8 and closing the third solenoid valve 9, the parallel circuit 5 in which the two air-cooled heat pump chillers 4A and 4B and the two air-cooled heat pump chillers 4C and 4D are connected in parallel with each other to the single cold/hot water circuit 2 is formed. Furthermore, by closing the first solenoid valve 7 and the second solenoid valve 8 and opening the third solenoid valve 9, the series circuit 6 in which all four air-cooled heat pump chillers 4A to 4D are connected in series to the single cold/hot water circuit 2 is formed.

[0034] As shown in Fig. 2, the plurality of air-cooled heat pump chillers 4A to 4D are each equipped with a compressor 10, a four-way switching valve 11, a heat-source-side air heat exchanger 12, an electronic expansion valve for heating (EEVH) 13, a receiver 15 with a fusible plug 14, an electronic expansion valve for cooling (EEVC) 16, a utilization-side refrigerant/water heat exchanger 17, and an accumulator 18, which are connected with a refrigerant pipe 19 to configure a closed-cycle refrigeration cycle 20. Such a refrigeration cycle 20 itself is a known one.

[0035] An inlet pipe 21 and an outlet pipe 22 that constitute the foregoing first series cold/hot water circuit 2A and second series cold/hot water circuit 2B are connected to the water pipe of the refrigerant/water heat exchanger 17. The refrigerant/water heat exchanger 17 is configured to exchange heat between water flowing in the water pipe and refrigerant flowing in the refrigerant pipe to obtain cold water during cooling operation and hot water during heating operation. A solenoid valve 23 that is opened during heating operation is connected in parallel to the electronic expansion valve for cooling (EEVC) 16, and a liquid-refrigerant bypass circuit 25 equipped with a flow regulating valve 24 is provided between a liquid-refrigerant pipe line 19B that connects the electronic expansion valve for heating (EEVH) 13 and the receiver 15 and an intake pipe 19C that connects the accumulator 18 and the compressor 10.

[0036] Furthermore, the liquid-refrigerant pipe line 19B that connects the receiver 15 and the electronic expansion valve for cooling (EEVC) 16 is provided with a supercooling heat exchanger 26 that cools liquid refrigerant flowing in the liquid-refrigerant pipe line 19B to apply supercooling thereto. This supercooling heat exchanger 26 is constituted by, for example, a double-pipe heat exchanger, and the liquid-refrigerant pipe line 19B is connected to one of the channels of the double-pipe heat exchanger, and a supercooling circuit 27 constituted by a branch pipe that branches from the liquid-refrigerant pipe line 19B is connected to the other channel thereof.

[0037] An electronic expansion valve for supercooling (EEVSC) 28 is provided at the refrigerant inlet side of the supercooling heat exchanger 26 in the supercooling circuit 27 and is configured to allow the amount of refrigerant diverted to the supercooling circuit 27 to be regulated and the refrigerant to be reduced in pressure and supplied to the supercooling heat exchanger 26. The other end of the supercooling circuit 27 is connected, at the outlet side of the supercooling heat exchanger 26, to the inlet side of the accumulator 18 provided in the intake pipe 19C for the compressor 10.

[0038] Furthermore, the foregoing supercooling circuit 27 is provided with a high-pressure-control bypass circuit 29, which connects a discharge pipe 19A of the compressor 10 and the outlet side of the supercooling heat exchanger 26, that is, the intake pipe 19C side of the supercooling heat exchanger 26. The bypass circuit 29 is connected via a solenoid valve 30 provided at the bypass circuit 29 side and a solenoid valve 31 provided in the supercooling circuit 27 on the intake pipe 19C side of the joint position of the bypass circuit 29 both of which constitute switching means. When the supercooling circuit 27 is to be operated, the solenoid valve 30 is closed, and the solenoid valve 31 is opened, and when the high-pressure-control bypass circuit 29 is to be operated, the solenoid valve 30 is opened, and the solenoid valve 31 is closed.

[0039] Furthermore, the heat pump system 1 is provided with a flowmeter 32 for detecting the flow rate of water flowing in the single cold/hot water circuit 2 and a control unit 33 that turns on and off the first to third solenoid valves 7, 8, and 9 that constitute switching means, depending on the water flow rate detected by the flowmeter 32, to switch the cold/hot water circuit 2 to one of the parallel circuit 5 and the series circuit 6. If there is a possibility of the flow rate of the water flowing in the cold/hot

water circuit 2 exceeding a set flow rate, so that the water pump 3 cannot make the water completely flow out due to the insufficient head with the series circuit 6, the control unit 33 switches the cold/hot water circuit 2 to the parallel circuit 5.

[0040] As shown in Fig. 3, the water pump 3 has a performance characteristic such that the external head decreases gradually as the flow rate increases, and comparing the case where the plurality of air-cooled heat pump chillers 4A to 4D are connected in series and the case where they are connected in parallel, as described above, the external head in the case of the series connection is smaller than that in the case of the parallel circuit 5 by an amount corresponding to an increase in the pipe length of the cold/hot water circuit 2 (the sum of the pipe lengths of the first series cold/hot water circuit 2A, the second series cold/hot water circuit 2B, and the series circuit 6). Accordingly, when the flow rate has exceeded a certain flow rate, the external head of the water pump 3 can be increased by switching the cold/hot water circuit 2 from the series circuit 6 to the parallel circuit 5.

[0041] Furthermore, since an input is smaller in the case where the cold/hot water circuit 2 is switched to the series circuit 6 than the case where it is switched to the parallel circuit 5, the COP (coefficient of performance) characteristics of the air-cooled heat pump chillers 4A to 4D are better, as shown in Fig. 4. That is, comparing the relationship between the water flow rate and compressor input (comp input) and pump input between the case of the parallel circuit 5 and the case of the series circuit 6, the compressor input is smaller with the series circuit 6 than that with the parallel circuit 5, as shown in Fig. 5(A), and the pump input is smaller with the parallel connection than that with the serial connection, as shown in Fig. 5(B).

