



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
13.09.2023 Bulletin 2023/37

(51) International Patent Classification (IPC):
F25B 13/00 ^(2006.01) **F25B 49/02** ^(2006.01)
F25B 41/22 ^(2021.01)

(21) Application number: **22160531.4**

(52) Cooperative Patent Classification (CPC):
F25B 13/00; F25B 41/22; F25B 49/02;
F25B 2313/0233; F25B 2313/02732;
F25B 2313/02742; F25B 2313/0315;
F25B 2700/1931; F25B 2700/21152

(22) Date of filing: **07.03.2022**

(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) **HEAT VENTILATION AND AIR CONDITIONING UNIT**

(57) A heat ventilation and air conditioning (HVAC) unit (100) is disclosed. The HVAC unit (100) includes a compressor (102), a condenser (104), a first expansion device (106), a second expansion device (118), a third expansion device (120), an evaporator (108), a heat recovery unit (110), a first 4-way valve (112), a second 4-way valve (114), a one-way valve (118) and a controller

(124). The controller (124) determines a first discharge superheat temperature for the refrigerant entering the evaporator (108) and a second discharge superheat temperature for the refrigerant entering the heat recovery unit (110) and adjust the first flow rate and the second flow rate to maintain ideal heat distribution between the heat recovery unit (110) and the evaporator (108).

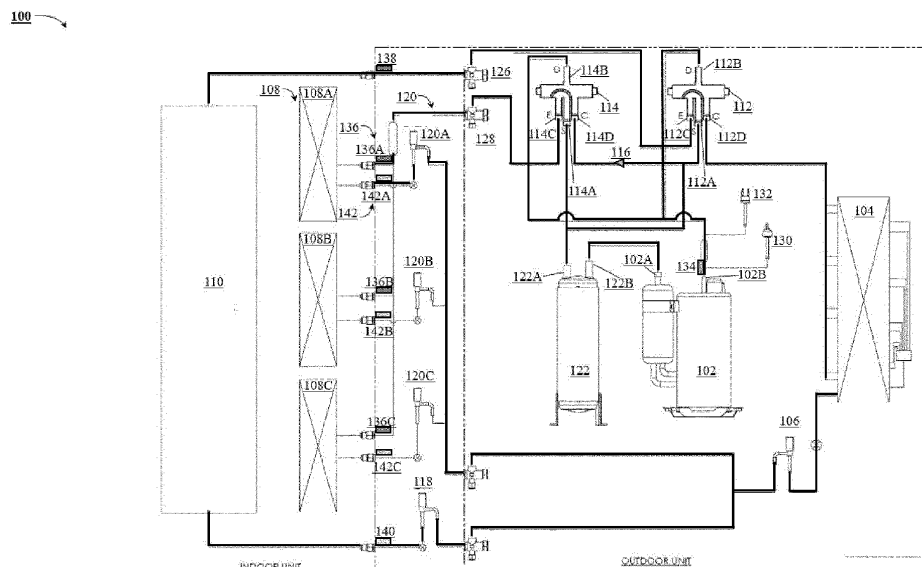


FIGURE 1

Description

[0001] The present disclosure relates to an air conditioning unit capable of ideally distributing heat between an evaporator and a heat recovery unit.

[0002] An air conditioning apparatus is an electric appliance that regulates a temperature or humidity of a space, such as a room. The air conditioning apparatus works on a vapour compression cycle in which a refrigerant undergoes temperature, pressure, and phase change to achieve cooling as well as heating of the space. The air conditioning apparatus includes a compressor that compresses the refrigerant, a condenser that removes heat from the compressed refrigerant, an expansion valve that lowers the pressure of the refrigerant coming from the condenser, and an evaporator that transfers the heat from the space to the refrigerant coming from the expansion valve and supplies the refrigerant back to the compressor. In the case of heating of the space, the compressed refrigerant is directed to the evaporator for heating the space and thereafter to the expansion device and the condenser to cool the refrigerant. Generally, the total amount of heat in the refrigerant may not be needed to heat or cool the space. Accordingly, some of the air conditioning apparatus has a water heater that recovers a portion of refrigerant heat to heat water for a different purpose, such as bathing. In such a system, a portion of the refrigerant may be diverted from the evaporator to the water heater to recover the heat from the refrigerant.

[0003] There are various limitations of the present technique for distributing the heat. For instance, due to different specific heat-carrying capacities of the water and the refrigerant, the amount of heat accumulated in the water heating unit may exceed the heat of the refrigerant resulting in the reverse heating of the refrigerant. The reverse heating may cause the cooling operation of the water heating unit. Moreover, reverse heating results in the rise in the temperature of the refrigerant entering the compressor resulting in extra load on the compressor to compress the refrigerant. In some scenarios, the rise in the temperature of the refrigerant may increase the intake pressure of the compressor beyond a limit, such that the compressor fails to compress the refrigerant resulting in the failure of the air conditioning unit.

[0004] It is an object of the present invention to provide a heat ventilation and air conditioning unit, and a method of operating the heat ventilation and air conditioning unit that ideally distributes the heat of the refrigerant between a heat recovery unit and the space to be heated without causing reverse heating or additional load on the compressor.

[0005] In an embodiment, a heat ventilation and air conditioning unit is disclosed. The HVAC unit includes a compressor adapted to compress a refrigerant to form a compressed refrigerant. The HVAC unit also includes a condenser in fluid communication with the compressor to exchange heat between the compressed refrigerant and ambient air to form a condensed refrigerant. In addition, the HVAC unit includes a first expansion device in fluid communication with the condenser to convert the condensed refrigerant into a cooled refrigerant. The HVAC unit also includes an evaporator in fluid communication with the first expansion device to exchange heat between a space to be cooled and the cooled refrigerant.

[0006] The HVAC includes a heat recovery unit in fluid communication with the compressor and the first expansion device to discharge heat of the condensed refrigerant to a medium. The HVAC unit also includes a first 4-way valve in fluid communication with the compressor, the heat recovery unit, and the condenser to supply a portion of the refrigerant to the heat recovery unit at a first flow rate. In addition to the first 4-way valve, the HVAC unit includes a second 4-way valve in fluid communication with the compressor, the first 4-way valve, and the evaporator to supply another portion of the refrigerant to the evaporator at a second flow rate.

[0007] According to the present disclosure, the HVAC unit includes a one-way valve in fluid communication with a first port of the first 4-way valve and a first port of the second 4-way valve to maintain a pressure of refrigerant entering the compressor above a threshold value. The HVAC unit also includes a controller adapted to control the operation of the compressor, the first 4-way valve and the second 4-way valve. The controller is adapted to determine the first discharge superheat temperature for the refrigerant entering the evaporator based on a high-pressure saturation temperature of refrigerant exiting the compressor and a first discharge temperature of refrigerant entering the evaporator, determine a second discharge superheat temperature for the refrigerant entering the heat recovery unit based on the high-pressure saturation temperature of the refrigerant exiting the compressor and a second discharge temperature of the refrigerant entering the heat recovery unit, and adjust the first flow rate and the second flow rate to maintain ideal heat distribution between the heat recovery unit and the evaporator. The ideal heat distribution may be understood that the distribution of heat in which the heat discharged to the heat recovery unit and the evaporator does not exceed the sum of amount of heat discharged to these components so that the scenario of reverse heating is prevented.

[0008] Moreover, the controller determines a discharge superheat temperature of the refrigerant exiting the compressor as a difference between an outlet temperature of the refrigerant exiting the compressor and a high-pressure saturation temperature corresponding to a measured pressure of the refrigerant exiting the compressor and a type of the refrigerant and operates the second expansion device and the third expansion device to adjust the discharge superheat temperature to a target value.

[0009] According to the present disclosure, the ideal heat distribution is achieved by regulating the temperature of the refrigerant at two levels. At the first level, the temperature of the refrigerant exiting the compressor is adjusted to a target

value so that the overall heat in the HVAC unit is optimally distributed. Thereafter, the heat of the refrigerant is ideally distributed between the evaporator and the heat recovery unit. The two-level temperature control enables accurate heat distribution and prevents reverse heating of the refrigerant. Moreover, the one-way valve maintains the pressure of the refrigerant entering the compressor above a threshold value thereby preventing additional load on the compressor.

