(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 879 206 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
15.09.2021 Bulletin 2021/37

(51) Int Cl.:
***F25B 25/00** (2006.01)* ***F24F 3/06** (2006.01)*

(21) Application number: **20162226.3**

(22) Date of filing: **10.03.2020**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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(54) HYDRONIC REFRIGERATION SYSTEM

(57) A hydronic refrigeration system 200 comprises: a coolant cooling system 210; an air side cooling load system 230 for cooling of air using coolant from the coolant cooling system 210; and a coolant distribution system 250 for transporting coolant from the coolant cooling system 210 to the air side cooling load system 230 and from the air side cooling load system 230 to coolant cooling system 210; wherein the coolant cooling system 250 comprises multiple chillers 211a, 211b, 211c connected in series, with each chiller 211a, 211b, 211c comprising a refrigeration circuit 212a, 212b, 212c.

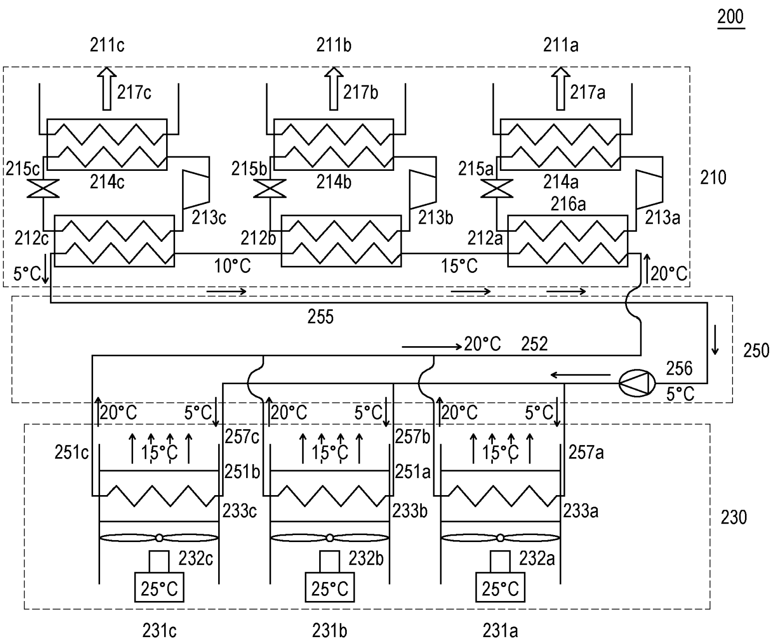

Fig. 2

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Description

[0001] The invention relates to a hydronic refrigeration system and a corresponding method for operating the hydronic refrigeration system.

[0002] A hydronic refrigeration system typically contains three sub systems; a coolant cooling system, a coolant distribution system and an air side cooling load system. The function of the air side cooling load system is to supply cooled air to a target area. Within the air side cooling load system heat is exchanged between warm air blown by fans over a hydronic coil and coolant flowing within the hydronic coil, thereby reducing the temperature of the air and increasing the temperature of the coolant. The function of the coolant cooling system is to remove the heat from the coolant that was gained whilst in the air side cooling load system. In this way heat gained by the hydronic refrigeration system in the air side cooling load system is expelled from the hydronic loop. The coolant cooling system typically contains thermodynamic machines called chillers comprising a compression device, a heat rejecting heat exchanger, an expansion device and a heat absorbing heat exchanger. Once the temperature of the coolant is reduced it can continue along the hydronic loop back to the air side cooling load to perform further cooling. The coolant distribution system comprises a network of pipes for transferring cooled coolant from the coolant cooling system to the air side cooling load system, and for transferring the heated coolant from the air side cooling load system to the coolant cooling system.

[0003] It would be beneficial to improve the efficiency of a hydronic refrigeration system.

[0004] Viewed from a first aspect, the invention provides a hydronic refrigeration system comprising: a coolant cooling system; an air side cooling load system for cooling of air using coolant from the coolant cooling system; and a coolant distribution system for transporting coolant from the coolant cooling system to the air side cooling load system and from the air side cooling load system to coolant cooling system; wherein the coolant cooling system comprises multiple chillers connected in series, with each chiller comprising a refrigeration circuit.

[0005] The above arrangement can allow for improvements the efficiency of the hydronic refrigeration systems without increasing the overall cost of the system, and without the need for significant investment in the development of the technology of the components of the hydronic refrigeration system. There is optimisation of the operating conditions of each of the three sub systems of the hydronic arrangement without the need for changes to the basic operating principles of each part. In particular, the series arrangement of the plurality of chillers within the coolant cooling system enables increases in the overall efficiency of the coolant cooling system. The efficiency of a chiller using a refrigeration circuit is directly proportional to the temperature at which the coolant exits the chiller; it is therefore desirable to increase the temperature at which the coolant leaves the chiller in order to increase the efficiency of the chiller.