[0042] The input characteristics in Fig. 4 show the sum of the values in Figs. 5(A) and 5(B); in a region in which the water flow rate is equal to or lower than a certain flow rate, the input value in the case of the series circuit 6 is smaller than the input value in the case of the parallel circuit 5, and thus, the efficiency is higher, and the COPs are higher with the series circuit 6. This is because a decrease in the water flow rates of the individual refrigerant/water heat exchangers 17 can be prevented, and hence a decrease in heat transfer coefficients of water can be suppressed by switching the cold/hot water circuit 2 to the series circuit 6 to make the water flow in series to the plurality of heat pump chillers 4A to 4D. On the other hand, in a region in which the water flow rate is equal to or higher than the certain flow rate, there is a possibility that the pump head may be insufficient in the case of the series circuit 6, and it is necessary to switch the cold/hot water circuit 2 to the parallel circuit 5, and the input (COP) in the case of the parallel circuit 5 becomes dominant.

[0043] Furthermore, the control unit 33, which switches the cold/hot water circuit to the parallel circuit 5 or the series circuit 6 on the basis of the detected value from the flowmeter 32, as described above, can be provided with a manual operation switch 34. This operation switch 34 is for switching the ON/OFF states of the first to third solenoid valves 7, 8, and 9 that switch the cold/hot water circuit 2 between the parallel circuit 5 and the series circuit 6 by manual operation, and in the case where it is desired to use the cold/hot water circuit 2 after being set to one of the parallel circuit 5 and the series circuit 6 in advance in accordance with the use of the heat pump system 1, required specifications at the load side, and so on, the cold/hot water circuit 2 can be used after being set to one of the parallel circuit 5 and the series circuit 6 by manually operating the operation switch 34.

[0044] With the configuration described above, this embodiment provides the following operational advantages.

[0045] With the foregoing heat pump system 1, cold water or hot water can be produced by supplying water to the single cold/hot water circuit 2 via the water pump 3 and by sequentially cooling or heating the water with the plurality of air-cooled heat pump chillers 4A to 4D, and the cold water or the hot water can be used for a desired purpose, such as air conditioning, by supplying it to a load side.

[0046] In the individual air-cooled heat pump chillers 4A to 4D, during cooling operation, refrigerant is circulated in the direction of the solid arrows by the four-way switching valve 11 and, during heating operation, the refrigerant is circulated in the direction of the broken arrows by the four-way switching valve 11. Thus, during cooling operation, cold water can be produced by operating the heat-source-side air heat exchanger 12 work as a condenser and making the utilization-side refrigerant/water heat exchanger 17 work as an evaporator to cool water flowing in through the inlet pipe 21 and flowing out through the outlet pipe 22. During heating operation, hot water can be produced by making the utilization-side refrigerant/water heat exchanger 17 work as a condenser and operating the heat-source-side air heat exchanger 12 work as an evaporator to heat water flowing in through the inlet pipe 21 and flowing out through the outlet pipe 22.

[0047] During this operation, by diverting part of the high-pressure liquid refrigerant circulating in the liquid-refrigerant pipe line 19B toward the supercooling circuit 27, reducing the pressure of this refrigerant with the electronic expansion valve for supercooling (EEVSC) 28, and introducing it to the supercooling heat exchanger 26, the heat thereof is exchanged with that of the liquid refrigerant flowing in the liquid-refrigerant pipe line 19B, and the liquid refrigerant can be supercooled by,being cooled with the latent heat of vaporization. The refrigerant evaporated by the supercooling heat exchanger 26 is merged with the intake pipe 19C at the inlet side of the accumulator 18 and is taken into the compressor 10.

[0048] To avoid a situation in which a high pressure does not rise during cooling operation under a low outside air temperature, heating operation in which a heating load becomes excessively large, and so on, causing a low-pressure protection device to be actuated and thus mak-

ing it difficult to continue the operation, the outside air temperature and the pressure are detected, the solenoid valve 30 is opened, and the solenoid valve 31 is closed as necessary to cause part of high-pressure refrigerant gas discharged from the compressor 10 to be diverted to the liquid-refrigerant pipe line 19B through the bypass circuit 29, the supercooling circuit 27, the supercooling heat exchanger 26, and the electronic expansion valve for supercooling (EEVSC) 28, thereby controlling the high pressure and allowing the operation to be continued.

[0049] On the other hand, if the flow rate of the water flowing in the single cold/hot water circuit 2 is equal to or lower than a set flow rate, this is detected by the flowmeter 32, the first and second solenoid valves 7 and 8 are closed, and the third solenoid valve 9 is opened with the control unit 33 so that the cold/hot water circuit 2 is switched to the series circuit 6 to make all four air-cooled heat pump chillers 4A to 4D be connected in series, thereby causing the water to circulate in the individual refrigerant/water heat exchangers 17. This can ensure the flow rates of the water circulating in the individual refrigerant/water heat exchangers 17 to suppress a decrease in the heat transfer coefficients of the water, allowing the individual air-cooled heat pump chillers 4A to 4D to be operated at high efficiency, thus allowing cold water or hot-water to be efficiently produced.

[0050] Furthermore, when the flow rate of the water flowing in the cold/hot water circuit 2 has increased, the external head of the water pump 3 decreases gradually, as shown in Fig. 3, and when the water flow rate exceeds a certain flow rate, there is a possibility that the water cannot be made to completely flow out due to the insufficient head. However, in this embodiment, when the water flow rate detected by the flowmeter 32 has exceeded the set flow rate, the first and second solenoid valves 7 and 8 are opened and the third solenoid valve 9 is closed by the control unit 33 to switch the cold/hot water circuit 2 to the parallel circuit 5, thereby causing the water to circulate in parallel in the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B to make the water flow in parallel in the air-cooled heat pump chillers 4A and 4B and the air-cooled heat pump chillers 4C and 4D. This can therefore decrease the pipe length of the cold/hot water circuit 2 as compared with the case of the series circuit 6, allowing the water to be made to completely flow out by increasing the external head of the water pump 3, as shown in Fig. 3.