[0010] To further clarify advantages and features of the present invention, a more particular description of the invention will be rendered by reference to specific embodiments thereof, which is illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

Figure 1 illustrates a schematic of a HVAC unit, according to an embodiment;
 Figure 2 illustrates a controller of the HVAC unit, according to an embodiment;
 Figure 3 illustrates the HVAC unit operating in a bi-heating mode, according to an embodiment;
 Figure 4 illustrates the HVAC unit operating in a heat recovery mode, according to an embodiment;
 Figure 5 illustrates the HVAC unit operating in a non-stop defrost mode, according to an embodiment;
 Figure 6 illustrates the HVAC unit operating in a normal-defrost mode, according to an embodiment;
 Figure 7 illustrates the HVAC unit operating in a heating mode of an evaporator, according to an embodiment;
 Figure 8 illustrates the HVAC unit operating in a heating mode of a heat recovery unit, according to an embodiment;
 Figure 9 illustrates the HVAC unit operating in a cooling mode, according to an embodiment; and
 Figure 10 illustrates a method for ideally distributing the heat by the HVAC unit, according to an embodiment.

[0012] Further, skilled artisans will appreciate that elements in the drawings are illustrated for simplicity and may not have necessarily been drawn to scale. Furthermore, in terms of the construction of the device, one or more components of the device may have been represented in the drawings by conventional symbols, and the drawings may show only those specific details that are pertinent to understanding the embodiments of the present invention so as not to obscure the drawings with details that will be readily apparent to those of ordinary skill in the art having benefit of the description herein.

[0013] For the purpose of promoting an understanding of the principles of the invention, reference will now be made to the embodiment illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated system, and such further applications of the principles of the invention as illustrated therein being contemplated as would normally occur to one skilled in the art to which the invention relates. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which invention belongs. The system and examples provided herein are illustrative only and not intended to be limiting.

[0014] For example, the term "some" as used herein may be understood as "none" or "one" or "more than one" or "all." Therefore, the terms "none," "one," "more than one," "more than one, but not all" or "all" would fall under the definition of "some." It should be appreciated by a person skilled in the art that the terminology and structure employed herein is for describing, teaching, and illuminating some embodiments and their specific features and elements and therefore, should not be construed to limit, restrict, or reduce the spirit and scope of the present disclosure in any way.

[0015] For example, any terms used herein such as, "includes," "comprises," "has," "consists," and similar grammatical variants do not specify an exact limitation or restriction, and certainly do not exclude the possible addition of one or more features or elements, unless otherwise stated. Further, such terms must not be taken to exclude the possible removal of one or more of the listed features and elements, unless otherwise stated, for example, by using the limiting language including, but not limited to, "must comprise" or "needs to include."

[0016] Whether or not a certain feature or element was limited to being used only once, it may still be referred to as "one or more features" or "one or more elements" or "at least one feature" or "at least one element." Furthermore, the use of the terms "one or more" or "at least one" feature or element do not preclude there being none of that feature or element, unless otherwise specified by limiting language including, but not limited to, "there needs to be one or more..." or "one or more elements is required."

[0017] Unless otherwise defined, all terms and especially any technical and/or scientific terms, used herein may be taken to have the same meaning as commonly understood by a person ordinarily skilled in the art.

[0018] Reference is made herein to some "embodiments." It should be understood that an embodiment is an example of a possible implementation of any features and/or elements of the present disclosure. Some embodiments have been described for the purpose of explaining one or more of the potential ways in which the specific features and/or elements of the proposed disclosure fulfil the requirements of uniqueness, utility, and non-obviousness.

[0019] Use of the phrases and/or terms including, but not limited to, "a first embodiment," "a further embodiment," "an alternate embodiment," "one embodiment," "an embodiment," "multiple embodiments," "some embodiments," "other embodiments," "further embodiment", "furthermore embodiment", "additional embodiment" or other variants thereof do not necessarily refer to the same embodiments. Unless otherwise specified, one or more particular features and/or elements described in connection with one or more embodiments may be found in one embodiment, or may be found in more than one embodiment, or may be found in all embodiments, or may be found in no embodiments. Although one or more features and/or elements may be described herein in the context of only a single embodiment, or in the context of more than one embodiment, or in the context of all embodiments, the features and/or elements may instead be provided separately or in any appropriate combination or not at all. Conversely, any features and/or elements described in the context of separate embodiments may alternatively be realized as existing together in the context of a single embodiment.

[0020] Any particular and all details set forth herein are used in the context of some embodiments and therefore should not necessarily be taken as limiting factors to the proposed disclosure.

[0021] Embodiments of the present invention will be described below in detail with reference to the accompanying drawings.

[0022] For the sake of clarity, the first digit of a reference numeral of each component of the present disclosure is indicative of the Figure number, in which the corresponding component is shown. For example, reference numerals starting with digit "1" are shown at least in Figure 1. Similarly, reference numerals starting with digit "2" are shown at least in Figure 2.

[0023] **Figure 1** illustrates a heat ventilation and air conditioning unit 100, according to an embodiment of the present disclosure. The HVAC unit 100 may also be referred to as an air conditioning unit that is configured to regulate the temperature and/or humidity of the air in a space. In one example, the HVAC unit 100 may cool the air in the space and in another example, the HVAC unit 100 may heat the air in the space. Moreover, the HVAC unit 100 may increase or reduce the humidity of the air. The HVAC unit 100 may also be used for heating water for other purposes, such as bathing or washing. Accordingly, the HVAC unit 100 may serve various purposes than currently known air conditioning units that are employed to cool the space.

[0024] The HVAC unit 100 may include, but is not limited to, a compressor 102, a condenser 104, a first expansion device 106, at least one evaporator 108, a heat recovery unit 110, a first 4-way valve 112, a second 4-way valve 114, a one-way valve 116, a second expansion device 118, at least one third expansion device 120, and an accumulator 122.

[0025] In one example, the accumulator 122 is designed to store the refrigerant and supply the refrigerant to the compressor 102. The accumulator 122 may also act as a surge tank and provides protection to the compressor 102 against a sudden change in the pressure of the refrigerant entering the compressor 102. Moreover, the accumulator 122 protects the compressor 102 by storing excess refrigerant coming towards the compressor 102. In addition, the accumulator 122 may supply excess refrigerant when needed by the compressor 102.

[0026] The compressor 102, on the other hand, is installed downstream of the accumulator 122. The compressor 102 has an inlet port 102A and an outlet port 102B, such that the inlet port 102A is fluidically coupled to an egress port 122B of the accumulator 122. The compressor 102 can be a reciprocating type pump that has high-pressure low discharge characteristics. Further, the compressor 102 is designed to compress and supply the refrigerant within the range of pressure and at variable flow rate. Accordingly, the compressor 102 can be instructed to discharge the refrigerant at different pressure and different flow rates. The compressor 102 is designed to supply the compressed refrigerant to various components, such as the condenser 104, the evaporator 108, among other examples.

[0027] In one example, the first 4-way valve 112 is fluidically coupled to the compressor 102. As shown in Figure 1, the first 4-way valve 112 has a first port 112A, a second port 112B, a third port 112C, and a fourth port 112D. Further, the second port 112B is coupled to the outlet port 102B via a tube. Furthermore, the third port 112C is coupled to the heat recovery unit 110 by a tube, for instance, a copper tube, via a first 3-way valve 126. The fourth port 112D is coupled to the condenser 104. The first 4-way valve 112 is configured to assume different configurations in which the second port 112B is fluidically coupled to either the third port 112C, or the fourth port 112D. In one example, the second port 112B is designed to be the inlet supply point of the refrigerant while the remaining ports can either be the outlet or the inlet of the first 4-way valve 112. In operation, the first 4-way valve 112 supplies a portion of the refrigerant from the compressor 102 to the heat recovery unit 110 at a first flow rate.

