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(54) CONNECTION OF HEAT PUMPS AND A METHOD OF CONTROLLING HEAT PUMPS OF THIS CONNECTION

(57) The invention discloses a novel connection of heat pumps (1) having primary fluid circuits (2) in a common fluid circuit (3) to form an efficient source of heat or cold. The heat pumps (1) are connected to the common fluid circuit (3) by the primary fluid circuits (2), and a temperature sensor (5) is installed before and after each connection of the primary fluid circuit (2) to the common fluid circuit (3). The operation of the heat pumps (1) is controlled by a controller (6) according to the sensed temperature from the temperature sensors (5).

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Description

Field of the Invention

[0001] The invention relates to the joint connection of at least two heat pumps pumping heat for heating or cooling purposes. At the same time, the invention relates to a method of controlling the individual heat pumps in the joint connection.

Background of the Invention

[0002] Most ordinary users will think of a heat pump as a device for heating but in terms of physical nomenclature, a heat pump is a device that pumps heat from one space to another as it works. A heat pump uses energy to transport heat, not to produce it.

[0003] Heat pumps having at least one compressor hydraulic circuit comprising a condenser, an expansion nozzle, an evaporator and a compressor are the most used technical solution of heat pumps. In principle, these heat pumps work by circulating refrigerant through the compressor hydraulic circuit, which condenses to a liquid in the condenser, wherein the refrigerant passes on the heat it carries, then the refrigerant in liquid form continues to the expansion nozzle, after which it turns into a gas. The refrigerant in gaseous form travels to the evaporator through which ambient heat is bound into the refrigerant, after which the refrigerant proceeds to the compressor, which compresses it, thereby concentrating the entrained heat. The cycle repeats, and the refrigerant with the concentrated heat enters the condenser. It will be appreciated that the power input of the heat pump is used to operate the compressor and to circulate the refrigerant through the compressor hydraulic circuit, not to produce heat.

[0004] If the heat pump is used for heating, the evaporator is located in the system from which the heat is extracted, while the condenser is located in the system with a primary fluid circuit, which takes heat for heating into the circulating liquid. For heat pumps for heating, the monitored parameter is the heating system coefficient COP (Coefficient of Performance). This dimensionless number tells about the efficiency of using electrical energy for the heat obtained through the heat pump. This is the theoretical ratio between the heat obtained and the electrical energy consumed. The higher the COP, the more efficient the heat pump.

[0005] If the heat pump is used for cooling, the evaporator is located in the system with the primary fluid circuit from which the heat is purposely extracted, while the condenser is located in the system in which the heat is dissipated or purposely diverted for other processing. For heat pumps for cooling, the monitored parameter is the cooling factor or EER (Energy Efficiency Ratio). This dimensionless number tells about the efficiency of using electrical energy for cold through the heat pump for cooling. This is the theoretical ratio between the cold generated and the electrical energy consumed. The higher the EER, the more efficient the heat pump is for cooling. In practice, the heat pump for cooling is referred to by the word "chiller", derived from the word "chill".

[0006] Currently, a group of heat pumps is connected to a common heating or cooling system in parallel or, exceptionally, in series. These methods are not patent-protected.

[0007] The disadvantage of the previously used parallel connection of heat pumps to a common heating system is that the system operates at a low temperature gradient, and all heat pumps work at the same high condensing temperature corresponding to the requirement for the output temperature to the heating system. This allows the heat pumps to operate at the same COP value in parallel. And at the same time, the disadvantage of the previously used method of parallel connection of heat pumps to a common cooling system is that the system operates at a low temperature gradient, and all heat pumps work at the same high condensing temperature corresponding to the requirement for the output temperature to the cooling system. As a result, they operate at the same EER value.

[0008] The disadvantage of the previously used method of a series connection of heat pumps is that the maximum flow through the heating or cooling systems is significantly limited. As a rule, only two heat pumps can be connected in this way.

[0009] The object of the invention is to find a heat pump connection and a method of controlling heat pumps in such a connection, which would eliminate the shortcomings of known solutions and would allow high flow rates to be achieved by heat pumps while achieving a higher temperature gradient and a lower flow rate in the heating or cooling system, overall higher COP and EER, and would also allow to achieve a higher accumulation capacity of the heating or cooling system and a lower seasonal number of heat pump compressor starts.

Summary of the Invention

[0010] The said task was solved by creating a heat pump connection and a method for controlling heat pumps in a connection according to the invention described below.

[0011] The connection is targeted at heat pumps that are equipped with primary fluid circuits for connection to a common fluid circuit to create an efficient source of heat or cold.

[0012] The essence of the invention is that at least two heat pumps are connected by their primary fluid circuits to a common fluid circuit. The connection overcomes the shortcomings of the state of the art of the described same-temperature parallel connection and series connection. At the same time, the common fluid circuit is provided with at least one hydraulic pump whose function is to circulate the fluid in the common fluid circuit. It is also essential that a temperature sensor is installed before and after each connection of the respective primary fluid circuit to the common fluid circuit. The temperature sensors detect the temperature of the circulating fluid after the contributions from the individual heat pumps connected. At the same time, the heat pumps and hydraulic pumps are communicatively connected to at least one controller to control their operation, because without the controller it would not be possible to harmonise the operation of the individual parts of the connection to the overall result, i.e. to the temperature of the fluid at the outlet of the common fluid circuit. At the same time, the controller is communicatively connected to the temperature sensors in order to have information on the extent to which the individual parts in the invented connection affect the temperature of the fluid circulating through the common fluid circuit.

[0013] The invented connection is suitable for both heating and cooling, and is applicable for creating an efficient source of heat or cold. Due to the parallel nature of the connection with unequal operating temperatures, the path to the desired temperature is divided into smaller sections, which is a more preferred solution in terms of heat pump operation than the parallel connection described in the prior art. At the same time, the invented connection outperforms the known series connection by being able to operate at a higher flow rate within the common fluid circuit. In an extending embodiment of the invention, the common fluid circuit is preferably connected to at least one accumulation vessel. The accumulation vessel can store a larger volume of circulating fluid at a higher temperature gradient, making storing more heat or cold possible.

[0014] Alternatively, it may be preferred for some applications of the invention if the common fluid circuit is connected directly to a heating system or to a cooling system.

[0015] In another possible extending embodiment of the invention, preferably, at least one of the primary fluid circuits is provided with an accumulation tank before being connected to the common fluid circuit. This variant of the invention finds application in situations where it is more preferred for the operation of the heat pump to accumulate heat or cold in advance, and then within the invented circuit, this heat is used to influence the temperature of the circulating fluid in the common fluid circuit.

[0016] For other permissible applications of the invention, an embodiment of the connection in which the primary fluid circuit is hydraulically independent of the common fluid circuit is preferred. Hydraulic independence is a prerequisite for reliable and safe operation of heat pumps.

[0017] If the invention is to serve as a source of cold, it is preferred for its operational efficiency that an absorption chiller is connected via the primary fluid circuit at the first point of the invented connection. The absorption chiller exhibits preferred operation efficiency when cooling from higher temperatures; therefore, placing it first in the invented connection will bring the most significant benefit.

[0018] The invention also includes a method of controlling heat pumps within the connection. After the known procedure step (a), in which the required temperature of the fluid at the outlet of the common fluid circuit is determined, and after the known procedure step (b), in which the temperature on the last temperature sensor is measured in the sense of the direction of circulation of the fluid through the common fluid circuit and the temperature difference between the required temperature and the actual temperature of the circulating fluid is determined, new procedure steps follow, forming the essence of the invention. These are procedure step (c), in which the temperature differences are divided into temperature intervals for the individual heat pumps connected in parallel, and procedure step (d), in which according to the required temperature intervals, the heat pumps are activated to achieve the required fluid temperature at the outlet of the common fluid circuit. Heat pumps performing the task of changing the temperature over the range of a temperature interval have a better overall result of COP or EER values.

[0019] In addition to controlling the operation of the heat pumps, an embodiment of the inventive method is preferred, in which the performance of the hydraulic pumps of the common fluid circuit is simultaneously controlled as part of procedure step (d). In addition to the instantaneous performance of the heat pumps, the rate of fluid circulation through the common fluid circuit can affect the fulfilment of the temperature interval.

[0020] Last but not least, an embodiment of the invented method is preferred, in which the temperature intervals within the procedure step (c) are of the same size. Dividing the temperature difference into equal temperature intervals will facilitate the process of heat pump control.

[0021] From a technical point of view, it is preferable that in the invented connection the heat transfer fluid from the common fluid circuit is led into an associated heat pump and subsequently returns to the common fluid circuit with the temperature altered according to the temperature interval. The primary circuit of another heat pump then follows on the common fuel circuit, and this is repeated according to the number of heat pumps.

[0022] The invented connection of heat pumps for the heat source will significantly increase the efficiency, allow the declared outlet temperature of the heating medium to be reached and enable the achievement of a high temperature gradient of the heating medium (up to 50/30 °C). The first heat pump in the connection will be operated at low temperature with high COP, the last heat pump in the connection will be operated at high temperature with low COP. In a classic parallel cascade connection, all heat pumps for heating would operate at high inlet and outlet temperatures of the heating medium with low COP.

[0023] Analogously, the invented connection for the source of cold will substantially increase the EER, i.e. the efficiency of the chillers. In cooling mode, the invented connection will also enable a higher temperature gradient while, in turn, increasing the overall EER and, greatly increasing the accumulation of cold and reducing the number of compressor starts. This applies except during periods when the maximum consumption of cold is at the limit of the cooling system's capacity (usually a very short period in the season).

Brief Description of the Drawings

[0024] The said invention will be explained in more detail in the following illustrations, wherein:

Fig. 1 is a schematic representation of the prior art with heat pumps connected in parallel and controlled by a cascade controller according to the desired temperature at the heating water outlet,

Fig. 2 is a schematic representation of the prior art with chillers connected in parallel and controlled by a cascade controller according to the desired temperature at the cooling water outlet,

Fig. 3 is a schematic representation of the prior art of serial hydraulic connection of heat pumps controlled by a cascade controller according to the required temperature at the heating water outlet,

Fig. 4 is a schematic representation of the prior art of serial hydraulic connection of the chillers controlled by a cascade controller according to the required temperature at the cooling water outlet,

Fig. 5 is a schematic representation of the invented connection of four heat pumps for heating, in which the common fluid circuit is connected to the heat accumulation,

Fig. 6 is a schematic representation of the invented connection of four heat pumps for heating, in which the common fluid circuit is connected directly to the heating system,

Fig. 7 is a schematic representation of the invented connection of four partial heat pumps for heating, in which the common fluid circuit of the partial heat pumps forms the primary fluid circuit of one composite heat pump,

Fig. 8 is a schematic representation of the invented connection of two heat pumps for heating, in which the heat pumps are controlled by a controller according to the temperature from temperature sensors and at the same time the common fluid circuit is connected to the heat accumulation,

Fig. 9 is a schematic representation of the invented connection of two heat pumps for heating, in which the primary fluid circuits of the pumps are led into accumulation vessels connected by the common fluid circuit,

Fig. 10 is a schematic representation of the invented connection of four heat pumps for heating, in which the primary fluid circuits of the pumps are led into accumulation vessels connected by the common fluid circuit,

Fig. 11 is a schematic representation of the invented connection of four chillers, in which the common fluid circuit is connected to the cold accumulation,

Fig. 12 is a schematic representation of the invented connection of four chillers, in which the common fluid circuit is connected directly to the cooling system,

Fig. 13 is a schematic representation of the invented connection of four partial chillers, in which the common fluid circuit of the partial chillers forms the primary fluid circuit of one composite chiller,

Fig. 14 is a schematic representation of the invented connection of three chillers, including one absorption chiller, in which the common fluid circuit is connected to the cold accumulation,

Fig. 15 is a schematic representation of the invented connection of two chillers, in which the chillers are controlled by a controller according to the temperature from temperature sensors and at the same time the common fluid circuit is connected to the heat accumulation,

Fig. 16 is a schematic representation of the invented connection of two chillers, in which the primary fluid circuits of the pumps are led into accumulation vessels connected by the common fluid circuit,

Fig. 17 is a schematic representation of the invented connection of four chillers, in which the primary fluid circuits of the chillers are led into accumulation vessels connected by the common fluid circuit.