[0051] As described above, according to this embodiment, in the case where there is a possibility of an increase in the flow rate of water flowing in the cold/hot water circuit 2, so that the water pump 3 cannot make the water completely flow out due to the insufficient head, the cold/hot water circuit 2 leading to the plurality of air-cooled heat pump chillers 4A to 4D is switched to the parallel circuit 5 formed of the individual series to decrease the pipe length of the cold/hot water circuit 2 leading to the air-cooled heat pump chillers 4A to 4D, thereby ensuring a sufficient pump head to allow the water to be made to completely flow out. On the other hand, in the case where the water flow rate is low, so that there is some excess pump head, the cold/hot water circuit 2 leading to the plurality of air-cooled heat pump chillers 4A to 4D is switched to the series circuit 6 to make the water flow in series in the individual air-cooled heat pump chillers 4A to 4D, thereby preventing a decrease in the water flow rates of the refrigerant/water heat exchangers 17 to suppress a decrease in the water-side heat transfer coefficients, so that the individual air-cooled heat pump chillers 4A to 4D can be operated at high efficiency.

[0052] As a result, as the water pump 3, there is no need to employ a higher head pump or a larger capacity pump than is necessary, which can reduce the cost of the water pump 3 and save power, and allows the plurality of air-cooled heat pump chillers 4A to 4D to be individually operated at high efficiency, thus enhancing the COPs (coefficients of performance).

[0053] Furthermore, in this embodiment, the parallel circuit 5 is configured such that the air-cooled heat pump chillers 4A and 4B and the air-cooled heat pump chillers 4C and 4D of the individual plurality of series (the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B) are connected in parallel with each other to the single cold/hot water circuit 2, and the series circuit 6 is configured such that the outlet side of the air-cooled heat pump chillers 4A and 4B of the first series (the cold/hot water circuit 2A) and the inlet side of the air-cooled heat pump chillers 4C and 4D of the second series (the cold/hot water circuit 2B) are connected. This allows the cold/hot water circuit 2 leading to the plurality of air-cooled heat pump chillers 4A to 4D to be easily switched to one of the parallel circuit 5 and the series circuit 6 by making the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B that are connected in parallel for each series communicate with the single cold/hot water circuit 2 or by closing the outlet side of the first series cold/hot water circuit 2A and the inlet side of the second series cold/hot water circuit 2B to bring the series circuit 6 that connects them into a communicating state with the switching means. Accordingly, optimum operation depending on the circumstances can be achieved by switching the plurality of air-cooled heat pump chillers 4A to 4D to serial connection or parallel connection depending on the operation mode.

[0054] Furthermore, the switching means for the parallel circuit 5 and the series circuit 6 is constituted by the first solenoid valve 7 provided at the outlet side of the air-cooled heat pump chillers 4A and 4B of the first series cold/hot water circuit 2A, the second solenoid valve 8 provided at the inlet side of the air-cooled heat pump chillers 4C and 4D of the second series cold/hot water circuit 2B, and the third solenoid valve 9 provided in the series circuit 6. By opening the first solenoid valve 7 and the second solenoid valve 8 and closing the third solenoid valve 9, the parallel circuit 5 in which the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B are connected in parallel can be formed,

and by closing the first solenoid valve 7 and the second solenoid valve 8 and opening the third solenoid valve 9, the series circuit 6 in which the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B are connected in series can be formed. This allows simple switching to the parallel circuit 5 or the series circuit 6 by turning on and off the inexpensive solenoid valves 7, 8, and 9, thus ensuring reliable circuit switching.

[0055] Furthermore, this embodiment is provided with the control unit 33, which detects the flow rate of water in the cold/hot water circuit 2 by means of the flowmeter 32 or the like; if the water flow rate becomes equal to or higher than a set value, exceeding a flow rate at which the head of the water pump 3 becomes insufficient, the cold/hot water circuit 2 for the plurality of air-cooled heat pump chillers 4A to 4D can be switched from the series circuit 6 to the parallel circuit 5 with the first to third solenoid valves 7, 8, and 9. Thus, the flow rate of the cold/hot water circuit 2 is monitored; if the water flow rate is equal to or higher than the set value, the cold/hot water circuit 2 is automatically switched to the parallel circuit 5, and if it is equal to or lower than the set value, the cold/hot water circuit 2 is automatically switched to the series circuit 6, so that insufficient head of the water pump 3 and a decrease in the efficiency of the air-cooled heat pump chillers 4A to 4D can be eliminated.

[0056] In addition, since the manual operation switch 34 is provided so that the cold/hot water circuit 2 can be switched' to one of the parallel circuit 5 and the series circuit 6 via the first to third solenoid valves 7, 8, and 9 by manually operating the operation switch 34, the cold/hot water circuit 2 can be used after being set to one of the parallel circuit 5 and the series circuit 6 with the manual operation switch 34 in the case where it is desired to use the cold/hot water circuit 2 after being set to one of the parallel circuit 5 and the series circuit 6 in advance in accordance with the use of the heat pump system 1, required specifications at the load side, and so on. Accordingly, providing the manual operation switch 34 allows various uses of the heat pump system 1.

{Other Embodiments}

[0057] Other embodiments of the present invention will be described hereinbelow.