[0028] The second 4-way valve 114 also has a first port 114D, a second port 114B, a third port 114C, and a fourth port 114A. The first port 114D is fluidically coupled to the first port 112A of the first 4-way valve 112 via the one-way

valve 116. In another word, a tube from the first port 112A is connected to one side of the one-way valve 116 whereas the first port 114D is connected to another side of the one-way valve 116. The one-way valve 116 is designed to stop the refrigerant flow from the second 4-way valve 114 to the first 4-way valve 112, when the second 4-way valve 114 setting is set to link the second port 114B to the first port 114D. This is not desirable because it will cause the back flow of the refrigerant to the first 4-way valve 112 and may cause malfunction of the first 4-way valve 112. Meanwhile the one-way valve 116 also provides additional passage for the refrigerant to return to accumulator 122. This also reduces the pressure drop of the refrigerant returning to the compressor 102 and maintains the pressure of the refrigerant entering the compressor 102 above a threshold value.

[0029] In one example, the second port 114B is fluidically coupled to an inlet the evaporator 108 via a second 3-way valve 128. Similarly, the third port 114C is coupled to the evaporator 108 via the second 3-way valve 128. The fourth port 114A is coupled to an ingress port 122A of the accumulator 122. In one example, the second 3-way valve 128 is coupled to the evaporator 108 via a tube connector. The second 4-way valve 114 can also assume different configurations like the first 4-way valve 112 to direct the refrigerant from its ports. In operation, the second 4-way valve 114 supplies a portion of the refrigerant from the compressor 102 to the evaporator 108 at a first flow rate.

[0030] As shown in Figure 1, the HVAC unit 100 may include one or more evaporators 108A, 108B, 108C. The evaporators 108 may also be referred to as a fan coil unit or an indoor unit that is installed in the space. As may be understood, the evaporators 108A, 108B, 108C may be installed in different spaces or zones or rooms. Further, an inlet of each evaporator 108A, 108B, 108C is connected in parallel to a single tube coming from the second 3-way valve 128, such that the refrigerant coming from the third port 114C of the second 4-way valve 114 can flow into each evaporator 108A, 108B, and 108C. Further, an outlet of the evaporator 108A, 108B, 108C is coupled with third expansion devices 120A, 120B, 120C respectively. The third expansion device 120, collectively referred hereinafter, may serve two purposes. First, the third expansion device 120 varies the pressure of the refrigerant passing therethrough and second, the third expansion device 120 regulates the second flow rate of the refrigerant flowing through the evaporator 108. In one example, the third expansion device 120 can be fully closed to stop the supply of the refrigerant to the evaporator 108. Accordingly, one of the third expansion device 120 can be operated to cut off the supply to the corresponding evaporator 108 that do not need cooling or heating.

[0031] In one example, the heat recovery unit 110 is coupled to the first 3-way valve 126 via a port of the heat recovery unit 110. The heat recovery unit 110 is a hot water supply unit adapted to supply hot water for bathing or washing. The heat recovery unit 110 includes a tank that holds water and a heat exchanger installed inside the tank, such that the heat exchanger is partially or fully submerged in the water in the heat recovery unit 110. Although not shown, the heat recovery unit 110 may include entry lines and discharge lines for the water to flow in and flow out from the heat recovery unit 110. In addition, the heat recovery unit 110 may include a temperature sensor that senses the water temperature and a level sensor that senses a water level inside the heat recovery unit 110.

[0032] The second expansion device 118 is coupled to one of the ports of the heat recovery unit 110 via a tube connector of a tube and is adapted to perform two tasks. First, the second expansion device 118 reduces the pressure of the refrigerant passing therethrough and second, the second expansion device 118 regulates the first flow rate of refrigerant passing through the heat recovery unit 110. The first expansion device 106, second expansion device 118 and the third expansion device 120 can either be a needle valve or thermally expansion valve and can be controlled electronically to precisely change the flow rate of the refrigerant.

[0033] In one example, both the second expansion device 118 and the third expansion device 120 are fluidically coupled to the first expansion device 106 as shown in Figure 1. Further, a tube connecting the first expansion device 106 to the second expansion device 118 may have a bifurcation that couples the first expansion device 106 to the third expansion device 120. Moreover, the third expansion device 120 is also coupled to the second expansion device 118, such that the refrigerant may flow between the second expansion device 118 and the third expansion device 120 when the first expansion device 106 is closed. The first expansion device 106 may have the same construction as the second expansion device 118 or the third expansion device 120 and can be electronically controlled.

[0034] In one example, the condenser 104 is coupled to the first expansion device 106 and the fourth port 112D of the first 4-way valve 112. The condenser 104 is designed to exchange the heat of the refrigerant with the ambient air. The condenser 104 can be a fin type heat exchanger with a fan blowing the air to the fins of the heat exchanger. The condenser 104 may also experience frosting due to prolonged operation of the HVAC unit 100 which can be defrosted. In one example, the condenser 104 is designed to be operated electronically and the flow rate of the refrigerant through the condenser 104 is regulated by the first expansion device 106.

[0035] The HVAC unit 100 may include various sensors that sense the temperature and pressure of the refrigerant at different locations in the HVAC unit 100. For instance, the HVAC unit 100 may include a pressure sensor 130 that measures the pressure of the refrigerant exiting the compressor 102. The HVAC unit 100 also includes a pressure switch 132 that is coupled to the pressure sensor 130 and may be employed to cut off the power supply to the compressor 102 when the pressure of the refrigerant exceeds a safety value. The HVAC unit 100 also include a compressor side temperature sensor 134 which senses the outlet temperature of the refrigerant exiting the compressor 102. The HVAC unit

100 also includes one or more first temperature sensors 136A, 136B, 136C, collectively referred to as 136 hereinafter, that measures a first discharge temperature of the refrigerant entering their respective evaporator 108. The HVAC unit 100 also includes a second temperature sensor 138 that measures a second discharge temperature of the refrigerant entering the heat recovery unit 110. The HVAC unit 100 includes a third temperature sensor 140 that measures the temperature of the refrigerant exiting the heat recovery unit 110. Lastly, the HVAC unit 100 includes multiple fourth temperature sensor 142A, 142B, 142C, collectively referred to 142 hereinafter, that measures the temperature of the refrigerant exiting the evaporator 108A, 108B, 108C respectively.

[0036] Referring now to **Figure 2**, the HVAC unit 100 may include a controller 124 124 that is configured to perform various operations of the HVAC unit 100. For instance, the controller 124 may include a processor 202, a memory 204, module 206, and data 208. The memory 204, in one example, may store the instructions to carry out the operations of the modules 206. The modules 206 and the memory 204 may be coupled to the processor 202.

[0037] The processor 202 can be a single processing unit or several units, all of which could include multiple computing units. The processor 202 may be implemented as one or more microprocessors, microcomputers, microcontrollers, digital signal processor, central processing units, state machines, logic circuitries, and/or any devices that manipulate signals based on operational instructions. Among other capabilities, the processor 202 is configured to fetch and execute computer-readable instructions and data stored in the memory 204.

[0038] The memory 204 may include any non-transitory computer-readable medium known in the art including, for example, volatile memory 204, such as static random-access memory and dynamic random-access memory, and/or non-volatile memory, such as read-only memory, erasable programmable ROM, flash memories, hard disks, optical disks, and magnetic tapes.

[0039] The modules 206, amongst other things, include routines, programs, objects, components, data structures, etc., which perform particular tasks or implement data types. The modules 206 may also be implemented as, signal processor 202, state machine, logic circuitries, and/or any other device or component that manipulate signals based on operational instructions.