Examples of Invention Embodiments

[0025] It is understood that the specific examples of embodiments of the invention disclosed and illustrated below are presented for illustrative purposes and not as a restriction of the invention to those examples. Persons skilled in the art will find or be able to provide, using routine experimentation, a greater or lesser number of equivalents to the specific embodiments of the invention disclosed herein.

[0026] The invention works with the general concept of a heat pump, being a machine that pumps heat when doing its job, and it only depends on the application, whether it is used for heating or cooling. Within the Example of Invention Embodiment chapter, the word chiller is used for a heat pump used for cooling.

[0027] Figure 1 shows a solution known in the prior art for the parallel hydraulic connection of heat pumps 1 controlled by a cascade controller 11 according to the required temperature at the heating water outlet. Since all heat pumps 1 have to overcome the same temperature difference, they have the same COP, which is very low at higher temperature gradients in higher temperature.

[0028] Figure 2 shows a solution known in the prior art for the parallel hydraulic connection of chillers 1' controlled by a cascade controller 11 according to the required temperature at the cooling water outlet. Since all chillers 1' have to overcome the same temperature difference, they have the same EER, which is very low at higher temperature gradients.

[0029] Figure 3 shows a solution known in the prior art for the serial hydraulic connection of heat pumps 1 controlled by a cascade controller 11 according to the required temperature at the heating water outlet. In a series connection, the temperature difference is overcome successively by the individual contributions from heat pumps 1, but at the cost of increasing hydraulic resistance, since in a series connection each member of the series adds its own internal hydraulic resistance and extends the length of the common fluid circuit 3. The series connection is therefore limited by the flow rate. It is analogous to that in Figure 4 for the chillers 1', whose task is to dissipate heat, not accumulate it.

[0030] Figure 5 shows the invented connection in an example embodiment, in which four heat pumps 1 are connected by their primary fluid circuits 2 to the common fluid circuit 3. Before and after each connection of the primary fluid circuit 2, a temperature sensor 5 is installed on the common fluid circuit 3. The temperature sensors 5 provide information about the temperature of the circulating fluid entering the beginning of the invented connection of the heat pumps 1, as well as the temperature change after each heat pump 1. The connection includes an accumulation tank 7 to which the common fluid circuit 1 is led. A heating system 8 is connected to the accumulation tank 7. The fluid circulation in the common fluid circuit 1 is provided by the hydraulic pump 4.

[0031] From Figure 5, it can be seen that the temperature of the circulating fluid was 30 °C at the beginning and 46 °C at the end. This means that the temperature difference was 16 °C, and was divided between four heat pumps 1 as 4 °C each. The first heat pump 1 in the sequence in terms of circulation direction heats at a low temperature level with a high COP, the following primary fluid circuit 2 with heat pump 1 heats the circulating fluid at a slightly higher temperature level with a slightly worse COP, and so on until the last heat pump 1 in the sequence heats the circulating fluid at the highest temperature level with the worst COP. The heat output of the heat pumps 1 is controlled by a controller 6 of the invented connection of the heat pumps 1 based on the readings from temperature sensors 5 so that the required outlet temperature of the circulating fluid (heating medium) is reached. The required temperature gradient is controlled by the controller 6 of the invented heat pump 1 connection so that based on the readings from temperature sensors 5, it controls the hydraulic output of the circulation pump 4 of the common fluid circuit 3.

[0032] The controller 6 is communicatively connected to the heat pumps 1 and to the temperature sensors 5 of the invented connection by cables or wirelessly. Communication data flows, or cable communication pathways, are not shown in Figure 5 with the hydraulic pathways depicted.

[0033] The example embodiment of Figure 6 differs from the example embodiment illustrated in Figure 5 in that the common fluid circuit 3 is connected directly to the heating system 8. The purpose of the example is to show that the invention can be applied to a variety of different heating implementations, either directly or via the accumulation tank 7.

[0034] Figure 7 shows an embodiment of the invention, which presents one composite heat pump 1 made of four compressor heat pump sub-circuits. The principle of the invention is therefore applicable not only in the production of entire systems, see previous examples of embodiments of the invention, but also in the production of a single composite heat pump with an increased COP value.

[0035] Figure 8 shows an exemplary embodiment of the invention with two heat pumps 1 heating a circulating medium in the common fluid circuit 1 equipped with the accumulation tank 7 for storing the heat obtained.

[0036] As for the example of the embodiment of the invention shown in Figure 9, the change in the invention is that the accumulation tanks 7 are connected directly to the primary circuits 2 of the heat pumps 1, and that the common fluid circuit 3 continues only after the accumulation tanks 7. The present example of the invention makes operation more efficient because the heat pumps 1 can accumulate heat in the accumulation tanks 7 under more favourable conditions (e.g., in a low electricity distribution tariff), and under less favourable operating conditions work with minimal deployment, or the number of starts is reduced due to heat accumulation, which extends the service life of the heat pumps 1. The control based on the determination of the temperature difference using the temperature sensed by the temperature sensors 5 and its distribution according to the number of connected heat pumps 1 still proceeds in the same way.

[0037] Figure 10 is a variation of the invention analogous to the example of Figure 9, except that the invention illustrated in Figure 10 includes four heat pumps 1.

[0038] The heat pumps 1 mentioned above in the text of the exemplary embodiment of the invention were used for heating. The graphic in the figures shows that the heat pumps 1 are compressor heat pumps, i.e. they have a compressor, a condenser, an expansion valve and an evaporator.

[0039] In the following illustrated examples of embodiments of the invention, heat pumps 1 used for cooling will be referred to as chillers 1'. In principle, chiller 1' = heat pump 1 for cooling. It will be appreciated from the schematic illustrations that the chillers 1' also have a compressor, an evaporator, a condenser and an expansion valve.

[0040] Figure 11 illustrates the invention with four chillers 1' having their primary fluid circuits 2 connected to a common fluid circuit 3. The common fluid circuit 1 is provided with an accumulation tank 7 for storing cold The concept of storing cold simply means that inside the accumulation tank 7 there is a cooled fluid which, due to its low temperature, has the potential to absorb heat, thus acting cold. Even for cooling, the invention works with temperature sensors 5 installed on the common fluid circuit 1 before and after each connection of the primary fluid circuit 2. The controller 6, analogous to the previous examples of embodiments of the invention, detects a temperature difference which it divides into temperature intervals for individual chillers 1'. The circulation in the common fluid circuit is provided by the hydraulic pump 4.

[0041] Figure 12 illustrates the invention similar to the variant of the invention of Figure 11, but with the difference that the common fluid circuit 3 is connected directly to the cooling system 9.

[0042] The first of the primary fluid circuits 2 with chiller 1' cools the circulating fluid (refrigerant) at a high temperature level at high EER, the next chiller 1' cools the refrigerant at a slightly lower temperature level at slightly worse EER and so on until the last chiller 1' in the circuit cools the refrigerant at the lowest temperature level at the worst EER. The heat output of the chillers 1' is controlled by the controller 6 of the invented connection of the chillers 1' based on the readings from temperature sensors 5 so that the required outlet temperature of the cooling medium is reached. The required temperature gradient is controlled by the controller 6 of the invented connection of chillers 1' so that based on the readings from temperature sensors 5, it controls the hydraulic output of the circulation hydraulic pump 4 of the common fluid circuit 3.

[0043] Figure 13 illustrates a composite chiller 1', which is constructed as a whole from several compressor circuits of sub-chillers 1', which are connected by their primary fluid circuits 2 to the common fluid circuit 3. It will be appreciated that the principle of the invention is applicable both to units (composite chillers 1') and entire systems, see previous examples of embodiments with chillers 1'.

[0044] Figure 14 illustrates an embodiment of the invention in which an absorption chiller 10 is used. The absorption chiller 10 is effective in removing heat from the higher temperature circulating fluid, and is therefore positioned first in the invented connection in terms of fluid circulation through the common fluid circuit 3. Then, in the invented connection, the chillers 1' with compressors follow. The controller 6 controls the operation of all heat pumps 1 in the connection, as well as the absorption chiller 10.

[0045] Figure 15 illustrates an example embodiment of the connection according to the invention, in which there are two chillers 1' and their common fluid circuit 1 is provided with an accumulation tank 7.

[0046] Figure 16 shows a variant in which the primary fluid circuits 2 of two chillers 1' are provided with accumulation tanks 7. The example is analogous to the example in Figure 9, except that it involves storing cold. Chillers 1' can prepare cold under more favourable conditions, whereas under less favourable conditions they do not need to be operated at high output. Chillers 1', thanks to the accumulation of cold, can reduce the number of starts and thus extend their service life.

[0047] Figure 17 illustrates a similar connection embodiment to the previous example, but with the difference that there are four chillers 1' in the connection.

[0048] The method of operation of heat pumps in the invented connection is as follows:

(a) the controller 6 determines the required temperature of the fluid at the outlet of the common fluid circuit 3,
(b) the controller 6 measures the temperature at the last temperature sensor 5 in the direction of circulation of the fluid through the common fluid circuit 1 and determines the temperature difference between the required temperature and the actual temperature of the circulating fluid,
(c) the controller 6 divides the temperature difference into temperature intervals for the individual connected heat pumps 1,
(d) according to the required temperature interval, the controller 6 activates the heat pumps 1 to reach the required temperature of fluid at the outlet from the common fluid circuit 3.

[0049] The above steps are automated by controller 6, which is e.g. a programmable automaton. The controller 6, according to its program, controls the operating parameters of the heat pumps 1 for heating (or chillers 1' for cooling) and/or controls the output of the hydraulic pump 4, by which it changes the parameters of the fluid circulation through the common fluid circuit 3.

[0050] If all heat pumps 1 have the same parameters, the temperature difference is divided between them into approximately equal temperature intervals. On the other hand, if the heat pumps 1 in the invented connection are different in terms of parameters, it is possible to program the controller 6 to take their operating parameters into account when dividing the temperature difference into temperature intervals.

[0051] The required outlet temperature of the heating medium, or cooling medium, varies with the outdoor temperature according to the equitherm curve. Equithermal temperature control consists in setting the temperature of the heating or cooling medium depending on the outdoor temperature. The characteristics of the heating or cooling consumers and the entire heating or cooling system 8 and 9 determine the amount of temperature difference. It can also change depending on the outdoor temperature.

[0052] The invented control determines the outlet temperature of the medium and the temperature gradient. This is already a known solution, but as a novelty, it subsequently divides the temperature gradient into individual entities (heat pumps 1 or chillers 1'), which are connected in parallel to the common fluid circuit 3, while controlling their performance and circulation of the medium through the entity so that the temperature gradient on the entity is reached. When the total output of the cascade of entities in the invented connection is required to be low, the control gradually disconnects the entities.

[0053] Practical experiments preliminarily show that the invention achieves a higher seasonal COP by 0.6 for heat pumps 1 and a higher seasonal EER by 0.5 for chillers 1'.

Industrial Applicability

[0054] The method of connecting heat pumps according to the invention is applicable to all central heat or cold sources comprising at least two heat pumps, both in air-conditioned buildings and in industrial cooling systems. It allows to increase the performance and accumulation capacity of systems when heat pumps are connected directly to the heating or cooling system. It allows to reduce the hydraulic flow through the heating or cooling system, saving pumping work and improving the hydraulic balance of the system. The invented method of connecting heat pumps increases their lifetime.