(1) In the foregoing first embodiment, by individually connecting the two air-cooled heat pump chillers 4A and 4B and the two air-cooled heat pump chillers 4C and 4D in series and by connecting the air-cooled heat pump chillers 4A and 4B and the air-cooled heat pump chillers 4C and 4D to the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B, respectively, the parallel circuit 5 in which the two air-cooled heat pump chillers 4A and 4B and the two air-cooled heat pump chillers 4C and 4D are connected in parallel with each other is formed, and by connecting the series circuit 6 to the air-cooled heat pump chillers 4A and 4B and the two air-cooled heat pump chillers 4C and 4D, switching between the parallel circuit 5 and the series circuit 6 is enabled; however, the number of air-cooled heat pump chillers provided in the first series cold/hot water circuit 2A and the second series cold/hot water circuit 2B is not limited to two; it may be three or more, or alternatively, the cold/hot water circuit 2 may be divided into three or more series with a similar circuit configuration. Also in this case, the same advantages as those of the first embodiment can be provided, and since the number of air-cooled heat pump chillers to be connected can easily be increased or decreased, the performance of the heat pump system 1 can easily be adjusted, and the COPs of the water pump 3 and the individual air-cooled heat pump chillers can be optimized.

(2) In the case where the cold/hot water circuit 2 is divided into a plurality of series, to each of which the plurality of air-cooled heat pump chillers are connected, the air-cooled heat pump chillers connected to the individual series may be modularized into a single unit, in which case the plurality of air-cooled heat pump chillers in each series can be modularized and can each be installed as a single unit, and hence the higher the number of air-cooled heat pump chillers to be connected is, the better the ease-of-installation and the lower the cost that can be achieved.

(3) Although the first embodiment is configured such that three valves, that is, the first solenoid valve 7, the second solenoid valve 8, and the third solenoid valve 9, are provided as switching means for the parallel circuit 5 and the series circuit 6, the first solenoid valve 7 and the third solenoid valve 9 can be replaced with a three-way switching valve provided at a joint portion of the series circuit 6 to the first series cold/hot water circuit 2A. This can decrease the number of valves that constitute switching means, simplifying the cold/hot water circuit 2, and thereby reducing the number of components and man-hours for installing the pipe of the cold/hot water circuit 2 to reduce the cost.

[0058] The present invention is not limited to the invention according to the foregoing embodiments, and various modifications can be made. The refrigerant circuit configuration of the air-cooled heat pump chillers 4A to 4D is not limited to that described above but may be any refrigerant circuit configuration. The present invention is not limited to the heat pump chillers in which it is possible to switch between cooling operation and heating operation, as in the foregoing embodiments, but may be heat pump chillers only for cooling or only for heating.

{Reference Signs List}

[0059]

1	heat pump system
2	cold/hot water circuit
2A	first series cold/hot water circuit
2B	second series cold/hot water circuit
3	water pump
4A, 4B, 4C, 4D	air-cooled heat pump chiller
5	parallel circuit
6	series circuit
7	first solenoid valve (switching means)
8	second solenoid valve (switching means)
9	third solenoid valve (switching means)
32	flowmeter
33	control unit
34	manual operation switch

Claims

1. A heat pump system in which a plurality of heat pump chillers (4A, 4B, 4C, 4D) are connected to a single cold/hot water circuit (2) equipped with a water pump,
wherein the plurality of heat pump chillers are divided into a plurality of series (4A, 4B, 4C, 4D), the heat pump system comprising:

a parallel circuit (5) in which the heat pump chillers of the individual series are connected in parallel to the single cold/hot water circuit (2),

characterized by further comprising:

a series circuit (6) in which the heat pump chillers of the individual series are connected in series to the single cold/hot water circuit (2),
wherein the parallel circuit (5) and the series circuit (6) are switchable to each other via a switching means (7, 8, 9),
wherein the parallel circuit (5) is a circuit that connects the heat pump chillers of the individual series in parallel with each other to the single cold/hot water circuit, and the series circuit is a circuit that connects the cold/hot water circuit outlet side of the heat pump chillers (4A, 4B) in a first series to the cold/hot water circuit inlet side of the heat pump chillers in a second series (4C, 4D).

2. The heat pump system according to Claim 1, wherein the heat pump chillers in each series are constituted by a plurality of the heat pump chillers (4A, 4B, 4C, 4D) connected in series.

3. The heat pump system according to Claim 2, wherein the plurality of heat pump chillers in each series are modularized into a single unit and are connectable in parallel or in series for each of the modules via the parallel circuit (5) or the series circuit (6).

4. The heat pump system according to one of Claims 1 to 3, wherein the switching means comprises a first solenoid (7) valve provided at the cold/hot water circuit outlet side of the heat pump chillers in the first series, a second solenoid valve (8) provided at the cold/hot water circuit inlet side of the heat pump chillers in the second series, and a third solenoid valve (9) provided in the series circuit (6).

5. The heat pump system according to one of Claims 1 to 4, wherein the switching means comprises a single three-way switching valve provided at a joint portion of the series circuit (6) to the first series cold/hot water circuit (2).

6. The heat pump system according to one of Claims 1 to 5, further comprising a control unit (33) that detects a flow rate of water flowing in the cold/hot water circuit (2), wherein when the flow rate is equal to or higher than a set value, the control unit switches the cold/hot water circuit of the heat pump chillers to the parallel circuit via the switching means (7,8,9) and, when the flow rate is equal to or lower than the set value, the control unit switches the cold/hot water circuit of the heat pump chillers to the series circuit via the switching means.

7. The heat pump system according to one of Claims 1 to 6, wherein the parallel circuit (5) and the series circuit (6) are switchable by a manual operation switch via the switching means.