[0040] Further, the modules 206 can be implemented in hardware, instructions executed by a processing unit, or by a combination thereof. The processing unit can comprise a computer, a processor, such as the processor 202, a state machine, a logic array, or any other suitable devices capable of processing instructions. The processing unit can be a general-purpose processor 202 which executes instructions to cause the general-purpose processor 202 to perform the required tasks or, the processing unit can be dedicated to performing the required functions. In another embodiment, the modules 206 may be machine-readable instructions which, when executed by a processor/processing unit, perform any of the described functionalities. Further, the data serves, amongst other things, as a repository for storing data processed, received, and generated by one or more of the modules 206. The data 208 may include information and/or instruction to perform activities by the processor 202.

[0041] The module 206 may perform different functionalities which may include, but may not be limited to, operating the HVAC unit 100 in different modes. One of the modes is a Bi-Heat Operation mode, a Heat Recovery Operation mode, a non-stop defrost operation mode, a normal-defrost operation mode, a space heating operation mode, a water heating operation mode, and a cooling operation mode.

[0042] In one example, the controller 124 is configured to operate the HVAC unit 100 to heat/cool the space as per the parameters set by a person in the space. For instance, the controller 124 may receive input temperature parameters to be maintained in the space and the water to be heated. Accordingly, the controller 124 may determine the amount of heat to be transferred and control the second expansion device 118 and the third expansion device 120 to regulate the first or the second flow rate to achieve the input temperature parameters.

[0043] Referring now to **Figure 3** which illustrates the bi-heating mode in which the amount of heat is ideally distributed between the space to be heated and the heat recovery unit 110. In the illustrated figure, the thickest line shows the refrigerant at high pressure and the thick line indicate the refrigerant at low pressure. In one example, the controller 124 may receive input from a person in the space. Based on the received input, the controller 124 may start controlling the components of the HVAC unit 100. Initially, the controller 124 may start the compressor 102. Further, the controller 124 may operate the first 4-way valve 112 and the second 4-way valve 114 to bifurcate flow of the refrigerant. In one example, a portion of the refrigerant is supplied to a first bi-heating fluid path which includes the second port 112B, the third port 112C, the first 3-way valve 126, and into the heat recovery unit 110 at the first flow rate. Further, another portion of the refrigerant is supplied to a second bi-heating fluid path that includes the second port 114B, the third port 114C, the second 3-way valve 128, and into the evaporator 108 at the second flow rate.

[0044] As the refrigerant is supplied to both the heat recovery unit 110 and the evaporator 108, the controller 124 constantly monitors the first discharge temperature and the second discharge temperature readings from the first temperature sensor 136, and the second temperature sensor 138. The first flow rate of the refrigerant exiting the heat recovery unit 110 is controlled by the second expansion device 118 while the second flow rate of the refrigerant exiting the evaporator 108 is controlled by the third expansion device 120. In one example, the amount of refrigerant is controlled by the second expansion device 118 and the third expansion device 120 may be based on a degree of opening of an

orifice inside the second expansion device 118 and the third expansion device 120.

[0045] In one example, the controller 124 may perform the controlling at two-level. At the first level, the controller 124 may optimise the total amount of heat that the HVAC unit 100 may generate during the bi-heating mode. To optimize the heat distribution, the controller 124 may receive a pressure reading from the pressure sensor 130 and a temperature reading from the compressor side temperature sensor 134. The pressure reading may be termed as the saturation pressure while the temperature of the reading may be termed as the outlet temperature of the refrigerant. The controller 124 may then determine a pressure saturation temperature of the refrigerant. The pressure saturation temperature may be based on the pressure of the refrigerant and the type of the refrigerant. In one example, data 208 (shown in Figure 2) may have a repository that indicates the relation between the pressure and temperature for the type of refrigerant.

[0046] Thereafter, the controller 124 may determine a discharge superheat temperature of the refrigerant. The discharge superheat temperature is determined by:

$$\text{discharge superheat temperature} = \text{compressor outlet temperature of the refrigerant} - \text{high pressure saturation temperature of the refrigerant}$$

[0047] In other words, the discharge superheat temperature may be based on the measured temperature of the refrigerant and the theoretical value of the temperature. Upon the determination, the controller 124 may determine a target value for the discharge superheat temperature. In one example, the target value may be based on the input by the user. For instance, in case the user has input a temperature to be maintained in the space, the controller 124 may determine the target value of the temperature of the refrigerant so that an adequate total amount of the heat is generated by compressing the refrigerant. Once the target value is determined, the controller 124 may adjust the discharge superheat temperature to the target value. The controller 124 may adjust the discharge superheat temperature by regulating the second expansion device 118 and the third expansion device 120 so that the first flow rate and the second flow rate are regulated. The controller 124, while controlling the first flow rate and the second flow rate constantly check the discharge superheat temperature to determine if the discharge superheat temperature has reached the target value. Once the target value is achieved, the HVAC unit 100 is generating adequate heat to provide heat to both the evaporator 108 and the heat recovery unit 110.

[0048] Thereafter, at a second level, the controller 124 may determine the amount of heat to be distributed to the heat recovery unit 110 and the evaporator 108. In one example, the temperature values of the refrigerant entering the heat recovery unit 110 and the evaporator 108 may be determined. For instance, the controller 124 may determine a first discharge superheat temperature for the refrigerant entering the evaporator 108. The first discharge superheat temperature may be determined by:

$$\text{first discharge superheat temperature} = \text{first discharge temperature} - \text{high-pressure saturation temperature}$$

[0049] In addition, the controller 124 may determine a second discharge superheat temperature for the refrigerant entering heat recovery unit 110. The second discharge superheat temperature may be determined by:

$$\text{second discharge superheat temperature} = \text{second discharge temperature} - \text{high-pressure saturation temperature}$$

[0050] Upon determining the first discharge superheat temperature and the second discharge superheat temperature, the controller 124 may operate the second expansion device 118 and the third expansion device 120 to vary the first flow rate and the second flow rate respectively. For instance, the controller 124 may increase the first flow rate to increase heat distribution to the heat recovery unit 110 in case the first discharge superheat temperature is greater than a threshold temperature reading. On the other hand, the controller 124 may decrease the second flow rate to reduce the heat distribution to the evaporator 108. The controller 124 may vary the first flow rate and the second flow rate so that the amount of heat is ideally distributed to the evaporator 108 and the heat recovery unit 110. The ideal heat distribution ensures that the heat discharged to the heat recovery unit 110 and the evaporator 108 does not exceed the sum of amount of heat discharged to these components so that the scenario of reverse heating is prevented.

[0051] In one example, the refrigerant from the first bi-heating fluid path (exiting the second expansion device 118) and the second bi-heating fluid path (exiting the third expansion device 120) enters the first expansion device 106 and through the condenser 104 to the fourth port 112D and to the first port 112A of the first 4-way valve 112. Thereafter, the refrigerant passes through the one-way valve 116 and then to the fourth port 114A via the first port 114D of the second 4-way valve 114, and finally to the accumulator 122 for resupply to the compressor 102. While entering the accumulator 122, the pressure of the refrigerant decreases after passing through the first expansion device 106, the second expansion device 118, and the third expansion device 120. In some scenarios, the pressure of the refrigerant returning to compressor 102 may drop below a threshold value. Such a scenario is prevented by the one-way valve 116 that provides additional passage returning to accumulator 122 and thereby maintains the pressure of the refrigerant entering the compressor 102 above the threshold value.

[0052] In addition to the bi-heating mode, the HVAC unit 100 is configured to cool the space while recovering the heat of the refrigerant instead of discharging the heat to the air by the condenser 104. An exemplary embodiment is illustrated in **Figure 4** which shows the HVAC unit 100 operating in heat recovery mode. In the illustrated figure, the thickest line shows the refrigerant at high pressure, the thick line indicate the refrigerant at low pressure, and dash lines indicate the non-refrigerant line.