[0006] Where multiple chillers are used in a conventional hydronic refrigeration system they are typically arranged in parallel such that coolant from the coolant distribution system enters directly into each individual chiller. In this way the temperature of the coolant entering each chiller is the same, being that of the coolant leaving the air side cooling load system. Each chiller reduces the temperature of the coolant to the final and lowest temperature attained within the hydronic refrigeration system. In contrast, with the presently proposed system by arranging chillers in series the temperature at which coolant exits one or more of the chillers can be increased compared to the temperature at which coolant leaves each chiller when arranged in parallel, thus resulting in an overall increase in the combined efficiency of the chillers in the coolant cooling system when arranged in series compared to a parallel arrangement of the chillers. Heated coolant from the air side cooling load system arrives at the coolant cooling system via the coolant distribution system and enters the first chiller in the hydronic loop; the coolant is cooled by the first chiller and then enters the second chiller at this reduced temperature. The coolant is further reduced in temperature by the second chiller and then transferred to any remaining chillers along the hydronic loop of the coolant cooling system to continue this coolant cooling process until the final and lowest temperature of the coolant attained within the hydronic refrigeration system is reached.

[0007] In one example the coolant entering and leaving each chiller is cooled by a fraction of the total temperature reduction attained by the coolant cooling system corresponding to the number of chillers present in the single hydronic loop. This may fraction may be an equal proportion of the required overall temperature reduction. For example, if the coolant cooling system contains two chillers, then a half of the temperature reduction is provided by each chiller; if the coolant cooling system contains three chillers, then one third of the temperature reduction is provided by each chiller; if the coolant cooling system contains four chillers, then one quarter of the temperature is provided by each chiller, and so on.

[0008] In another example, each chiller may reduce the temperature of the coolant by unequal proportions of the total temperature reduction achieved by the cooling coolant system.

[0009] To take further advantage of the increased efficiency afforded by the series arrangement of chillers in the coolant cooling system, the temperature range of the coolant, i.e. the difference between the coolant temperature entering the coolant cooling system and leaving the coolant cooling system and equivalently the difference in coolant temperature leaving the air side cooling load system and entering the air side cooling load system, may be increased. By increasing the temperature at which coolant leaves the air side cooling load system and enters the coolant cooling system, the temperature to which an individual chiller must reduce the coolant may be increased, with the exception of the final chiller in the hydronic loop.

[0010] The temperature of the coolant leaving the air side cooling load system can be increased by reducing the flow rate of the coolant through the hydronic refrigeration system. The air side cooling load may comprise one or more air handling units. With a reduced flow rate of coolant, provided that the cooling capacity of the air handling units of the air side cooling load system remains constant, the temperature of the coolant exiting the cooling load is increased by the same factor by which the flow rate of the coolant is reduced.

[0011] Decreasing the flow rate of the coolant through the hydronic refrigeration system has the additional advantage of reducing the size of the components within the hydronic refrigeration system. For a given cooling capacity at the air side, with a larger temperature range for coolant the consequent reduction in flow rate has the result that the size of a coolant pump may be reduced, the diameter of coolant piping within the coolant distribution system may be reduced, the surface area of coolant pipes requiring insulation and therefore the volume of insulation required may be reduced, and/or the size of hydronic components within the coolant distribution system for example valves, elbows, flanges, gaskets etc. may be reduced. Such reductions have the effect of reducing the weight and volume of the system, and may therefore decrease the cost of the system and/or increase the ease of installation of the system. The coolant pump may also require reduced power resulting in reduced energy consumption thus contributing to the increase in efficiency of the hydronic refrigeration system. Alternatively or additionally, this can allow for increases in cooling capacity of a pre-existing hydronic system without the need to install plumbing of increased size: instead the pre-existing plumbing can be used with differing coolant temperatures (via switching to series coolant chillers) to allow for increased cooling capacity with the same flow rate.

[0012] Optionally, in order to maintain the cooling capacity of the air side cooling load when the flow rate of the coolant is reduced, the heat transfer capacity of the air side cooling load is increased. For example, the heat transfer capacity of air coils within the air handling units of the air side cooling load system can be increased.