Patentansprüche

1. Wärmepumpensystem, in dem mehrere Wärmepumpenkühler (4A, 4B, 4C, 4D) mit einem einzigen Kalt-/Warmwasserkreis (2), der mit einer Wasserpumpe ausgestattet ist, verbunden sind,
wobei die mehreren Wärmepumpenkühler in mehrere Reihen (4A, 4B, 4C, 4D) unterteilt sind, wobei das Wärmepumpensystem umfasst:

einen Parallelkreis (5), in dem die Wärmepumpenkühler der einzelnen Reihen mit dem einzigen Kalt-/Warmwasserkreis (2) parallel geschaltet sind,
dadurch gekennzeichnet, dass es ferner umfasst:

einen Reihenkreis (6), in dem die Wärmepumpenkühler der einzelnen Reihen mit dem einzigen Kalt-/Warmwasserkreis (2) in Reihe geschaltet sind,
wobei der Parallelkreis (5) und der Reihen-

kreis (6) über ein Schaltmittel (7, 8, 9) miteinander schaltbar sind,
wobei der Parallelkreis (5) ein Kreis ist, der die Wärmepumpenkühler der einzelnen Reihen mit dem einzigen Kalt-/Warmwasserkreis parallel schaltet, und der Reihenkreis ein Kreis ist, der die Kalt-/Warmwasserkreis-Auslassseite der Wärmepumpenkühler (4A, 4B) in einer ersten Reihe mit der Kalt-/Warmwasserkreis-Einlassseite der Wärmepumpenkühler in einer zweiten Reihe (4C, 4D) verbindet.

2. Wärmepumpensystem nach Anspruch 1, wobei die Wärmepumpenkühler in jeder Reihe durch mehrere Wärmepumpenkühler (4A, 4B, 4C, 4D), die in Reihe geschaltet sind, gebildet werden.

3. Wärmepumpensystem nach Anspruch 2, wobei die mehreren Wärmepumpenkühler in jeder Reihe zu einer einzigen Einheit modularisiert und für jedes der Module über den Parallelkreis (5) oder den Reihenkreis (6) parallel oder in Reihe schaltbar sind.

4. Wärmepumpensystem nach einem der Ansprüche 1 bis 3, wobei das Schaltmittel ein erstes Magnetventil (7), das an der Kalt-/Warmwasserkreis-Auslassseite der Wärmepumpenkühler in der ersten Reihe vorgesehen ist, ein zweites Magnetventil (8), das an der Kalt-/Warmwasserkreis-Einlassseite der Wärmepumpenkühler in der zweiten Reihe vorgesehen ist, und ein drittes Magnetventil (9), das in dem Reihenkreis (6) vorgesehen ist, umfasst.

5. Wärmepumpensystem nach einem der Ansprüche 1 bis 4, wobei das Schaltmittel ein einziges Dreiwege-Schaltventil umfasst, das an einem Verbindungsabschnitt des Reihenkreises (6) zu dem Kalt-/Warmwasserkreis (2) der ersten Reihe vorgesehen ist.

6. Wärmepumpensystem nach einem der Ansprüche 1 bis 5, ferner umfassend eine Regelungseinheit (33), die eine Durchflussrate von Wasser, das in dem Kalt-/Warmwasserkreis (2) fließt, detektiert, wobei, wenn die Durchflussrate größer als oder gleich einem eingestellten Wert ist, die Regelungseinheit den Kalt-/Warmwasserkreis der Wärmepumpenkühler über das Schaltmittel (7, 8, 9) zu dem Parallelkreis schaltet, und, wenn die Durchflussrate kleiner als oder gleich dem eingestellten Wert ist, die Regelungseinheit den Kalt-/Warmwasserkreis der Wärmepumpenkühler über das Schaltmittel zu dem Reihenkreis schaltet.

7. Wärmepumpensystem nach einem der Ansprüche 1 bis 6, wobei der Parallelkreis (5) und der Reihenkreis (6) durch einen Handbedienungsschalter über das Schaltmittel schaltbar sind.

Revendications

1. Système de pompe à chaleur dans lequel une pluralité de refroidisseurs de pompe à chaleur (4A, 4B, 4C, 4D) sont raccordés à un circuit d'eau froide/chaude (2) unique équipé avec une pompe à eau, dans lequel la pluralité de refroidisseurs de pompe à chaleur sont divisés en une pluralité de séries (4A, 4B, 4C, 4D), le système de pompe à chaleur comprenant :

un circuit parallèle (5) dans lequel les refroidisseurs de pompe à chaleur des séries individuelles sont raccordés en parallèle au circuit d'eau froide/chaude (2) unique,
caractérisé en ce qu'il comprend en outre :

un circuit série (6) dans lequel les refroidisseurs de pompe à chaleur des séries individuelles sont raccordés en série au circuit d'eau froide/chaude (2) unique,
dans lequel le circuit parallèle (5) et le circuit série (6) peuvent être commutés entre eux, via un moyen de commutation (7, 8, 9),
dans lequel le circuit parallèle (5) est un circuit qui raccorde les refroidisseurs de pompe à chaleur des séries individuelles en parallèle entre eux au circuit d'eau froide/chaude unique, et le circuit série est un circuit qui raccorde le côté de sortie du circuit d'eau froide/chaude des refroidisseurs de pompe à chaleur (4A, 4B) en une première série au côté d'entrée du circuit d'eau froide/chaude des refroidisseurs de pompe à chaleur en une seconde série (4C, 4D).

2. Système de pompe à chaleur selon la revendication 1, dans lequel les refroidisseurs de pompe à chaleur dans chaque série sont constitués par une pluralité de refroidisseurs de pompe à chaleur (4A, 4B, 4C, 4D) raccordés en série.

3. Système de pompe à chaleur selon la revendication 2, dans lequel la pluralité de refroidisseurs de pompe à chaleur, dans chaque série, sont modularisés en une unité unique et peuvent être raccordés en parallèle ou en série pour chacun des modules, via le circuit parallèle (5) ou le circuit série (6).