Reference Signs List

[0055]

1	heat pump
1'	chiller
2	primary fluid circuit
3	common fluid circuit
4	hydraulic pump
5	temperature sensor
6	controller
7	accumulation vessel
8	heating system
9	cooling system
10	absorption chiller

Claims

1. A connection of heat pumps (1) to form an efficient source of heat or cold, wherein each heat pump (1) is provided with a primary fluid circuit (2), **characterised in that** at least two heat pumps (1) are connected by their primary fluid circuits (2) to a common fluid circuit (3), the common fluid circuit (3) being provided with at least one hydraulic pump (4), further, that a temperature sensor (5) is installed upstream and downstream of each connection of the respective primary fluid circuit (2) to the common fluid circuit (3), wherein the heat pumps (1) and the hydraulic pumps (4) are communicatively connected to at least one controller (6) for controlling their operation, and at the same time the controller (6) is communicatively connected to the temperature sensors (5).

2. The connection according to claim 1,**characterised in that** the common fluid circuit (3) is connected to at least one accumulation vessel (7).

3. The connection according to claim 1,**characterised in that** the common fluid circuit (3) is connected directly to a heating system (8) or a cooling system (9).

4. The connection according to any one of claims 1 to 3, **characterised in that** at least one of the primary fluid circuits (2) is connected to the common fluid circuit (3) via the accumulation tank (7).

5. The connection according to any one of claims 1 to 4, **characterised in that** each primary fluid circuit (2) is hydraulically independent of the common fluid circuit (3).

6. The connection according to any one of claims 1 to 5, **characterised in that** for an effective source of cold, the primary fluid circuit (2) of the absorption chiller (10) is connected at the first position of the common fluid circuit (3) in the connection in terms of fluid circulation.

7. A method of controlling heat pumps (1) in the connection according to any one of claims 1 to 6, comprising the following procedure steps:

   (a) the required temperature of the fluid at the outlet of the common fluid circuit (3) is determined, and by procedure step
   (b) the temperature at the last temperature sensor (5) in the direction of circulation of the fluid through the common fluid circuit (3) is measured and the temperature difference between the required temperature and the actual temperature of the circulating fluid is determined, **characterised in that** it further comprises the procedure steps:

      (c) the temperature difference is divided into temperature intervals for the individual connected heat pumps (1), and in the procedure step
      (d) the heat pumps (1) are activated according to the required temperature interval to reach the required temperature of fluid at the outlet from the common fluid circuit (3).

8. The method according to claim 7, **characterised in that** in the procedure step (d), the output of the hy-

draulic pumps (4) of the common fluid circuit (3) is simultaneously controlled.

9. The method according to claim 7 or 8 **characterised in that** in the procedure step (c) the temperature intervals are substantially of the same size.

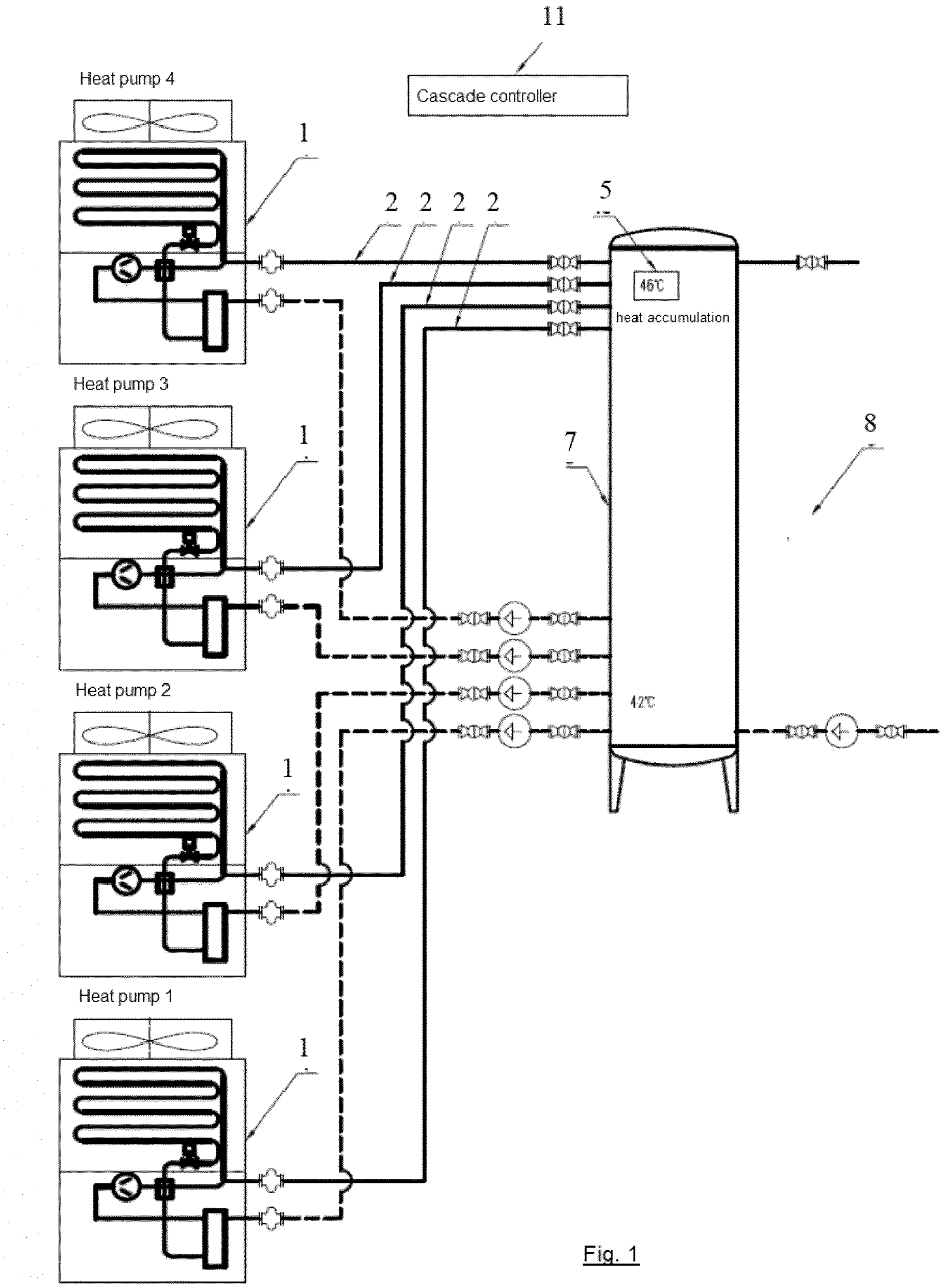
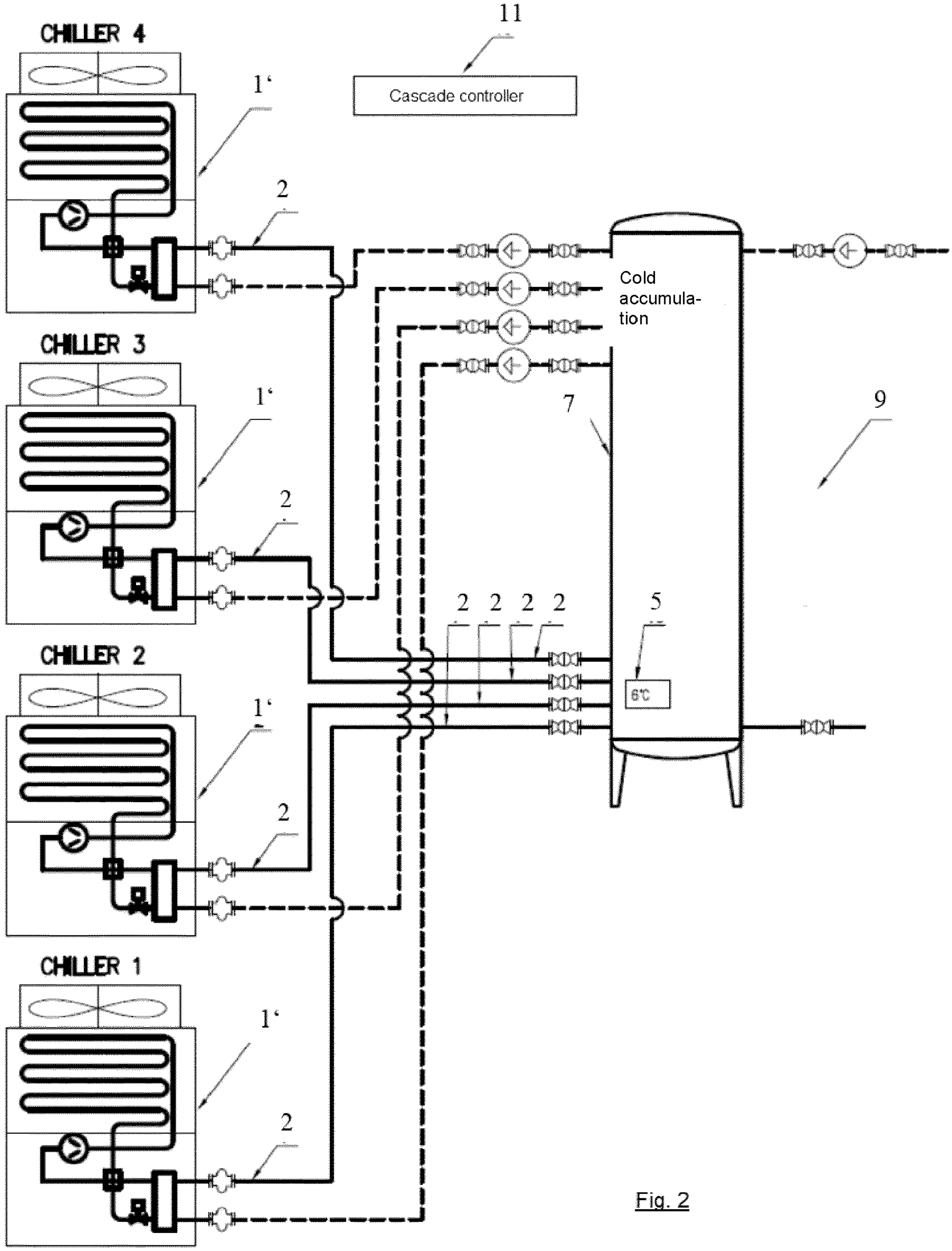