[0013] The cooling capacity (P) of air handling units is directly proportional to the heat transfer coefficient (U) of the air coils, the heat transfer surface area (A) of the air coils and the logarithmic mean temperature difference (LMTD). The cooling capacity is therefore described by the equation $P=U*A*(LMTD)$. The LMTD is a logarithmic average of the temperature difference between the coolant and air at the air entrance end of the air coils and the temperature difference between the coolant and air at the air exit end of the air coils. As a result of the reduced flow rate of the coolant through the system, the temperature of the coolant exiting the air coils is increased; this has the effect of lowering the LMTD value. Therefore to maintain the cooling capacity at that where there is reduced flow, the value of UA must be increased by the same factor by which the LMTD is reduced.

[0014] The value of UA for the air coils can be increased by increasing the surface area of the air coils (A); this may be achieved by increasing the number of rows in the coils and/or by increasing the length of the rows in the coils amongst others. UA can also be increased by designing the coil circuiting to have counter flow and with appropriate coolant side pressure drop. In one example the number of rows in the coil may be increased from 4 to 6 and the length of each row may be increased from 300 mm to 320 mm so that the cooling capacity of the air handling unit may remain the same as one in which the flow rate of the coolant is standard in the field e.g. 0/169 l/s per kW of cooling capacity. Such modifications to the air handling systems may result in an increase in power and production costs leading to a negative contribution to the change in efficiency arising from the proposed arrangement, however it can be demonstrated that this additional cost in efficiency will be less than the increase in efficiency gained from the coolant distribution system and the efficiency gains due to series configuration of chillers.

[0015] Designing the hydronic refrigeration system to have a higher LMTD can minimise the cost in efficiency incurred by modifying the air coils. Shifting the temperature range of the coolant across the air coils to lower temperatures increases the value of the LMTD. This in turn reduces the amount by which UA must be increased in order to maintain the cooling capacity of the air handling units. The lower temperature of the coolant thereby acts to minimise the negative contribution to efficiency resulting from increased power consumption of the air coils and fans.

[0016] In one example the hydronic refrigeration system may function as an air conditioning unit; the air side cooling load may hence be for cooling building air, for example. Where the air side cooling load comprises air handling units then these may be for providing cooling to air in a space occupied by humans and thereby providing comfort to their environment. The air handling units may be configured to reduce the temperature of air circulated through the air side cooling load system by at least 5 °C, such as from around 20 °C to around 15 °C or from around 25 °C to around 15 °C thereby acting as an air conditioning unit.

[0017] The flow rate of the coolant through the hydronic refrigeration system is decreased by at least 1.25 times the standard flow rate used in the field, and in one example may be decreased by three times compared to the standard flow rate used in the field. In such an example, with the standard flow rate used in the field being 0.169 l/s per kW of cooling capacity, the flow rate may be reduced to 0.0563 l/s per kW of cooling capacity. In this example, with an air side cooling load comprising air coils as discussed above, the temperature difference across the air coils would therefore also increase three fold such that a hydronic refrigeration system that typically employs a coolant temperature difference of 7 °C to 12 °C across the air coils, i.e. a 5 °C change, could have a 15 °C change instead, such as a coolant temperature difference of 7 °C to 22 °C or 5 °C to 20 °C across the air coils. It will be appreciated that the ability of the series arrangement of chillers to create a larger temperature difference has synergy with such changes to flow rates allowing the coolant temperature difference at the air side to mirror the chiller side.

[0018] The hydronic refrigeration system may be arranged for an overall temperature reduction of the coolant by the chillers that gives a temperature range of the coolant with a difference of at least 10 °C between the upper and lower temperatures thereof, for example a difference of about 15 °C. For example, the temperature range of the coolant may be 20 °C to 5 °C.

[0019] In one example the coolant cooling system comprises three or more chillers arranged in series. Each chiller may provide a cooling to reduce the coolant temperature by at least 3 °C, such as a reduction of about 5 °C. For example, there may be three chillers each providing a temperature reduction of about 5 °C in context of a total temperature range of 20 °C to 5 °C. In that case, the temperature of the coolant entering the first chiller is 20 °C and the coolant leaves the first chiller having been cooled to 15 °C; this coolant then enters the second chiller at 15 °C and leaves the second chiller having been cooled to 10 °C; this coolant then enters the third chiller at 10 °C and leaves the third chillers having been cooled to 5 °C.

[0020] In some embodiments, the coolant cooling system comprises at least two chillers and not more than six chillers. Each of the chillers may reduce the temperature of the coolant by at least 3 °C.

[0021] In one example the coolant may be water. In another example the coolant may be ethylene glycol, or a mixture of water and ethylene glycol, or another suitable liquid.

[0022] In one example the air side cooling load system comprises at least one air handling unit wherein air is passed over fan coils containing the coolant and heat is exchanged from air at a higher temperature to the coolant in the coils at a lower temperature.