4. Système de pompe à chaleur selon l'une des revendications 1 à 3, dans lequel le moyen de commutation comprend une première électrovanne (7) prévue au niveau du côté de sortie du circuit d'eau froide/chaude des refroidisseurs de pompe à chaleur dans la première série, une deuxième électrovanne (8) prévue au niveau du côté d'entrée du circuit d'eau froide/chaude des refroidisseurs de pompe à chaleur dans la seconde série, et une troisième électrovanne

(9) prévue dans le circuit série (6).

5. Système de pompe à chaleur selon l'une des revendications 1 à 4, dans lequel le moyen de commutation comprend une valve de commutation à trois voies unique prévue au niveau d'une partie d'assemblage du circuit série (6) au circuit d'eau froide/chaude (2) de la première série.

6. Système de pompe à chaleur selon l'une des revendications 1 à 5, comprenant en outre une unité de commande (33) qui détecte un débit d'eau s'écoulant dans le circuit d'eau froide/chaude (2), dans lequel lorsque le débit est égal ou supérieur à une valeur de consigne, l'unité de commande commute le circuit d'eau froide/chaude des refroidisseurs de pompe à chaleur sur le circuit parallèle via le moyen de commutation (7, 8, 9) et lorsque le débit est égal ou inférieur à la valeur de consigne, l'unité de commande commute le circuit d'eau froide/chaude des refroidisseurs de pompe à chaleur sur le circuit série via le moyen de commutation.

7. Système de pompe à chaleur selon l'une des revendications 1 à 6, dans lequel le circuit parallèle (5) et le circuit série (6) peuvent être commutés par un commutateur à commande manuelle via le moyen de commutation.