[0053] In order to operate the HVAC unit 100 in the heat recovery mode, the controller 124 may determine the temperature to be maintained in the space based on an input from the user. Based on the received inputs, the controller 124 may determine the amount of cooling to be achieved. Thereafter, the controller 124 may operate the first 4-way valve 112 and the second 4-way valve 114 to form a heat-recovery fluid path. The heat-recovery fluid path may originate from the compressor 102 and may culminate back to the compressor 102 via the accumulator 122. The heat-recovery fluid path includes the second port 112B of the first 4-way valve 112, the third port 112C of the first 4-way valve 112, the heat recovery unit 110, the second expansion device 118, the third expansion device 120, the evaporator 108, the third port 114C of the second 4-way valve 114, the fourth port 114A of the second 4-way valve 114, and the accumulator 122.

[0054] During operation, the compressed refrigerant exiting the compressor 102 enters the first 4-way valve 112 via the second port 112B and exits through the third port 112C. The refrigerant then travels to the heat recovery unit 110 via the first 3-way valve 126 in which the compressed refrigerant releases its heat to the water in the heat recovery unit 110. The refrigerant, upon releasing the heat, travels toward the third expansion device 120 via the second expansion device 118. The third expansion device 120 lowers the pressure of the refrigerant thereby liquifying the refrigerant. The liquified refrigerant passes through the evaporator 108 in which the heat from the air is discharged to the refrigerant in the evaporator 108. The refrigerant may then flow into the second 4-way valve 114 via the third port 114C and exit through the fourth port 114A into the accumulator 122.

[0055] During the operation, the condenser 104 may develop frost around the fins of the condenser 104 and the first expansion device 106. Frost deposition of the condenser 104 and the first expansion device 106 may affect the performance of the condenser 104, for instance, reducing the efficiency to absorb the heat of the refrigerant to air. The HVAC unit 100 of the present disclosure is also capable of defrosting the condenser 104 while heating the space. Such a mode is termed the non-stop defrost mode and is illustrated in **Figure 5**. In the illustrated figure, the thickest line shows the refrigerant at high pressure, the thick line indicates the refrigerant at low pressure. In order to heat the space and simultaneously defrost the condenser 104, the controller 124 may actuate the first 4-way valve 112 and the second 4-way valve 114 to form two fluid paths, namely the space-heating fluid path to heat the space and the non-stop defrost fluid path to defrost the condenser 104. The controller 124 may first determine the discharge superheat temperature in the manner explained above to determine the total amount of heat needed.

[0056] The refrigerant flowing through the space-heating fluid path originates from the compressor 102 and flows into the second port 114B of the second 4-way valve 114 and exits through the third port 114C of the second 4-way valve 114. Thereafter, the refrigerant flows into the evaporator 108 via the second 3-way valve 128 and exits the evaporator 108 into the third expansion device 120. From the third expansion device 120, the refrigerant flows into the second expansion device 118 and then into the heat recovery unit 110. The refrigerant exits the heat recovery unit 110 and enters the third port 112C of the first 4-way valve 112 via the first 3-way valve 126 and exits the first 4-way valve 112 via the first port 112A of the first 4-way valve 112. Upon exiting, the refrigerant passes through the one-way valve 116 into the first port 114D of the second 4-way valve 114 where the refrigerant exit via the fourth port 114A of the second 4-way valve 114 into the accumulator 122 and finally back into the compressor 102.

[0057] On the other hand, the refrigerant flowing through the non-stop defrost fluid path originates from the compressor 102 to the second port 112B of the first 4-way valve 112 and exits through the fourth port 112D of the first 4-way valve 112. The refrigerant then flows into the condenser 104 in which the heat of the refrigerant is used to defrost ice deposited on the condenser 104. The refrigerant may then flow into the first expansion device 106 where the hot refrigerant defrosts the first expansion device 106. The refrigerant then mixes with the refrigerant in the space-heating fluid path after exiting the first expansion device 106. Further, the controller 124 opens the second expansion device 118 and thus, the refrigerant flows into the heat recovery unit 110, through the second expansion device 118. Thereafter, the refrigerant exits the

heat recovery unit 110 via the first 3-way valve 126 and into the third port 112C of the first 4-way valve 112 and exits from the first port 112A of the first 4-way valve 112. The refrigerant passes through the one-way valve 116 into the first port 114D of the second 4-way valve 114. Then the refrigerant enters the accumulator 122 via the fourth port 114A of the second 4-way valve. During the non-stop defrost mode, the one-way valve 116 provides additional passage returning to accumulator 122. As a result, the pressure of the refrigerant entering the compressor 102 via the accumulator 122 is maintained above the threshold value. Moreover, the controller continues to adjust the discharge superheat temperature to the target value.

[0058] According to the present disclosure, the HVAC unit 100 may defrost its condenser 104 without providing heating to the space. Such an exemplary is termed the normal-defrost mode is shown in **Figure 6**. In such a scenario, the refrigerant supplied to the heat recovery unit 110 is cut-off by closing the second expansion device 118. Further, the controller 124 may determine that frost is deposited on the condenser 104 or/and the first expansion device 106. The controller 124 may determine the deposition of the frost by either measuring the temperature of the condenser 104/ first expansion device 106 or by determining the reduction in the performance of the condenser 104/ first expansion device 106. Based on the determination, the controller 124 may actuate the first 4-way valve 112 and the second 4-way valve 114 to form a normal-defrost fluid path. The refrigerant in the normal-defrost fluid path originates from the compressor 102 and flow into the second port 112B of the first 4-way valve 112, exit the fourth port 112D of the first 4-way valve 112 and into the condenser 104. The hot and compressed refrigerant defrost the condenser 104 and then flows into the first expansion device 106. From the first expansion device 106, the refrigerant flows into the third expansion device 120 which reduces the pressure and temperature of the refrigerant. The cooled refrigerant then passes through the evaporator 108 and into the third port 114C of the second 4-way valve 114. The refrigerant exit through the fourth port 114A of the second 4-way valve 114 and into the accumulator 122. As shown in Figure 6, a portion of the refrigerant may enter the second port 114B and flow out through the first port 114D of the second 4-way valve 114. The refrigerant is then stopped by the one-way valve 116 in order to prevent its flow towards the first port 112A and prevents any malfunction of the first 4-way valve 112.

[0059] According to the present disclosure, the HVAC unit 100 may also heat the space without a need to recover the heat of the refrigerant. Such a scenario may arise when either the hot water is not needed, or the heat recovery unit 110 does not have the water. Such a scenario is shown in **Figure 7** which shows the HVAC unit 100 operating in a normal-heating mode. In the illustrated embodiment, the flow of the refrigerant is as per a normal-heating fluid path which is identical to the second bi-heating fluid path explained with respect to Figure 3. The controller 124, to distribute the heat to the evaporator 108, performs the first level of heat distribution in a manner explained above. Further, the controller 124 may operate the third expansion device 120 to increase the second flow rate of the refrigerant to the evaporator 108. Further, the second expansion valve 118 is set minimum opening so that least volume of refrigerant flows through the heat recovery unit 110. Thus, almost all the refrigerant is directed to evaporator 108 thereby flowing through the second bi-heating fluid path as explained in Figure 3, and all the heating capacity is provided for space heating.

[0060] In addition to the heating of the space, the HVAC unit 100 may be employed to heat the water in the heat recovery unit 110. Such an exemplary embodiment is shown in **Figure 8** which shows the HVAC unit 100 in the heating mode of a heat recovery unit 110. In such a scenario, the controller 124 may actuate the first 4-way valve 112 and the second 4-way valve 114 to form a water-heating fluid path. The refrigerant flowing through the water-heating fluid path originates from the compressor 102 and then flows into the second port 112B of the first 4-way valve 112. The refrigerant then exits through the third port 112C of the first 4-way valve 112 and into the heat recovery unit 110 via the first 3-way valve 126. The refrigerant flowing through the heat recovery unit 110 discharges its heat thereby heating the water. The refrigerant then flows into the second expansion device 118 which lowers the pressure of the refrigerant. The refrigerant then flows to the condenser 104 via the first expansion device 106 and into the fourth port 112D of the first 4-way valve 112. Thereafter, the refrigerant exit through the first port 112A of the first 4-way valve 112 and into the accumulator 122. As clearly seen, the one-way valve 116 prevents the flow of the refrigerant to the first 4-way valve 112 thereby preventing a change in refrigerant pressure from entering the compressor 102 via the accumulator 122.