[0023] In one example the air side cooling load system comprises multiple air handling units connected in parallel such that cooled coolant from the coolant distribution system enters each air handling unit directly and therefore the coolant enters and leaves each air handling unit at the about same temperature as coolant entering and leaving the other air handling units.

[0024] The chillers each comprise a refrigeration circuit. Each one of the multiple chillers may comprise a heat pump system comprising a compression device, a heat rejecting heat exchanger, an expansion device and a heat absorbing heat exchanger. The coolant may be cooled by the heat absorbing heat exchanger. Thus, the chillers may comprise a circuit in which refrigerant fluid undergoes a refrigeration cycle passing in sequence through the compression device, the heat rejecting heat exchanger, the expansion device and the heat absorbing heat exchanger, with heat for the heat absorbing heat exchanger being provided by the coolant of the hydronic refrigeration system. Heat rejected at the heat rejecting heat exchanger may be rejected to atmosphere, or otherwise, as is known in the art. The refrigeration circuits may include additional suitable features, for example economisers, heat recovery and so on.

[0025] Viewed from a second aspect, the invention extends to a method for operating a hydronic refrigeration system as in the first aspect, coolant the method comprising; arranging a the coolant cooling system, and an the air side cooling load system for cooling of air using coolant from the coolant cooling system, and using a coolant distribution system for transporting coolant from the coolant cooling system to the air side cooling load system and from the air side cooling load system to coolant cooling system in series to form a hydronic loop of the hydronic refrigeration system; wherein the coolant cooling system comprises multiple chillers connected in series, with each chiller comprising a refrigeration circuit, and the method comprises flowing coolant sequentially through the series connected chillers.

[0026] The method may include the use of a refrigeration system having other features as discussed above in connection with optional features of the first aspect.

[0027] Certain embodiments of the invention will now be described by way of example only and with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a hydronic refrigeration system using multiple parallel chillers as known in the art.

Figure 2 is a schematic diagram of a hydronic refrigeration system using multiple chillers in series.

[0028] As seen in Figure 1, a hydronic refrigeration system 100 known in the art includes a coolant cooling system 110, a coolant distribution system 150, and an air side cooling load system 130. In this example the coolant cooling system 110 contains a first chiller 111a, a second chiller 111b and a third chiller 111c. The air side cooling load system 130 contains a first air handling unit 131a, a second air handling unit 131b and a third air handling unit 131c. These three systems, 110, 150, and 130, are linked by hydronic loop in which heated coolant is transported from the air side cooling load system 130 and to the coolant cooling system 110 through pipes 152. The coolant from pipe 152 enters each of the chillers 111a, 111b, 111c through pipes 152a, 152b, 152c respectively. As a result, coolant enters each of the chillers at around the same temperature as it left the air side cooling load system 130, this is typically around 12 °C. Coolant exits each chiller having been cooled by around 5 °C, and travels along pipes 153a, 153b, 153c respectively to re-join pipe 155. In this way the chillers 111a, 111b, 111c of the prior art hydronic refrigeration system 100 are connected to the hydronic loop in parallel. The cooled coolant is pumped through an in line coolant pump 156 before travelling along pipes 157a, 157b, 157c to enter air handling units 131a, 131b, 131c. Similarly, therefore, the air handling units are also arranged in parallel in the hydronic loop. The coolant passes through the air handling units 131a, 131b, 131c and exchanges heat with warm air blown through each unit such that the temperature of the coolant increases and the temperature of the air decreases. The warm coolant travels along pipes 151a, 151b, 151c to re-join pipe 152 and complete the hydronic loop.

[0029] Typically the coolant in the hydronic loop is reduced from 12 °C to 7 °C by each of the chillers 111a, 111b, 111c connected to the hydronic loop in parallel, and correspondingly the coolant is increased in temperature from 7 °C to 12 °C when passing through each air handling unit 131a, 131b, 131c also connected to the hydronic loop in parallel. The hydronic refrigeration system 200 of Figure 2 alters the connectivity of the chillers from series to parallel in order to increase the efficiency of the coolant cooling system 210.

[0030] When acting as an air conditioning unit, the hydronic refrigeration system 100 cools air from around 25 °C to around 15 °C.