FIG. 1

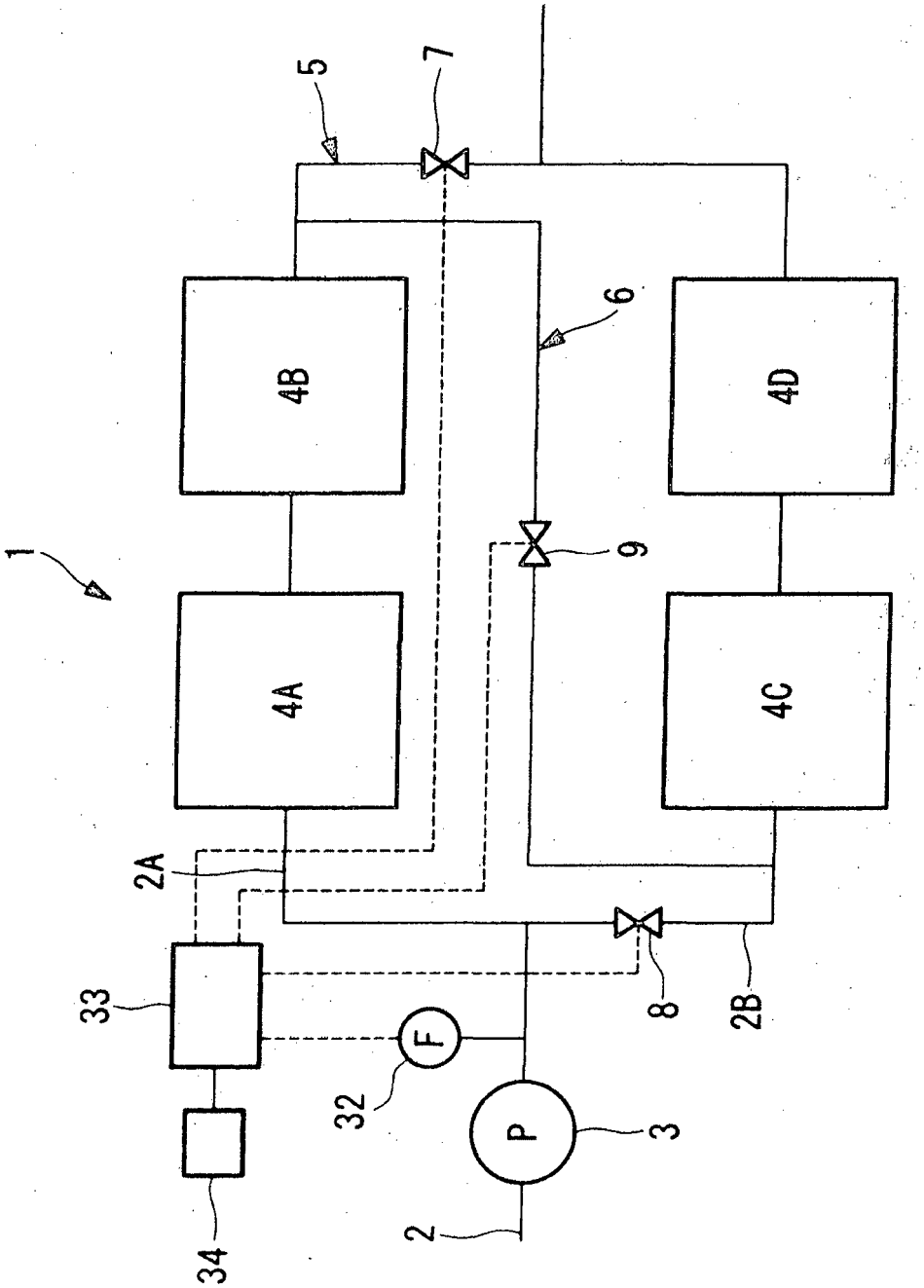


FIG. 2

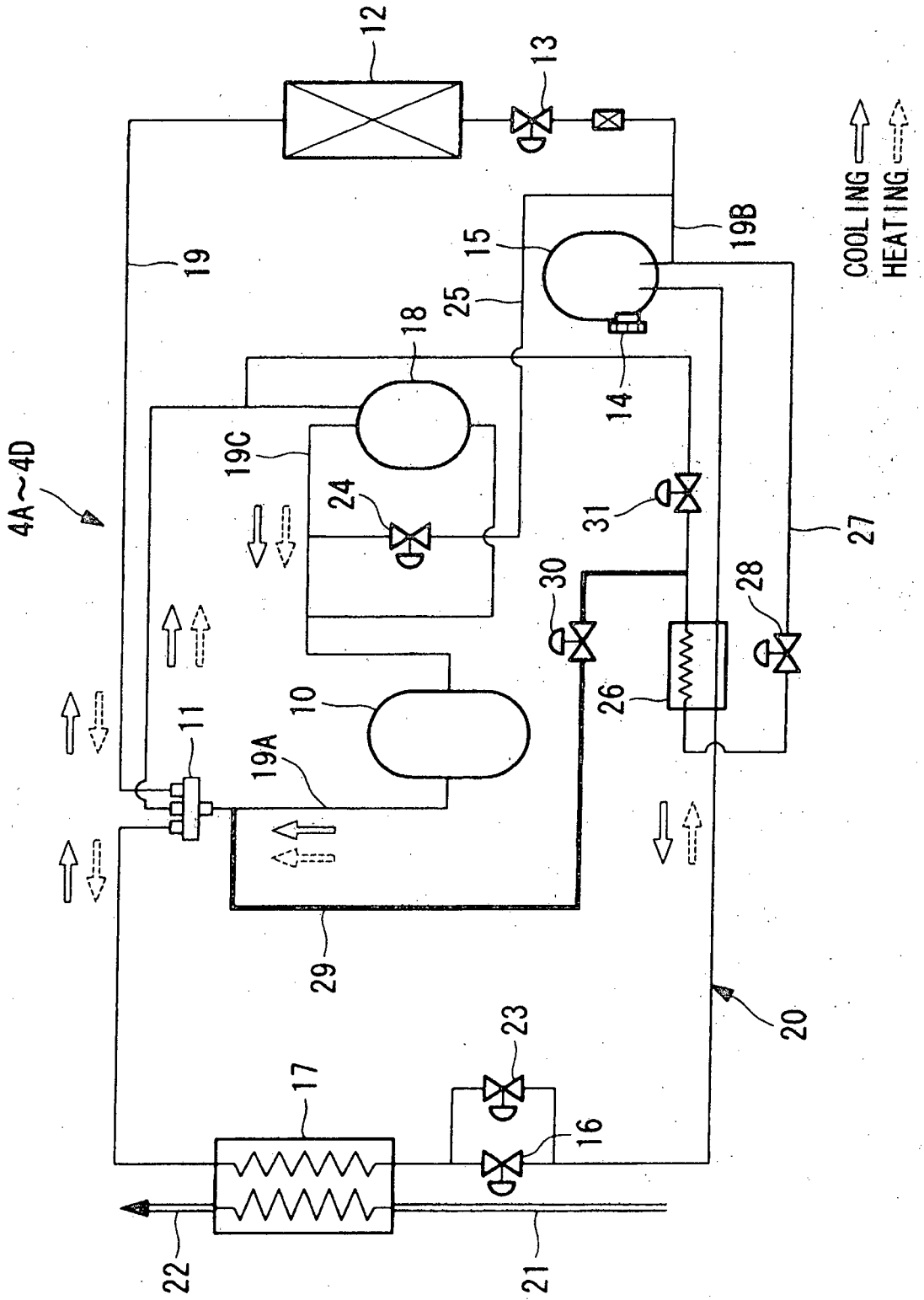

12
13
COOLING
HEATING
19
19B
15
25
18
14
19C
24
31
4A~4D
27
30
28
26
10
11
19A
29
20
23
17
16
22
21

FIG. 3

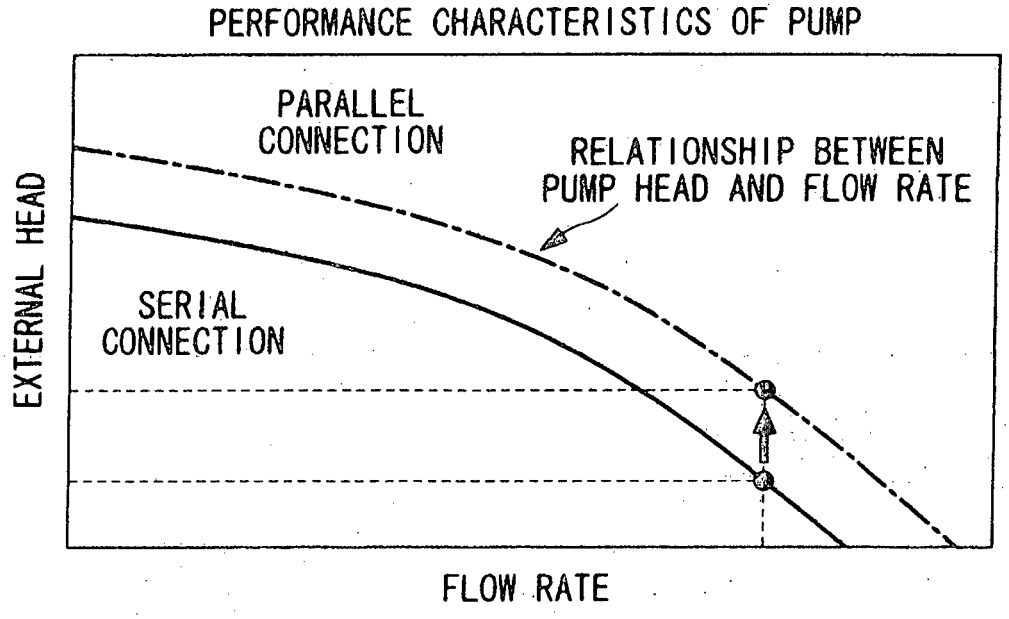

PERFORMANCE CHARACTERISTICS OF PUMP
PARALLEL CONNECTION
RELATIONSHIP BETWEEN PUMP HEAD AND FLOW RATE
SERIAL CONNECTION
EXTERNAL HEAD
FLOW RATE