11
Cascade controller
Heat pump 4
Heat pump 3
Heat pump 2
Heat pump 1
1
2
5
46℃
heat accumulation
42℃
7
8

Fig. 1



11
Cascade controller
CHILLER 4
1'
2
Cold accumula-tion
CHILLER 3
1'
2
7
9
CHILLER 2
1'
2 2 2 2
5
6°C
2
CHILLER 1
1'
2

Fig. 2

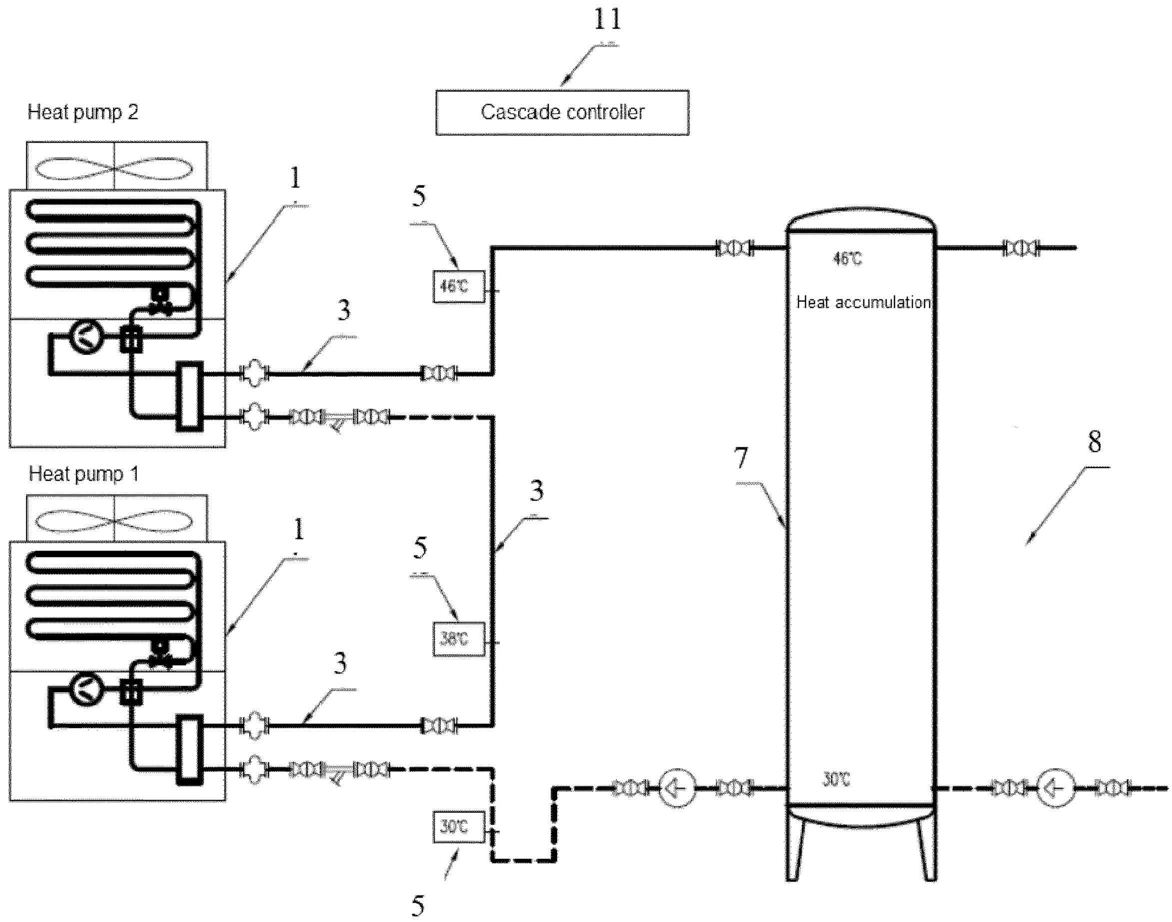

11
Cascade controller
Heat pump 2
1
5
46℃
3
46℃
Heat accumulation
Heat pump 1
1
5
38℃
3
3
7
8
30℃
30℃
5

Fig. 3

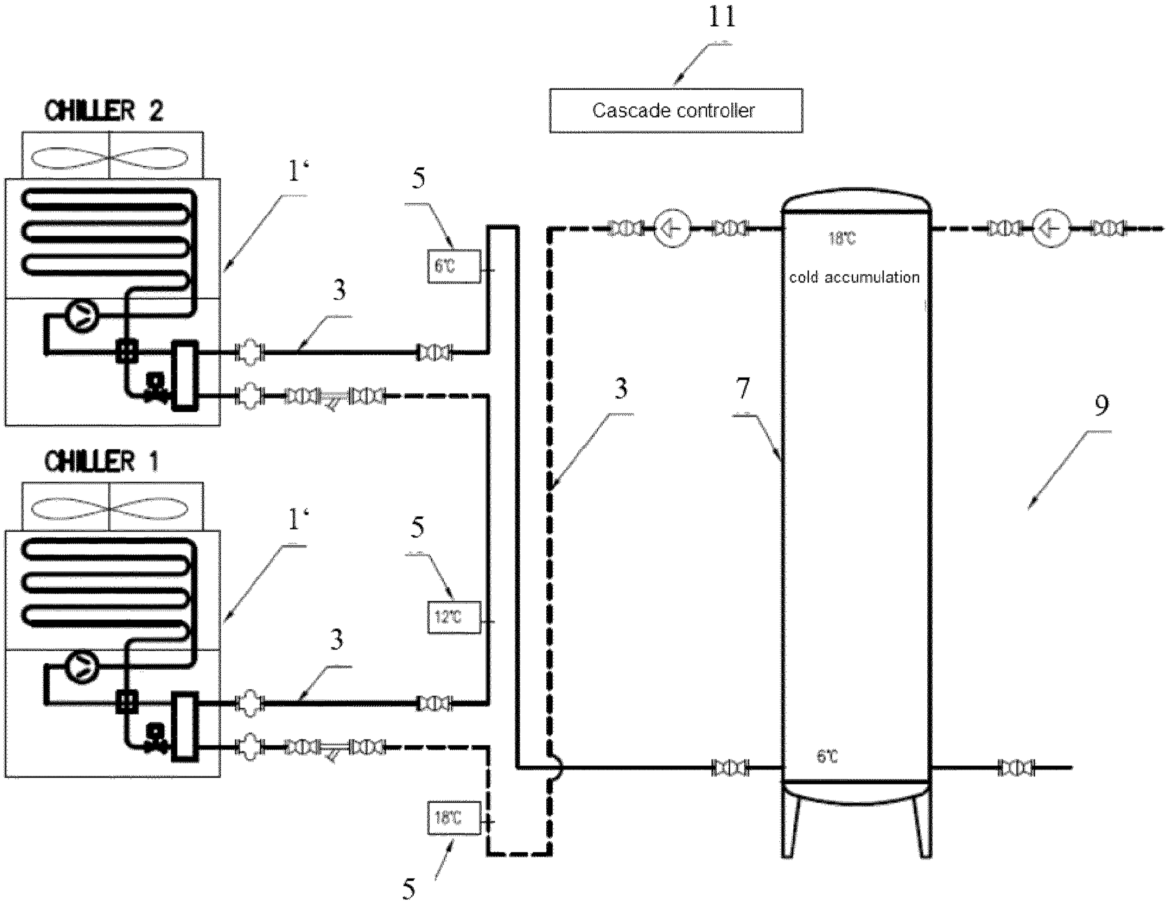

11
Cascade controller
CHILLER 2
CHILLER 1
1'
1'
5
5
5
3
3
3
7
9
6℃
12℃
18℃
18℃
cold accumulation
6℃

Fig. 4

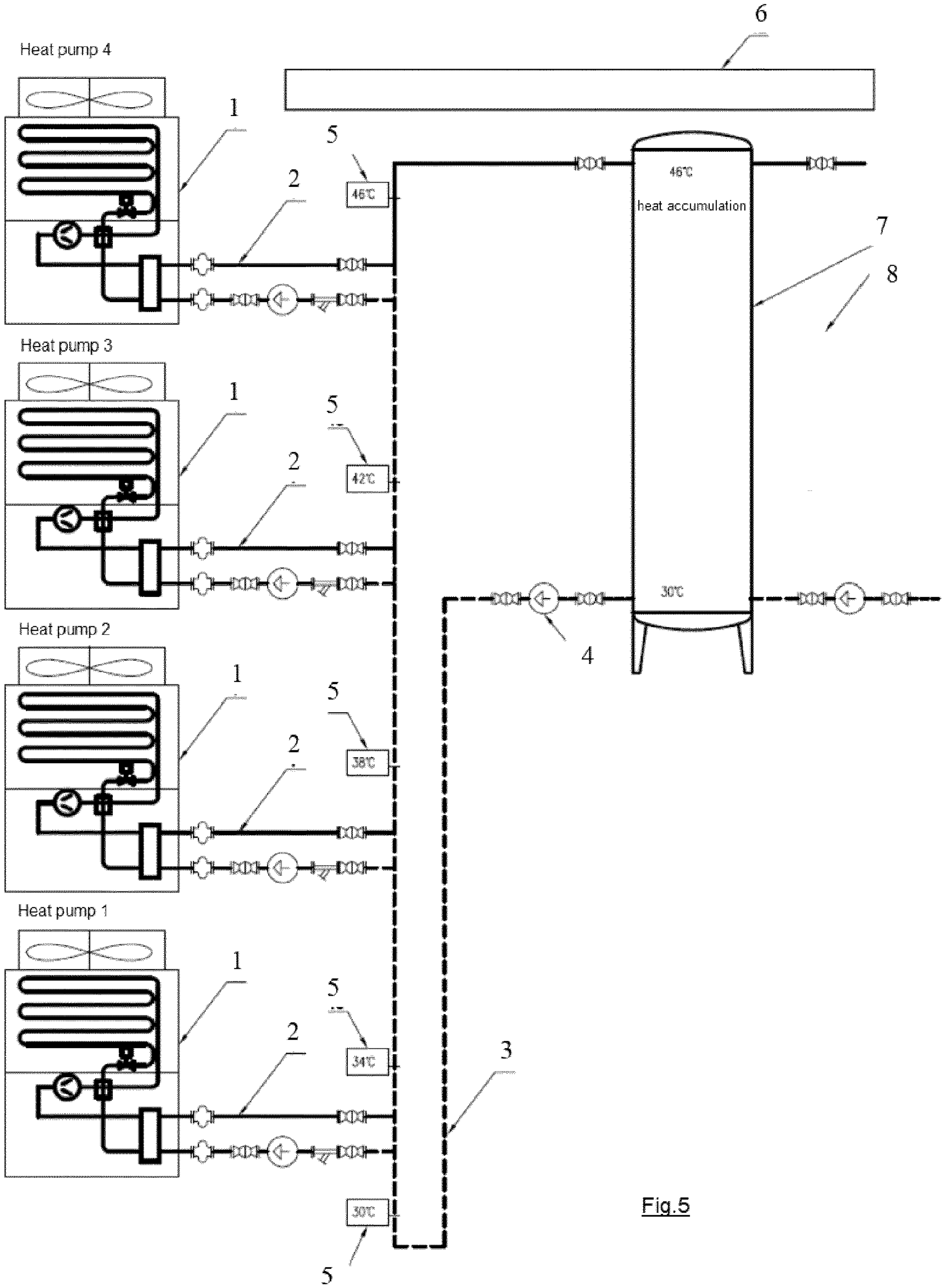

6
Heat pump 4
1
5
2
46℃
46℃
heat accumulation
7
8
Heat pump 3
1
5
2
42℃
30℃
4
Heat pump 2
1
5
2
38℃
Heat pump 1
1
5
2
34℃
3
30℃
5