[0031] A proposed hydronic refrigeration system 200 uses multiple chillers in series as seen in Figure 2. The hydronic refrigeration system 200 includes a coolant cooling system 210, a coolant distribution system 250, and an air side cooling load system 230. In this example the coolant cooling system 210 contains a first chiller 211a, a second chiller 211b and a third chiller 211c, and the air side cooling load system 230 contains a first air handling unit 231a, a second air handling unit 231b and a third air handling unit 231c. The hydronic refrigeration system 200 may comprise more or fewer chillers and more or fewer air handling units than are discussed in relation to Figure 2. The coolant cooling system 210, coolant distribution system 250 and air side cooling system 230 are linked by a hydronic loop in which heated coolant is transported from the air side cooling load system 230 and to the coolant cooling system 210 through pipes 252. The coolant from pipe 252 passes through the first chiller 211a, travels to the second chiller 211b through pipe 253, and then travels through pipe 254 to the third chiller 211c, the cooled coolant may then travel back to the air side cooling load system 230 through pipe 255. The cooled coolant is pumped through the in line pump 256 and then enters each individual air handling units 231a, 231b, 231c through pipes 257a, 257b, 257c respectively, and leaves each air handling unit 231a, 231b, 231c through pipes 251a, 251b, 251c respectively before each re-joining pipe 252. The hydronic loop is constructed in this way so that the three chillers 211a, 211b, 211c of the coolant cooling system 210 are connected in series and the three air handling units 231a, 231b, 231c of the air side cooling load system 230 are connected in parallel.

[0032] The series arrangement of the chillers 211a, 211b, 211c has the result that coolant in the hydronic loop enters the first chiller 211a at around the same temperature at which it left each air handling unit e.g. 20 °C, the coolant then enters the second chiller 211b at a reduced temperature e.g. 15 °C, and then enters the third chiller 211c at a further reduced temperature e.g. 10 °C, whereas the parallel arrangement of the air handling units 231a, 231b, 231c results in the coolant in the hydronic loop entering each air handling unit 231a, 231b, 231c at around the same temperature as it left the third chiller 211c e.g. 5 °C. Correspondingly the coolant is increased in temperature by the same amount e.g. from 5 °C to 20°C when passing through each air handling unit 231a, 231b, 231c, each being connected to the hydronic loop in parallel.

[0033] In this example each chiller 211a, 211b, 211c of the coolant cooling system 210 contains a refrigeration circuit 212a, 212b, 212c. The refrigeration circuit 212a, 212b, 212c of each chiller 211a, 211b, 211c contains a refrigerant fluid flowing through circuit 212a, 212b, 212c, a compression device 213a, 213b, 213c, a heat rejecting heat exchanger 214a, 214b, 214c, an expansion device 215a, 215b, 215c and a heat absorbing heat exchanger 216a, 216b, 216c that together form a main refrigeration circuit 212a, 212b, 212c. Circulation of the refrigerant fluid through the refrigeration circuits 212a, 212b, 212c via the compression device 213a, 213b, 213c enables the refrigeration system to utilise a refrigeration cycle to satisfy the cooling load required by the chiller 211a, 211b, 211c to cool the coolant of the hydronic loop. In this example each compression device 213a, 213b, 213c is a compressor for compression of gaseous refrigerant fluid, each heat rejecting heat exchanger 214a, 214b, 214c is a condenser for at least partially condensing the refrigerant fluid, each expansion device 215a, 215b, 215c is an expansion valve for expanding the refrigerant fluid, and each heat absorbing heat exchanger 216a, 216b, 216c is an evaporator for at least partially evaporating the refrigerant fluid. The heat rejecting heat exchangers 214a, 214b, 214c expel heat to the surroundings shown by arrows 217a, 217b, 217c.

[0034] In this example each air handling unit 231a, 231b, 231c of the air side cooling load system 230 contains a fan coil system wherein heat is exchanged from outside air to the coolant in the hydronic loop. Fans 232a, 232b, 232c blow air from the ventilated occupant space over air-to-coolant heat exchangers e.g. coolant coils 233a, 233b, 233c, once cooled the cold air is blown back into the ventilated occupant space to provide air conditioning. When the hydronic refrigeration system is used for a typical air conditioning application the air from the ventilated occupant space may enter the air handling unit at around 25 °C and be reintroduced into the ventilated occupant space having been cooled to around 15 °C. In this example coolant entering the coolant coils 233a, 233b, 233c may be at around 5 °C and leaves the coolant coils 233a, 233b, 233c at around 20 °C. The coolant coils

233a, 233b, 233c are constructed so that air is pushed over the coolant coils 233a, 233b, 233c in a counter flow configuration such that air first entering the air handling unit 231a, 231b, 231c and therefore at its hottest e.g. 25 °C exchanges heat with the coolant about to exit the air handling unit 231a, 231b, 231c so that the coolant is also at its hottest e.g. 20 °C. Accordingly the air about to leave the air handling unit 231a, 231b, 231c and therefore at its coolest e.g. 15 °C exchanges heat with coolant first entering the air handling unit 231a, 231b, 231c and therefore at its coolest e.g. 5 °C.