[0061] The HVAC unit 100 of the present disclosure may also operate in cooling mode as shown in **Figure 9** in which the controller 124 actuates the first 4-way valve 112 and the second 4-way valve 114 to form a cooling fluid path. The refrigerant flowing through the cooling fluid path originates from the compressor 102 and flows into the second port 112B of the first 4-way valve 112. The refrigerant exit through the fourth port 112D of the first 4-way valve 112 and the condenser 104 in which the heat from the refrigerant is released to ambient air. The refrigerant may then flow towards the third expansion device 120 via the first expansion device 106. Since the second expansion device 118 is closed, the refrigerant flows through the third expansion device 120 in which the refrigerant pressure and temperature is reduced. The cooled refrigerant absorbs heat in the space thereby cooling the air. The refrigerant exits the evaporator 108 into the third port 114C and exits via the fourth port 114A of the second 4-way valve 114.

[0062] The present disclosure also relates to a method 1000 for operating the HVAC unit 100 as shown in **Figure 10**. The order in which the method steps are described below is not intended to be construed as a limitation, and any number of the described method steps can be combined in any appropriate order to execute the method or an alternative method.

Additionally, individual steps may be deleted from the method without departing from the spirit and scope of the subject matter described herein.

[0063] The method 1000 can be performed by programmed computing devices, for example, based on instructions retrieved from non-transitory computer readable media. The computer readable media can include machine-executable or computer-executable instructions to perform all or portions of the described method. The computer readable media may be, for example, digital memories, magnetic storage media, such as a magnetic disks and magnetic tapes, hard drives, or optically readable data storage media.

[0064] In one example, the method 1000 can be performed partially or completely by the HVAC unit 100. The method begins at step 1002 at which the compressor 102 is actuated to pump the refrigerant. At step 1004, the controller 124 determines a first discharge superheat temperature for the refrigerant entering the evaporator 108 based on a high-pressure saturation temperature of the refrigerant exiting the compressor 102 and a first discharge temperature of the refrigerant entering the evaporator 108. Further, at step 1006, the controller 124 determines a second discharge superheat temperature for the refrigerant entering the heat recovery unit 110 based on the high-pressure saturation temperature of the refrigerant exiting the compressor 102 and a second discharge temperature of the refrigerant entering the heat recovery unit 110. Finally, at step 1008, the controller 124 actuates a first flow rate of the refrigerant via the first 4-way valve 112 and a second flow rate via the second 4-way valve 114 to maintain ideal heat distribution between the heat recovery unit 110 and the evaporator 108.

[0065] According to the present disclosure, the HVAC unit 100 is configured to optimise the total heat capacity before adjusting the flow thereby preventing all possible scenarios of reverse heating. Moreover, the one-way valve 116 prevents pressure drop to prevent unnecessary load on the compressor 102. In addition, the HVAC unit 100 recovers the refrigerant heat for heating the water making the HVAC unit 100 overall efficient. In addition, the HVAC unit 100 not only provides air conditioning but also a water heater thereby serving the purpose of two appliances in a single unit.

[0066] While specific language has been used to describe the present disclosure, any limitations arising on account thereto, are not intended. As would be apparent to a person in the art, various working modifications may be made to the method in order to implement the inventive concept as taught herein. The drawings and the foregoing description give examples of embodiments. Those skilled in the art will appreciate that one or more of the described elements may well be combined into a single functional element. Alternatively, certain elements may be split into multiple functional elements. Elements from one embodiment may be added to another embodiment.

Claims

1. A heat ventilation and air conditioning (HVAC) unit (100) comprising:

a compressor (102) adapted to compress a refrigerant to form a compressed refrigerant;
 a condenser (104) in fluid communication with the compressor (102) to exchange heat between the compressed refrigerant and ambient air to form a condensed refrigerant;
 a first expansion device (106) in fluid communication with the condenser (104) to convert the condensed refrigerant into a cooled refrigerant;
 an evaporator (108) in fluid communication with the first expansion device (106) to exchange heat between a space to be cooled and the cooled refrigerant;
 a heat recovery unit (110) in fluid communication with the compressor (102) and the first expansion device (106) to discharge heat of the condensed refrigerant to a medium;
 a first 4-way valve (112) in fluid communication with the compressor (102), the heat recovery unit (110) and condenser (104) to supply a portion of the refrigerant to the heat recovery unit (110) at a first flow rate;
 a second 4-way valve (114) in fluid communication with the compressor (102), the first 4-way valve (112), and the evaporator (108) to supply another portion of the refrigerant to the evaporator (108) at a second flow rate; and
characterized by:

a one-way valve (116) in fluid communication with a first port (112A) of the first 4-way valve (112) and a first port (114D) of the second 4-way valve (114) to maintain a pressure of refrigerant entering the compressor (102) above a threshold value; and
 a controller (124) adapted to control an operation of the compressor (102), the first 4-way valve (112) and the second 4-way valve (114), wherein the controller (124) is adapted to:

determine a first discharge superheat temperature for the refrigerant entering the evaporator (108) based on a high-pressure saturation temperature of refrigerant exiting the compressor (102) and a first discharge temperature of refrigerant entering the evaporator (108);

determine a second discharge superheat temperature for the refrigerant entering the heat recovery unit (110) based on the high-pressure saturation temperature of the refrigerant exiting the compressor (102) and a second discharge temperature of the refrigerant entering the heat recovery unit (110); and adjust the first flow rate and the second flow rate to maintain ideal heat distribution between the heat recovery unit (110) and the evaporator (108).

2. A HVAC unit (100) according to claim 1, wherein the high-pressure saturation temperature is based on a measured pressure of the refrigerant exiting the compressor (102) and a type of the refrigerant.

3. A HVAC unit (100) according to claim 1 further comprising:

a second expansion device (118) in fluid communication with a port of the heat recovery unit (110) and the first expansion device (106);

a third expansion device (120) in fluid communication with a port of the evaporator (108) and the first expansion device (106).

4. A HVAC unit (100) according to claim 3, wherein the second expansion device (118) is configured to regulate the first flow rate, and the third expansion device (120) is configured to regulate the second flow rate.

5. A HVAC unit (100) according to claim 3, wherein the controller 124:

is configured to determine a discharge superheat temperature as a difference between an outlet temperature of the refrigerant exiting the compressor (102) and a pressure saturation temperature corresponding to a measured pressure of the refrigerant exiting the compressor (102) and a type of the refrigerant, and

is configured to operate the second expansion device (118) and the third expansion device (120) to adjust the discharge superheat temperature to a target value.

6. A HVAC unit (100) according to claim 1, wherein the first 4-way valve (112) comprises:

a second port (112B) in fluid communication with the compressor (102),

a third port (112C) in fluid communication with the heat recovery unit (110), and a

a fourth port (112D) in fluid communication with the condenser (104); and the second 4-way valve (114) comprises:

a second port (114B) in fluid communication with the compressor (102),

a third port (114C) in fluid communication with the evaporator (108), and

a fourth port (114A) in fluid communication with an accumulator (122), wherein the accumulator (122) is adapted to supply the refrigerant to the compressor (102).