Fig.5

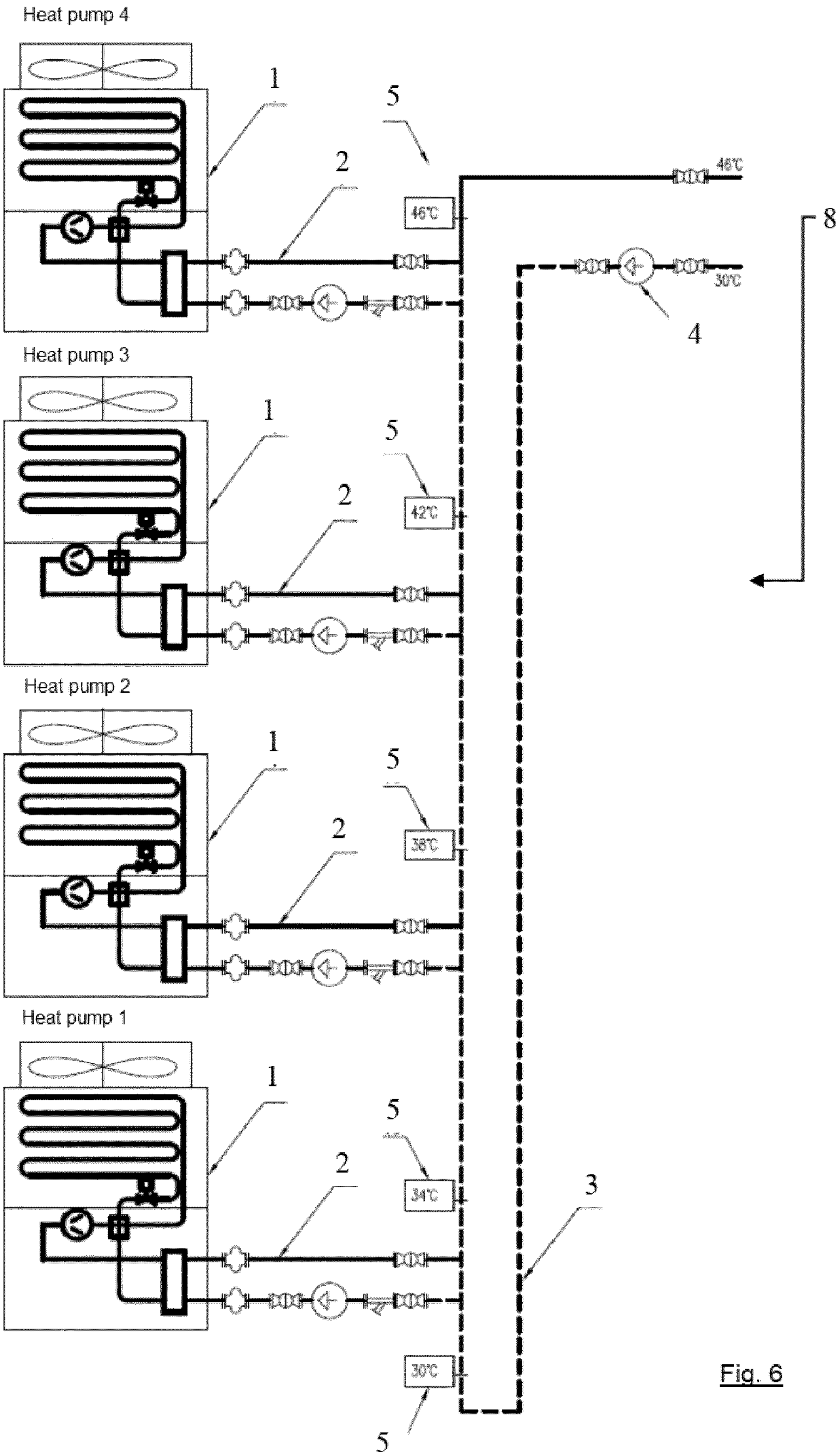

Heat pump 4
Heat pump 3
Heat pump 2
Heat pump 1
1
2
3
4
5
8
46℃
42℃
38℃
34℃
30℃

Fig. 6

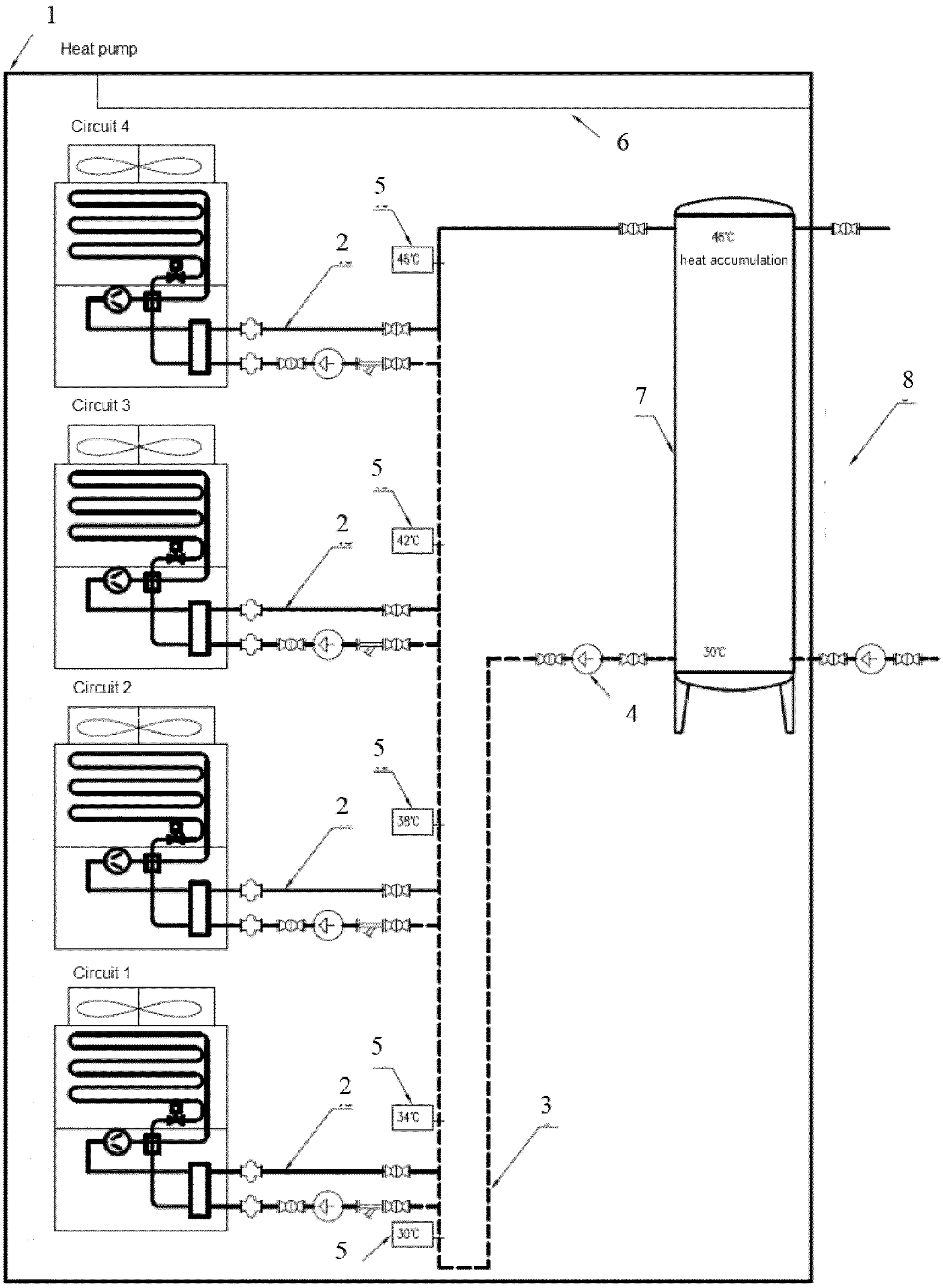
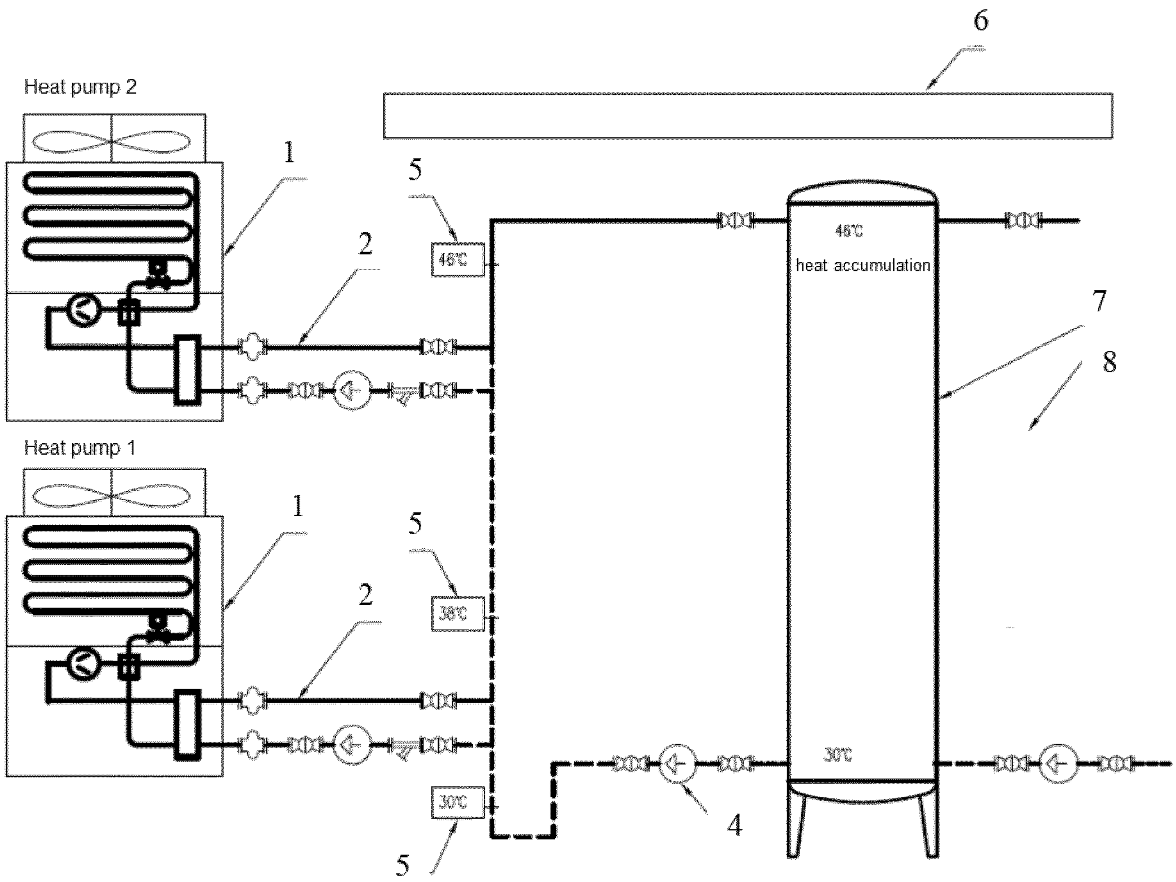

1
Heat pump
6
Circuit 4
5
45℃
2
46℃
heat accumulation
8
7
Circuit 3
5
42℃
2
30℃
4
Circuit 2
5
38℃
2
Circuit 1
5
2
34℃
3
30℃
5