[0035] In this example the components required by the coolant distribution system 250 such as the in line coolant pump 256 and other components not illustrated including piping, valves, elbows, flanges, gaskets etc. have been adapted from those used in the example hydronic refrigeration system 100 of Figure 1 to cause a reduced flow rate of the coolant through the hydronic loop of hydronic refrigeration system 200. By reducing the flow rate, the power, size, cost, insulation cost, weight and volume of the components can be reduced and increases in efficiency can be made as result.

[0036] Hydronic refrigeration systems in the prior art such as hydronic refrigeration system 100 typically use a flow rate of coolant within the hydronic loop of around 0.169 l/s per kW of cooling capacity. In hydronic refrigeration system 200 this flow rate is reduced at least 1.25 times, for example the flow rate can be reduced 3 times to 0.0563 l/s per kW of cooling capacity. The reduced flow rate of the hydronic refrigeration system 200 allows for increased heat exchange between the coolant and the air in the air handling units 231a, 231b, 231c as a result of the extended time spent in the heat exchange system. Provided that the cooling capacity of the coolant coils 233a, 233b, 233c within the air handing units 231a, 231b, 231c remains the same, decreasing the flow rate of coolant through the hydronic loop causes the temperature change of the coolant entering and leaving the air side cooling load system 230 to increase by the same factor as that by which the flow rate is decreased.

[0037] In this example and as compared to the hydronic refrigeration system 100 of Figure 1, the coolant coils 233a, 233b, 233c have been adapted by increasing the number of rows of coils from 4 to 6 and by increasing the length of each row from 300 mm to 320 mm so that the same cooling capacity of the air handling units 231a, 231b, 231c can be maintained following the reduction in the flow rate of the coolant through the coolant coils 233a, 233b, 233c and the increase in temperature difference between the coolant flowing into and out of the coolant coils 233a, 233b, 233c. Although there may be increased costs in efficiency in relation to the modifications to the coolant coils 233a, 233b, 233c, this can be outweighed by the increased efficiency in relation to the reduced flow rate of the coolant around the hydronic loop as well as the series arrangement of the chillers within the hydronic loop as discussed above.

Claims

1. A hydronic refrigeration system comprising:

a coolant cooling system;
an air side cooling load system for cooling of air using coolant from the coolant cooling system; and
a coolant distribution system for transporting coolant from the coolant cooling system to the air side cooling load system and from the air side cooling load system to coolant cooling system;
wherein the coolant cooling system comprises multiple chillers connected in series, with each chiller comprising a refrigeration circuit.

2. A hydronic refrigeration system as claimed in claim 1, wherein each one of the multiple chillers has the effect of reducing the temperature of the coolant by an equal proportion of the overall temperature reduction provided by the combination of chillers in the coolant cooling system.

3. A hydronic refrigeration system as claimed in claim 1 or 2, wherein the overall temperature reduction of the coolant by the chillers gives a temperature range of the coolant with a difference of at least 10 °C between the upper and lower temperatures thereof.

4. A hydronic refrigeration system as claimed in claim 3, wherein the overall temperature reduction of the coolant is 15 °C.

5. A hydronic refrigeration system as claimed in claim 3 or 4, wherein the temperature range of the coolant is 20 °C to 5 °C.

6. A hydronic refrigeration system as claimed in any preceding claim, wherein the coolant cooling system comprises at least two chillers but not more than six chillers, and wherein each of the chillers reduces the temperature of the coolant by at least 3 °C.

7. A hydronic refrigeration system as claimed in any preceding claim, wherein the coolant cooling system comprises a first chiller, a second chiller and a third chiller.

8. A hydronic refrigeration system as claimed in claim 7, wherein the first chiller reduces the coolant temperature by about 5 °C, the second chiller reduces the coolant temperature by about a further 5 °C, and the third chiller reduces the coolant temperature by about a further 5 °C.

9. A hydronic refrigeration system as claimed in any preceding claim, wherein the air side cooling load system is for cooling building air.

10. A hydronic refrigeration system as claimed in any preceding claim, wherein the air side cooling load system contains multiple air handling units connected in parallel.

11. A hydronic refrigeration system as claimed in any preceding claim, wherein the air side cooling load is arranged to operate as an air conditioning system.

12. A hydronic refrigeration system as claimed in any preceding claim, wherein the air handling units reduce the temperature of the air by at least 5 °C.

13. A hydronic refrigeration system as claimed in any preceding claim, wherein each one of the multiple chillers comprises a refrigeration circuit comprising a compression device, a heat rejecting heat exchanger, an expansion device and a heat absorbing heat exchanger with the coolant being cooled via the heat absorbing heat exchanger.