7. A heat ventilation and air conditioning unit comprising:

a compressor (102) adapted to compress a refrigerant to form a compressed refrigerant;

a condenser (104) in fluid communication with the compressor (102) to exchange heat between the compressed refrigerant and ambient air to form a condensed refrigerant;

a first expansion device (106) in fluid communication with the condenser (104) to convert the condensed refrigerant into a low pressure and low temperature refrigerant;

a second expansion device (118) in fluid communication with a port of the heat recovery unit (110) and the first expansion device (106);

a third expansion device (120) in fluid communication with a port of the evaporator (108) and the first expansion device (106);

an evaporator (108) in fluid communication with the third expansion device (120) to exchange heat between a space to be cooled and the cooled refrigerant;

a heat recovery unit (110) in fluid communication with the compressor (102) and the second expansion device (118) to discharge heat of the condensed refrigerant to a medium;

a first 4-way valve (112) in fluid communication with the compressor (102), the heat recovery unit (110) and condenser (104) to supply a portion of the refrigerant to the heat recovery unit (110) at a first flow rate;

a second 4-way valve (114) in fluid communication with the compressor (102), the first 4-way valve (112), and

the evaporator (108) to supply another portion of the refrigerant to the evaporator (108) at a second flow rate; and
characterized by:

a one-way valve (116) in fluid communication with a first port (112A) of the first 4-way valve (112) and a first port (114D) of the second 4-way valve (114) to maintain a pressure of refrigerant entering the compressor (102) above a threshold value; and
 a controller (124) adapted to control an operation of the compressor (102), the first 4-way valve (112) and the second 4-way valve (114), wherein the controller (124) is adapted to:
 actuate the first 4-way valve (112) and the second 4-way valve (114) to form a heat-recovery fluid path originating from the compressor (102) to cool the space and recover heat of the compressed refrigerant, wherein
 the heat-recovery fluid path includes the second port (112B) of the first 4-way valve (112), the third port (112C) of the first 4-way valve (112), the heat recovery unit (110), the second expansion device (118), the third expansion device (120), the evaporator (108), the third port (114C) of the second 4-way valve (114), the fourth port (114A) of the second 4-way valve (114), and the accumulator (122).

8. A heat ventilation and air conditioning unit comprising:

a compressor (102) adapted to compress a refrigerant to form a compressed refrigerant;
 a condenser (104) in fluid communication with the compressor (102) to exchange heat between the compressed refrigerant and ambient air to form a condensed refrigerant;
 a first expansion device (106) in fluid communication with the condenser (104) to convert the condensed refrigerant into a low pressure and low temperature refrigerant;
 a second expansion device (118) in fluid communication with a port of the heat recovery unit (110) and the first expansion device (106);
 a third expansion device (120) in fluid communication with a port of the evaporator (108) and the first expansion device (106);
 an evaporator (108) in fluid communication with the third expansion device (120) to exchange heat between a space to be cooled and the cooled refrigerant;
 a heat recovery unit (110) in fluid communication with the compressor (102) and the second expansion device (118) to discharge heat of the condensed refrigerant to a medium;
 a first 4-way valve (112) in fluid communication with the compressor (102), the heat recovery unit (110) and condenser (104) to supply a portion of the refrigerant to the heat recovery unit (110) at a first flow rate;
 a second 4-way valve (114) in fluid communication with the compressor (102), the first 4-way valve (112), and the evaporator (108) to supply another portion of the refrigerant to the evaporator (108) at a second flow rate; and
characterized by:

a one-way valve (116) in fluid communication with a first port (112A) of the first 4-way valve (112) and a first port (114D) of the second 4-way valve (114) to maintain a pressure of refrigerant entering the compressor (102) above a threshold value; and
 a controller (124) adapted to control an operation of the compressor (102), the first 4-way valve (112) and the second 4-way valve (114), wherein the controller (124) is adapted to:

actuate the first 4-way valve (112) and the second 4-way valve (114) to form a space-heating fluid path originating from the compressor (102) to heat the space simultaneous to the defrosting of the condenser (104),

wherein the space-heating fluid path includes a second port (114B) of the second 4-way valve (114), a third port (114C) of the second 4-way valve (114), the evaporator (108), the third expansion device (120), the second expansion device (118), the heat recovery unit (110), a third port (112C) of the first 4-way valve (112), a first port (112A) of the first 4-way valve (112), the one-way valve (116), a first port (114D) of the second 4-way valve (114), a fourth port (114A) of the second 4-way valve (114), and an accumulator (122); and

actuate the first 4-way valve (112) and the second 4-way valve (114) to form a non-stop defrost fluid path originating from the compressor (102) to defrost the condenser (104) simultaneous to the heating of the space, wherein the non-stop defrost fluid path includes a second port (112B) of the first 4-way valve (112), a fourth port (112D) of the first 4-way valve (112), the condenser (104), the first expansion device (106), the second expansion device (118), the heat recovery unit (110), a third port (112C) of the first 4-way valve (112), a first port (112A) of the first 4-way valve (112), the one-way valve (116),

a first port (114D) of the second 4-way valve (114), a fourth port (114A) of the second 4-way valve (114), and an accumulator (122).

9. A method of operating a heat ventilation and air conditioning unit, the method comprising:

actuating a compressor (102) of the HVAC unit (100) to compress a refrigerant, wherein the HVAC unit (100) comprising a condenser (104), a first expansion device (106), second expansion device (118), third expansion device (120), an evaporator (108), a heat recovery unit (110), a first 4-way valve (112), a second 4-way valve (114), a one-way valve (116), and a controller (124), wherein the one-way valve (116) maintains a pressure of refrigerant entering the compressor (102) above a threshold value;
determining, by the controller (124), a first discharge superheat temperature for the refrigerant entering the evaporator (108) based on a high-pressure saturation temperature of the refrigerant exiting the compressor (102) and a first discharge temperature of the refrigerant entering the evaporator (108);
determining, by the controller (124), a second discharge superheat temperature for the refrigerant entering the heat recovery unit (110) based on the high-pressure saturation temperature of the refrigerant exiting the compressor (102) and a second discharge temperature of the refrigerant entering the heat recovery unit (110);
actuating, by the controller (124), a first flow rate of the refrigerant via the first 4-way valve (112) and a second flow rate via the second 4-way valve (114) to maintain ideal heat distribution between the heat recovery unit (110) and the evaporator (108).

10. A method according to claim 9, wherein the high-pressure saturation temperature is based on a measured pressure of the refrigerant exiting the compressor (102) and a type of the refrigerant.

11. A method according to claim 9, wherein the HVAC unit (100) comprises:

a second expansion device (118) in fluid communication with a port of the heat recovery unit (110) and the first expansion device (106);

a third expansion device (120) in fluid communication with a port of the evaporator (108) and the first expansion device (106), wherein

the first 4-way valve (112) comprising:

a second port (112B) in fluid communication with the compressor (102),

a third port (112C) in fluid communication with the heat recovery unit (110),

a fourth port (112D) in fluid communication with the condenser (104); and the second 4-way valve (114) comprising:

a second port (114B) in fluid communication with the compressor (102),

a third port (114C) in fluid communication with the evaporator (108),

a fourth port (114A) in fluid communication with an accumulator (122), wherein the accumulator (122) is adapted to supply the refrigerant to the compressor (102).

12. A method according to claim 11, comprising:

determining, by the controller (124), a discharge superheat temperature as a difference between an outlet temperature of the refrigerant exiting the compressor (102) and a pressure saturation temperature corresponding to a measured pressure of the refrigerant exiting the compressor (102) and a type of the refrigerant, and operating, by the controller (124), the second expansion device (118) and the third expansion device (120) to adjust the discharge superheat temperature to a target value.

13. A method of operating a heat ventilation and air conditioning unit, the method comprising:

actuating a compressor (102) of the HVAC unit (100) to compress a refrigerant, wherein the HVAC unit (100) comprising a condenser (104), a first expansion device (106), an evaporator (108), a heat recovery unit (110), a first 4-way valve (112), a second 4-way valve (114), a one-way valve (116), and a controller (124), wherein the one-way valve (116) maintains a pressure of refrigerant entering the compressor (102) above a threshold value;

actuating, by the controller (124), the first 4-way valve (112) and the second 4-way valve (114) to form a heat-

recovery fluid path originating from the compressor (102) to cool the space and recover heat of the compressed refrigerant, wherein

the heat-recovery fluid path includes the second port (112B) of the first 4-way valve (112), the third port 112C of the first 4-way valve, the heat recovery unit (110), the second expansion device (118), the third expansion device (120), the evaporator (108), the third port (114C) of the second 4-way valve (114), the fourth port of second 4-way valve (114A), and the accumulator (122).