Fig. 7



6
Heat pump 2
1
5
2
46℃
46℃
heat accumulation
7
8
Heat pump 1
1
5
2
38℃
30℃
30℃
4
5

Fig. 8

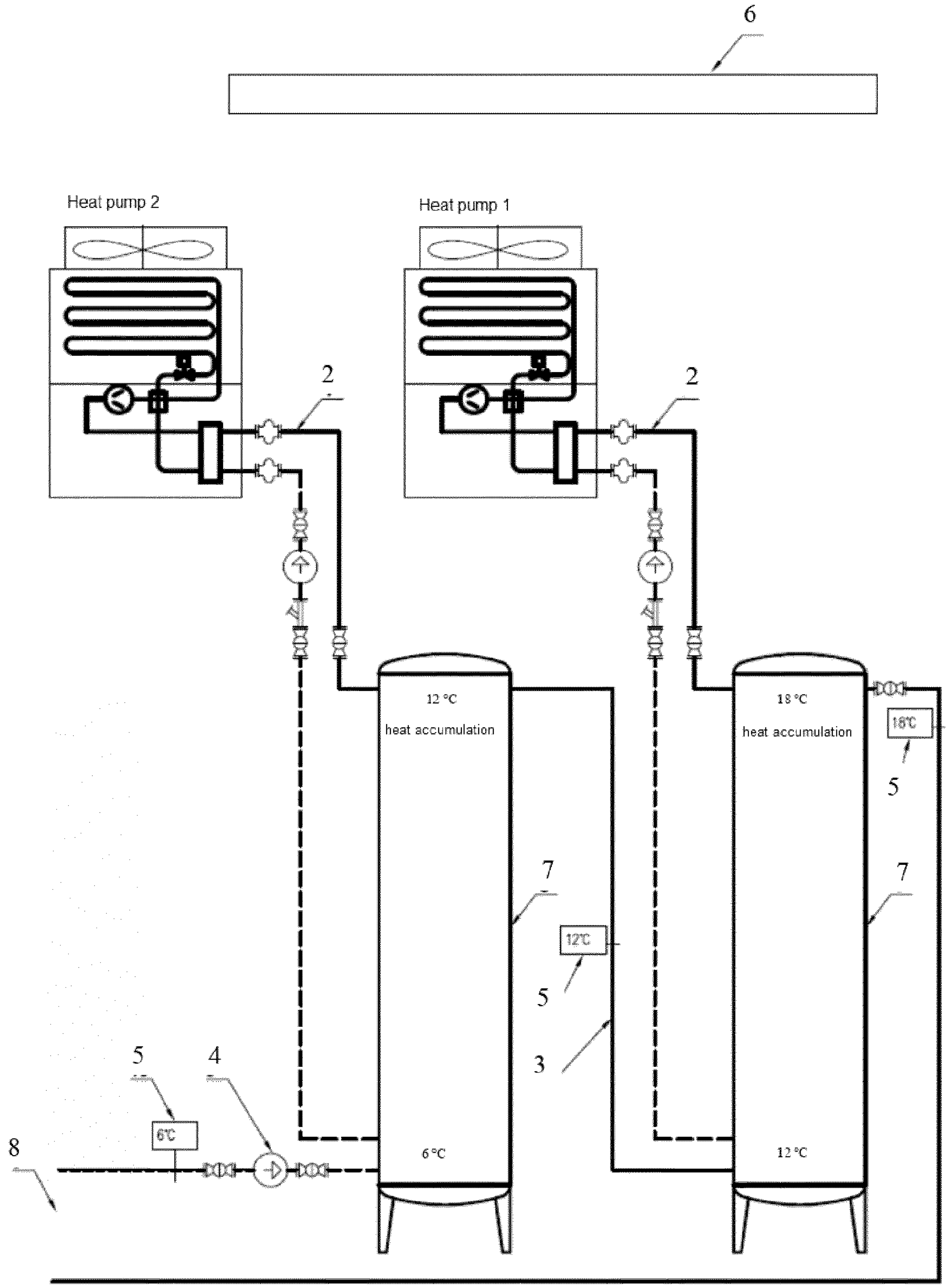

6
Heat pump 2
Heat pump 1
2
2
12 °C
heat accumulation
18 °C
heat accumulation
18℃
5
7
7
12℃
5
3
5
4
6℃
8
6 °C
12 °C

Fig. 9

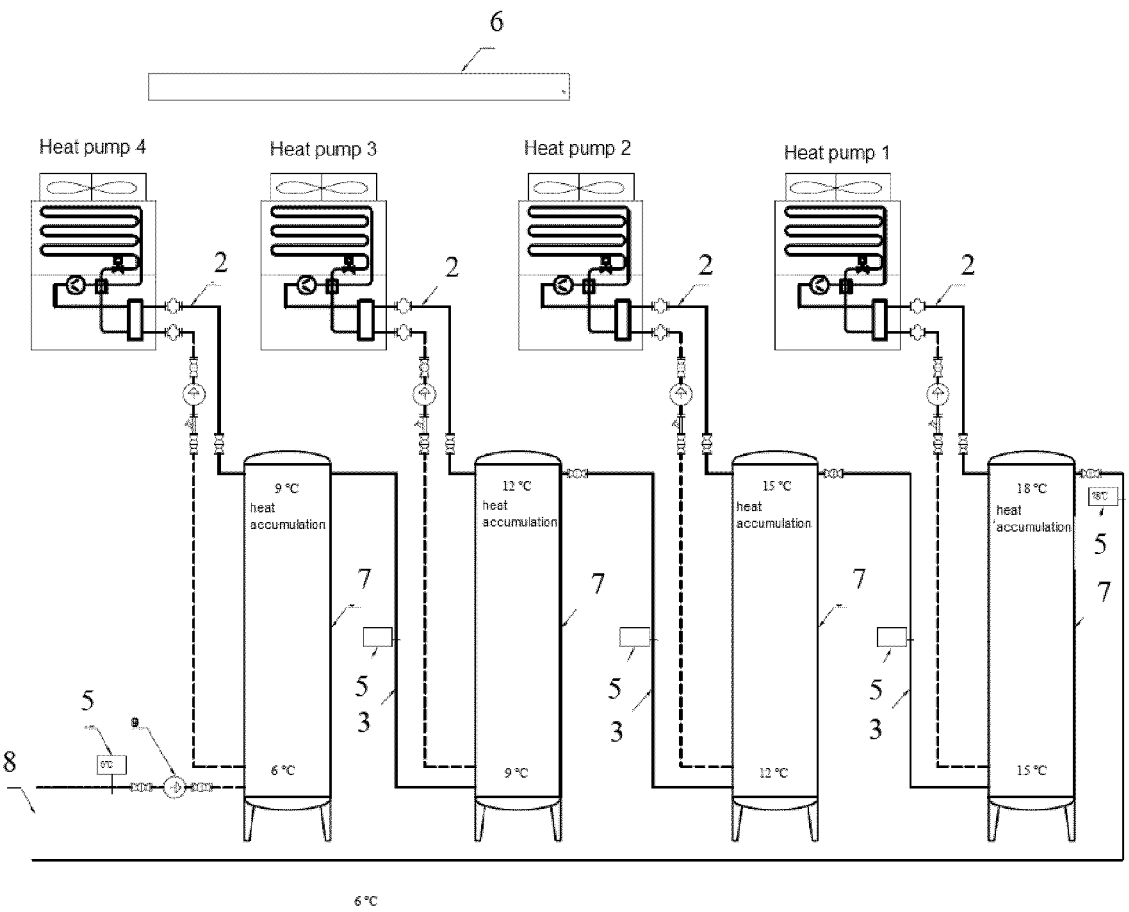

6
Heat pump 4
Heat pump 3
Heat pump 2
Heat pump 1
2
2
2
2
9 °C
heat
accumulation
12 °C
heat
accumulation
15 °C
heat
accumulation
18 °C
heat
accumulation
7
7
7
7
5
5
5
5
5
3
3
3
8
9
6 °C
9 °C
12 °C
15 °C
6 °C

Fig. 10

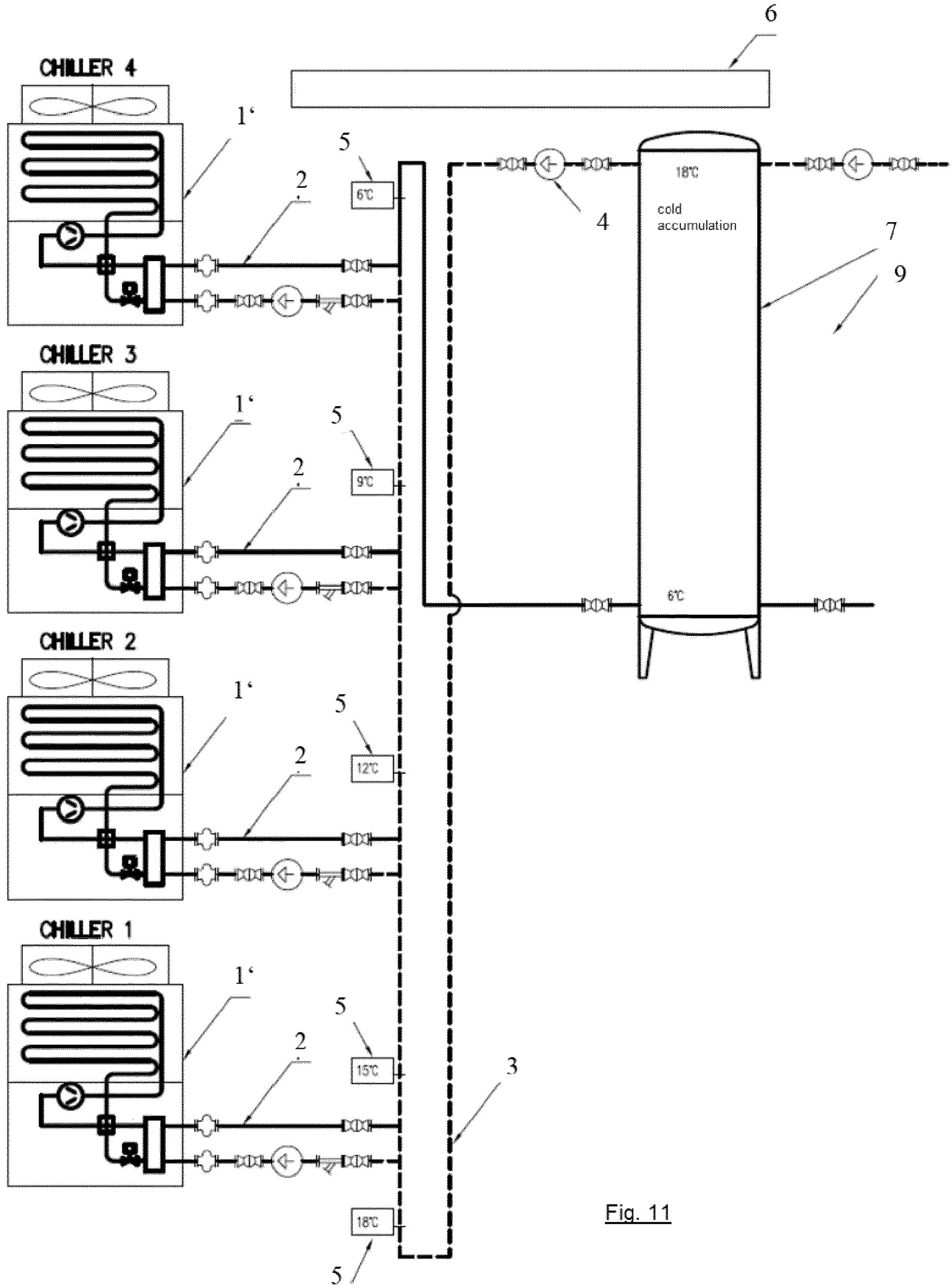

6
CHILLER 4
1'
5
6℃
2
4
18℃
cold
accumulation
7
9
CHILLER 3
1'
5
9℃
2
6℃
CHILLER 2
1'
5
12℃
2
CHILLER 1
1'
5
15℃
2
3
18℃
5