14. A method for operating the hydronic refrigeration system of any preceding claim, the method comprising;
arranging the coolant cooling system and the air side cooling load system for cooling of air using coolant from the coolant cooling system, and using the coolant distribution system for transporting coolant from the coolant cooling system to the air side cooling load system and from the air side cooling load system to coolant cooling system in series to form a hydronic loop of the hydronic refrigeration system;
wherein the coolant cooling system comprises multiple chillers connected in series, with each chiller comprising a refrigeration circuit, and the method comprises flowing coolant sequentially through the series connected chillers.

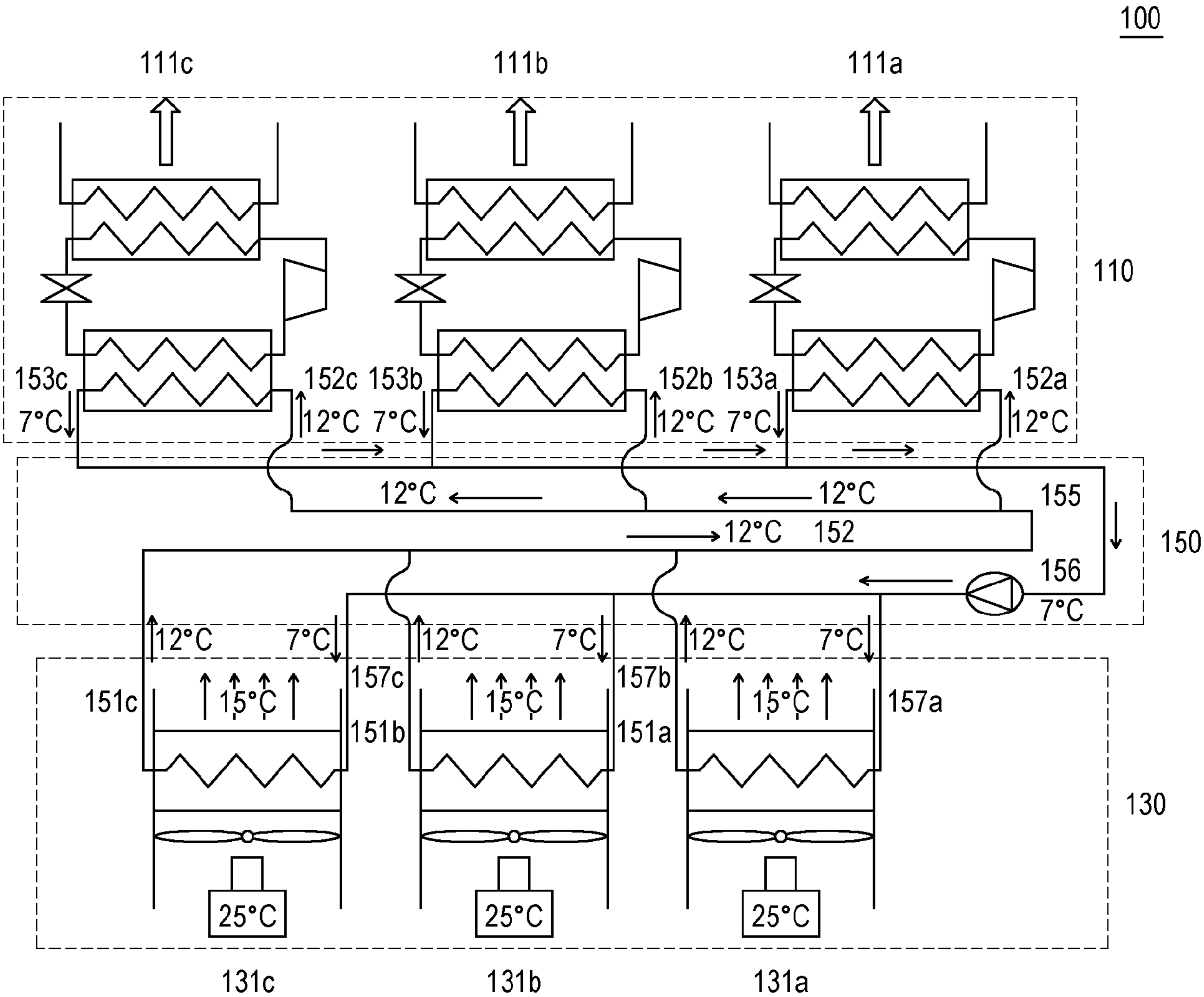

Fig. 1
(PRIOR ART)