FIG. 4

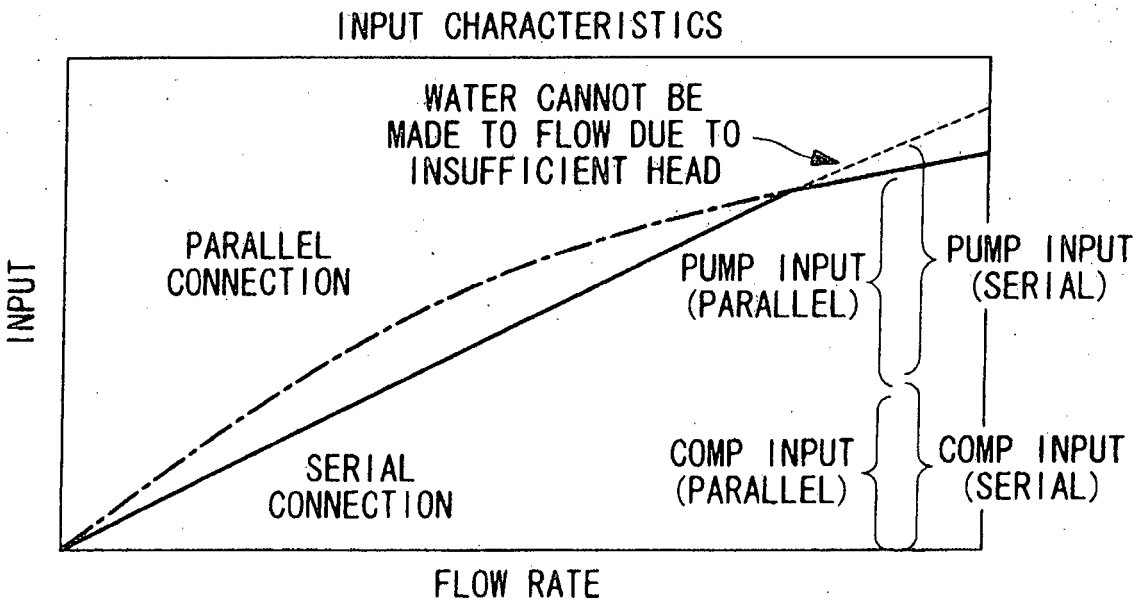
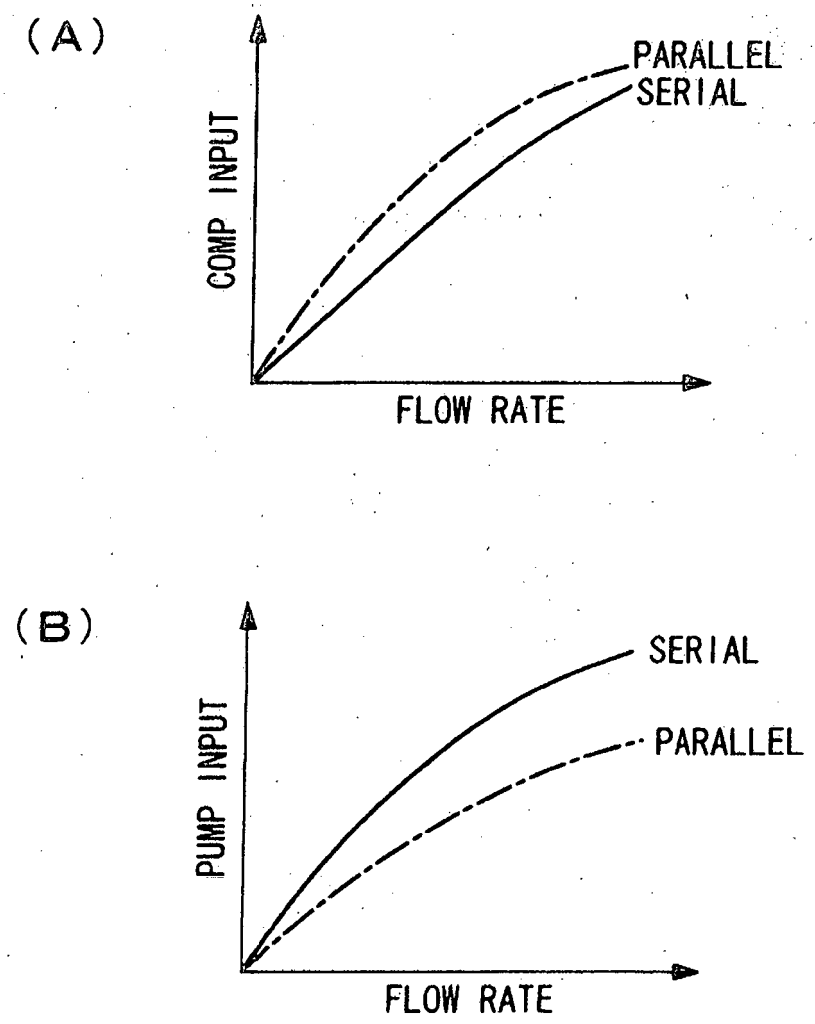

INPUT CHARACTERISTICS
WATER CANNOT BE MADE TO FLOW DUE TO INSUFFICIENT HEAD
PARALLEL CONNECTION
PUMP INPUT (PARALLEL)
PUMP INPUT (SERIAL)
COMP INPUT (PARALLEL)
COMP INPUT (SERIAL)
SERIAL CONNECTION
INPUT
FLOW RATE

FIG. 5


(A)
COMP INPUT
PARALLEL
SERIAL
FLOW RATE
(B)
PUMP INPUT
SERIAL
PARALLEL
FLOW RATE

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 4350468 A **[0003]**
- JP 2007198693 A **[0003]**
- JP 2002195684 A **[0003]**
- JP 2008267722 A **[0004]**