Fig. 11

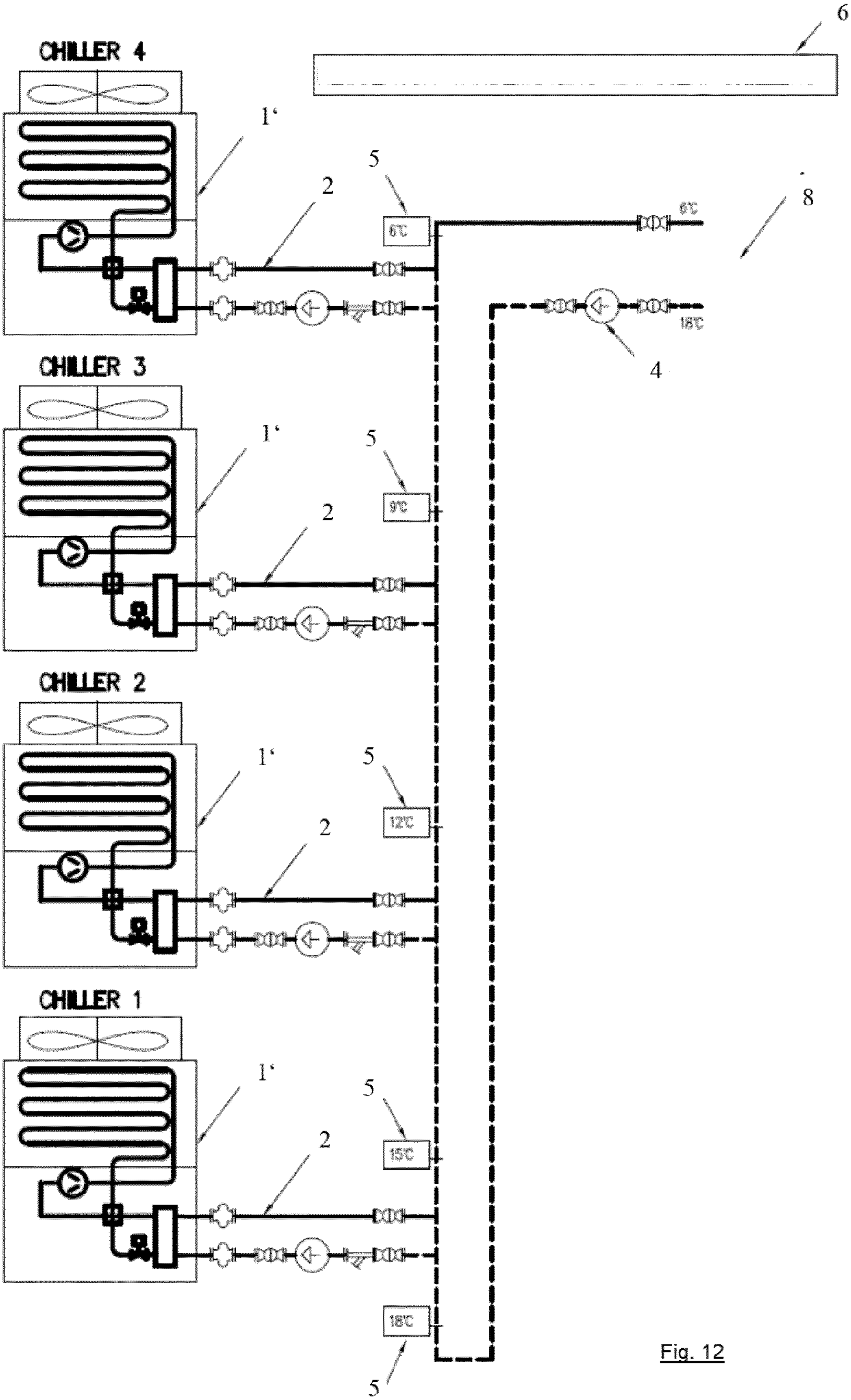

6
CHILLER 4
1‘
5
2
8
6°C
6°C
18°C
4
CHILLER 3
1‘
5
9°C
2
CHILLER 2
1‘
5
12°C
2
CHILLER 1
1‘
5
15°C
2
18°C
5

Fig. 12

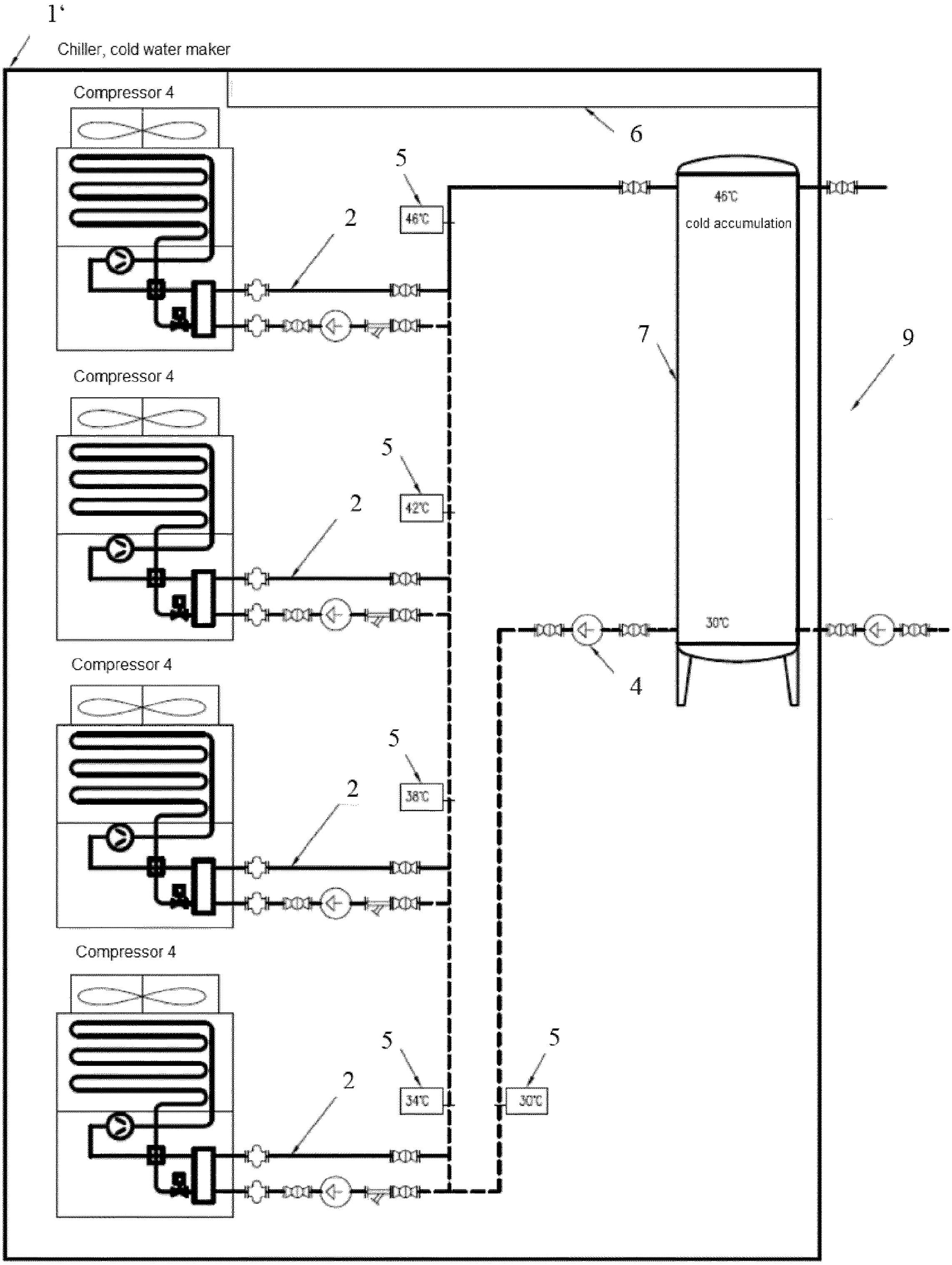

1'
Chiller, cold water maker
Compressor 4
Compressor 4
Compressor 4
Compressor 4
6
5
5
5
5
5
2
2
2
2
46℃
42℃
38℃
34℃
30℃
46℃
cold accumulation
30℃
7
9
4

Fig. 13

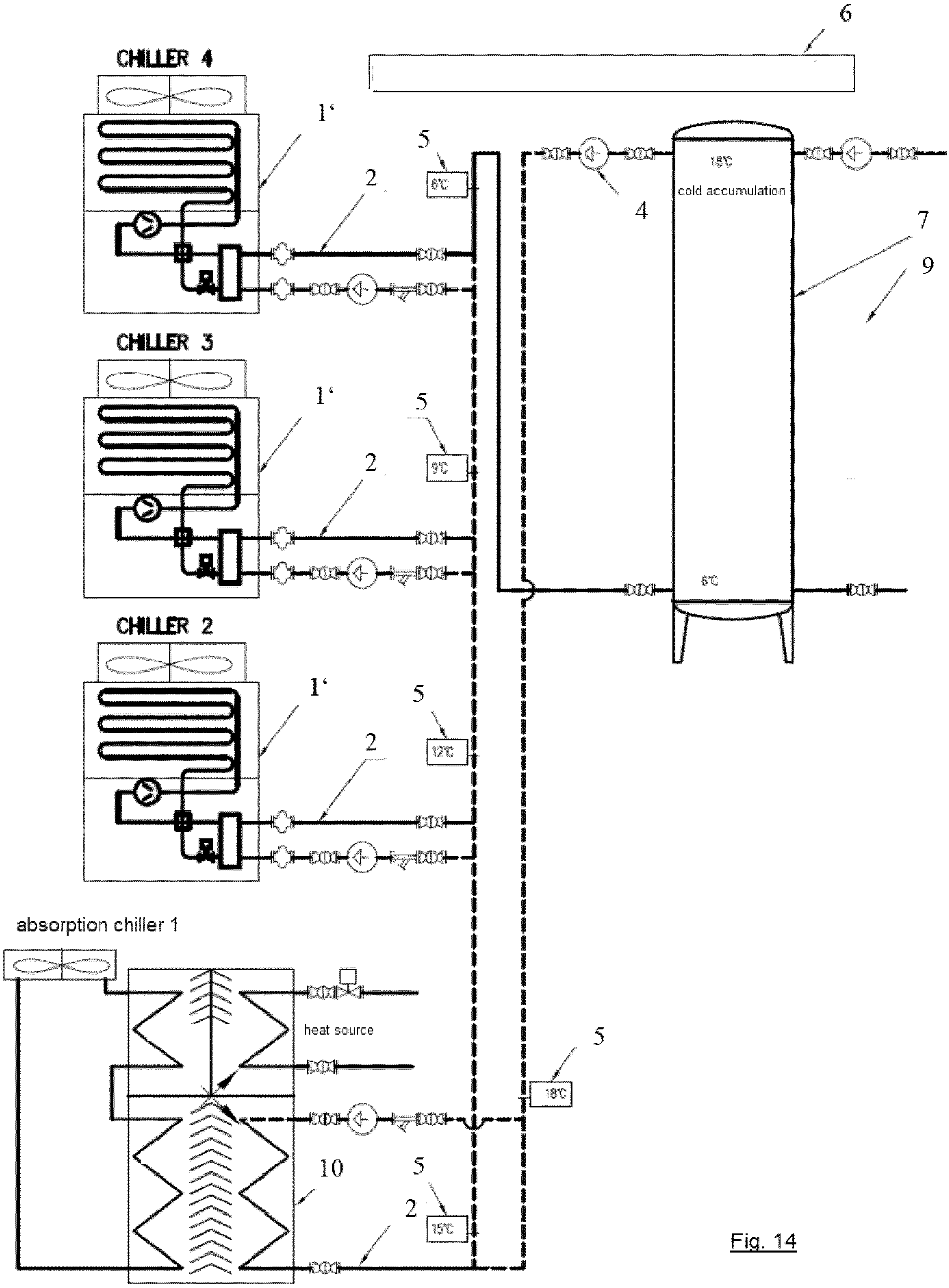

6
CHILLER 4
1'
5
6℃
2
18℃
cold accumulation
4
7
9
CHILLER 3
1'
5
9℃
2
6℃
CHILLER 2
1'
5
12℃
2
absorption chiller 1
heat source
5
18℃
10
5
2
15℃