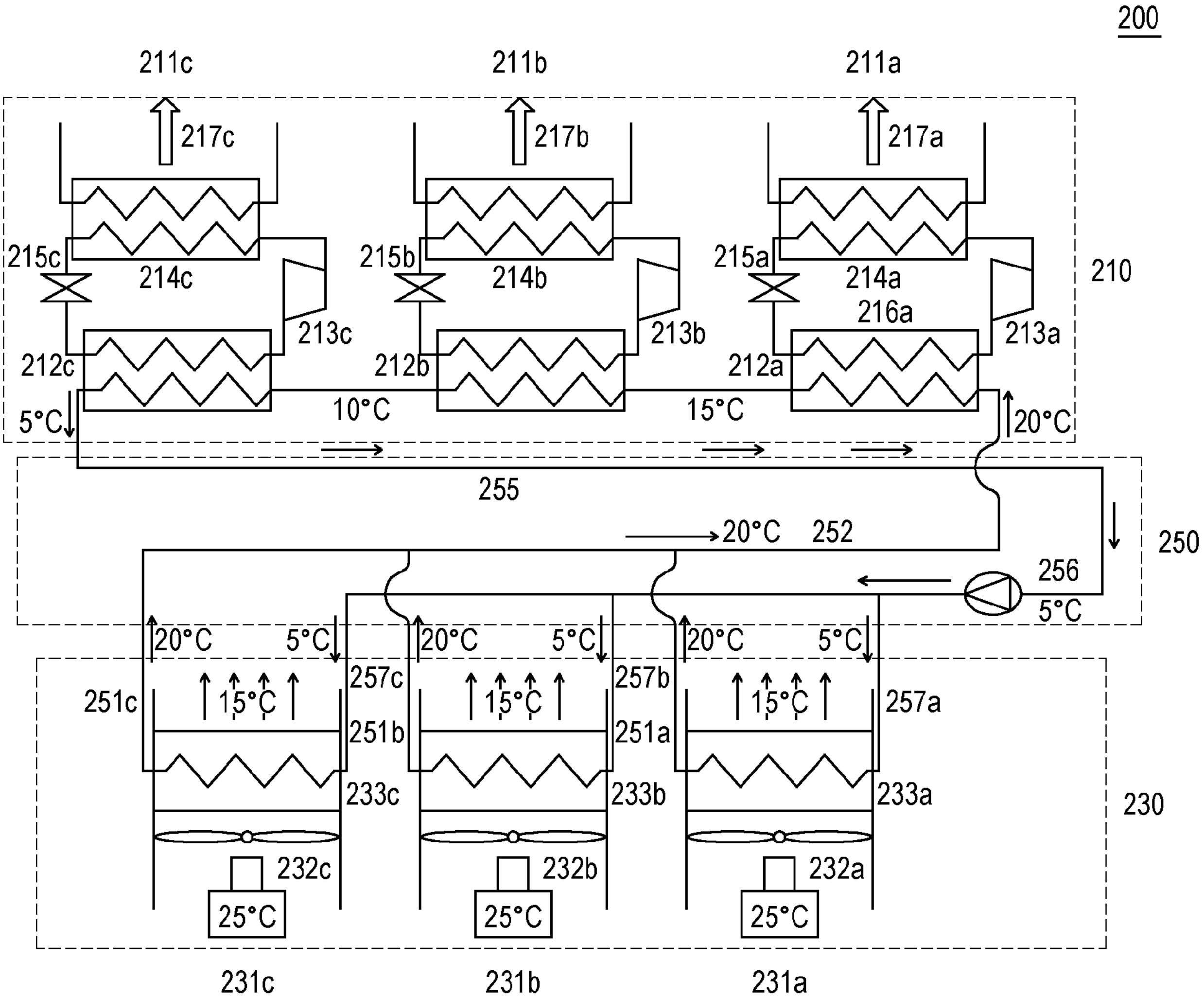
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Fig. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 2226

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2010/121495 A1 (OKOREN RONALD W [US] ET AL) 13 May 2010 (2010-05-13) * page 1, paragraph 13 - page 2, paragraph 23; figure 1 * -----	1-14	INV. F25B25/00 F24F3/06
X	WO 2016/077559 A1 (CARRIER CORP [US]) 19 May 2016 (2016-05-19) * page 3, paragraph 22 - page 5, paragraph 34; figures 3,4 * -----	1-14	
A	US 2004/000155 A1 (CLINE LEE R [US] ET AL) 1 January 2004 (2004-01-01) * the whole document * -----	1	

TECHNICAL FIELDS SEARCHED (IPC)

F25B
F24F

The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	14 September 2020	Hoffmann, Stéphanie

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