Fig. 14

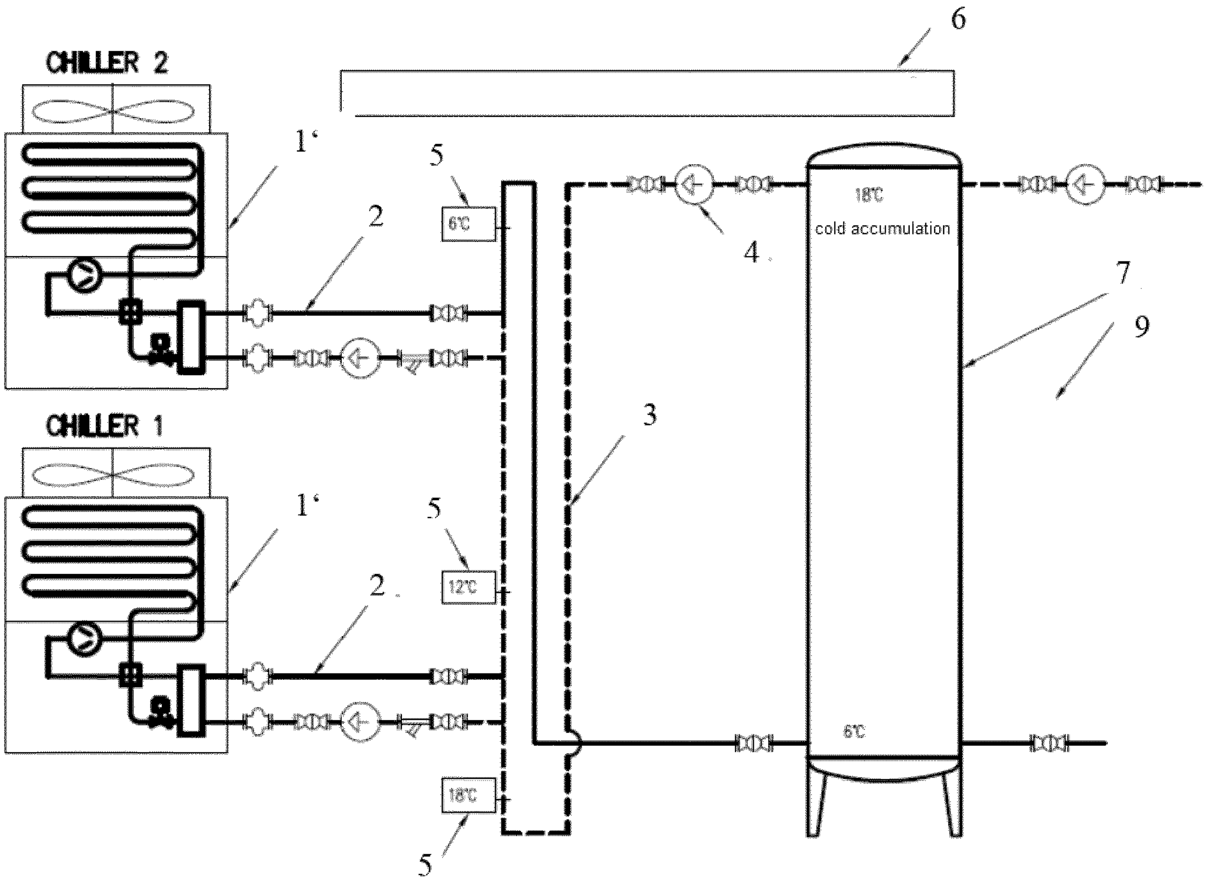


Fig. 15

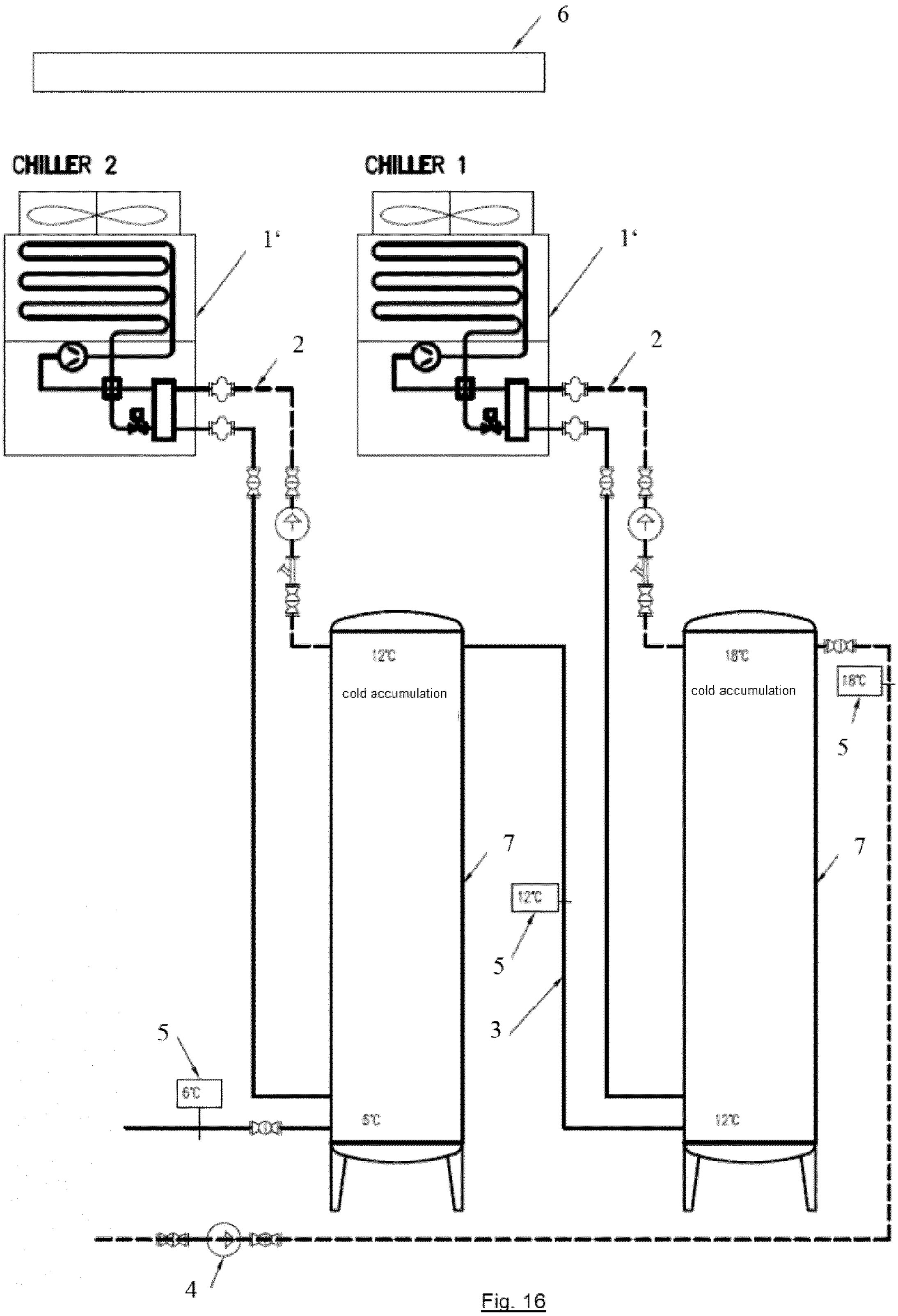

6
CHILLER 2
CHILLER 1
1'
1'
2
2
12°C
cold accumulation
18°C
cold accumulation
18°C
5
7
7
12°C
5
3
5
6°C
6°C
12°C
4

Fig. 16

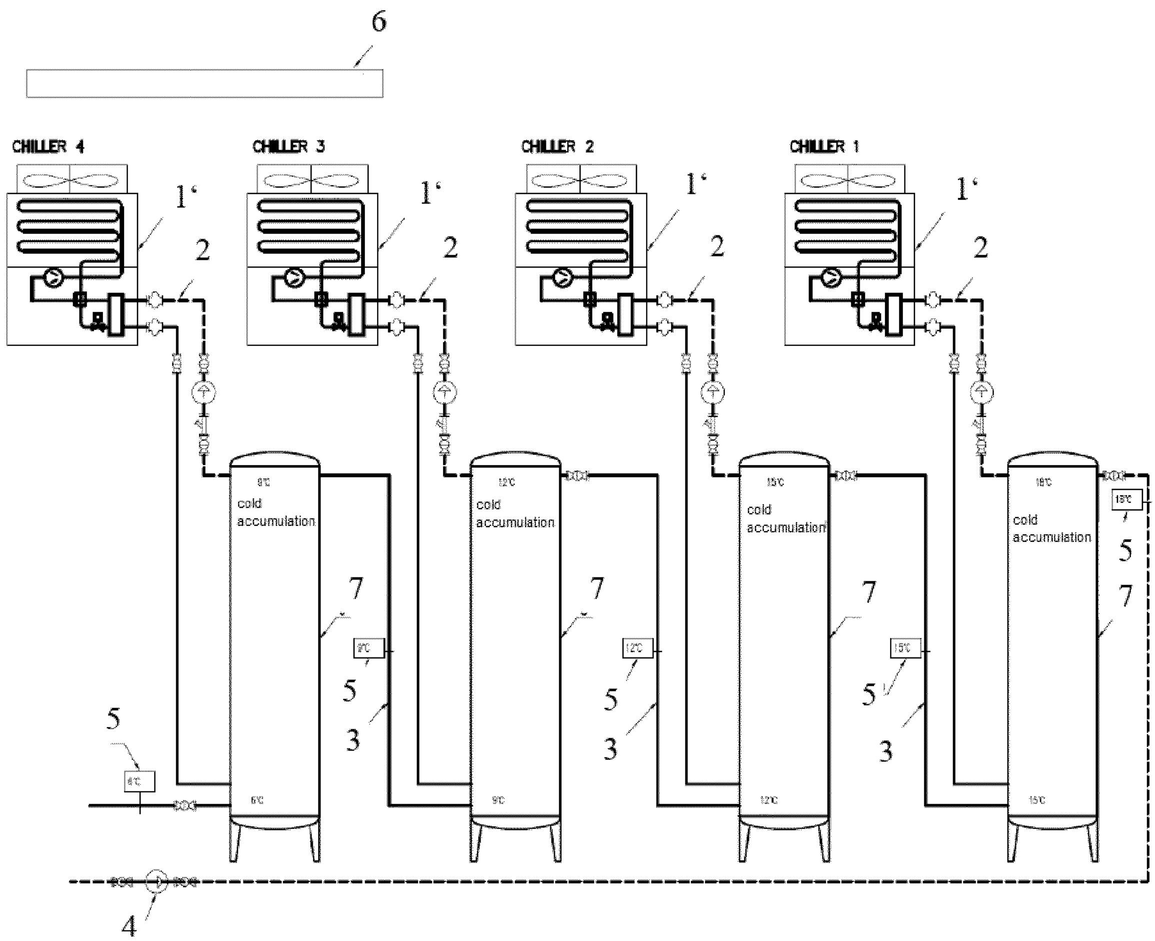

6
CHILLER 4
CHILLER 3
CHILLER 2
CHILLER 1
1'
2
cold
accumulation
7
5
3
4

Fig. 17

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 9716

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	EP 3 264 009 A1 (MITSUBISHI HEAVY IND THERMAL SYSTEMS LTD [JP]) 3 January 2018 (2018-01-03) * paragraph [0043] - paragraph [0046]; figures 1,2 * -----	1-9	INV. F25B13/00 F24D3/18 F25B49/02
X	JP 2011 052838 A (MITSUBISHI ELECTRIC CORP) 17 March 2011 (2011-03-17) * paragraph [0021]; figure 1 * -----	1-9	
X	EP 3 904 790 A1 (DAIKIN IND LTD [JP]) 3 November 2021 (2021-11-03) * paragraph [0024] - paragraph [0040]; figure 1 * -----	1-6	
A	WO 2012/144581 A1 (HITACHI PLANT TECHNOLOGIES LTD [JP]; MIZUSHIMA TAKANARI [JP] ET AL.) 26 October 2012 (2012-10-26) * paragraph [0055]; figure 1 * -----	6-9	
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			F25B F24H F24D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	14 March 2024	Szilagyi, Barnabas

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