14. A method of operating a heat ventilation and air conditioning unit, the method comprising:

actuating a compressor (102) of the HVAC unit (100) to compress a refrigerant, wherein the HVAC unit (100) comprising a condenser (104), a first expansion device (106), an evaporator (108), a heat recovery unit (110), a first 4-way valve (112), a second 4-way valve (114), a one-way valve (116), and a controller (124), wherein the one-way valve (116) maintains a pressure of refrigerant entering the compressor (102) above a threshold value;

actuating, by a controller (124), the first 4-way valve (112) and the second 4-way valve (114) to form a space-heating fluid path originating from the compressor (102) to heat the space simultaneous to the defrosting of the condenser (104), wherein

the space-heating fluid path includes a second port (114B) of the second 4-way valve (114), a third port (114C) of the second 4-way valve (114), the evaporator (108), a third expansion device (120), a second expansion device (118), the heat recovery unit (110), a third port (112C) of the first 4-way valve (112), a first port (112A) of the first 4-way valve (112), the one-way valve (116), a first port (114D) of the second 4-way valve (114), fourth port (114A) of the second 4-way valve (114), and an accumulator (122); and

actuating, by the controller (124), the first 4-way valve (112) and the second 4-way valve (114) to form a non-stop defrost fluid path originating from the compressor (102) for defrosting of the condenser (104) simultaneous to heating the space, wherein

the non-stop defrost fluid path includes a second port (112B) of the first 4-way valve (112), a fourth port (112D) of the first 4-way valve (112), the condenser (104), the first expansion device (106), the second expansion device (118), the heat recovery unit (110), a third port (112C) of the first 4-way valve (112), a first port (112A) of the first 4-way valve (112), the one-way valve (116), the first port (114D) of the second 4-way valve (114), the fourth port (114A) of the second 4-way valve (114), and the accumulator (122).

100

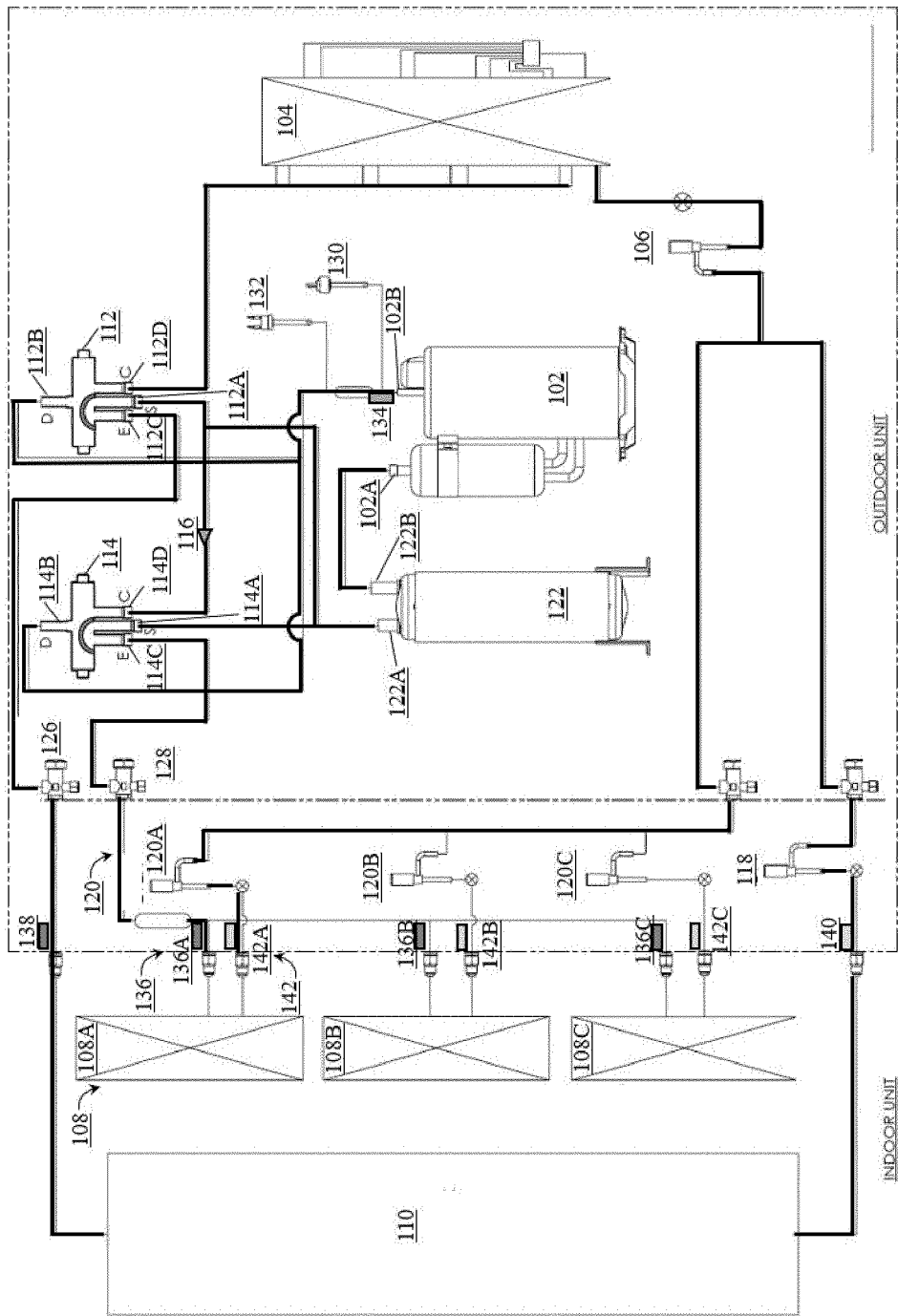


FIGURE 1

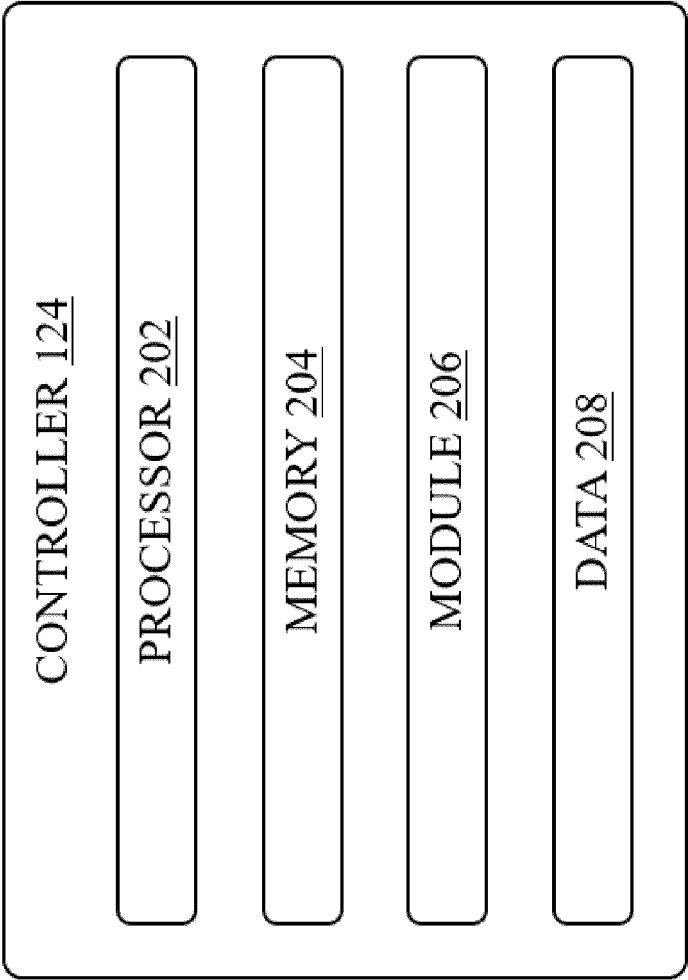


FIGURE 2

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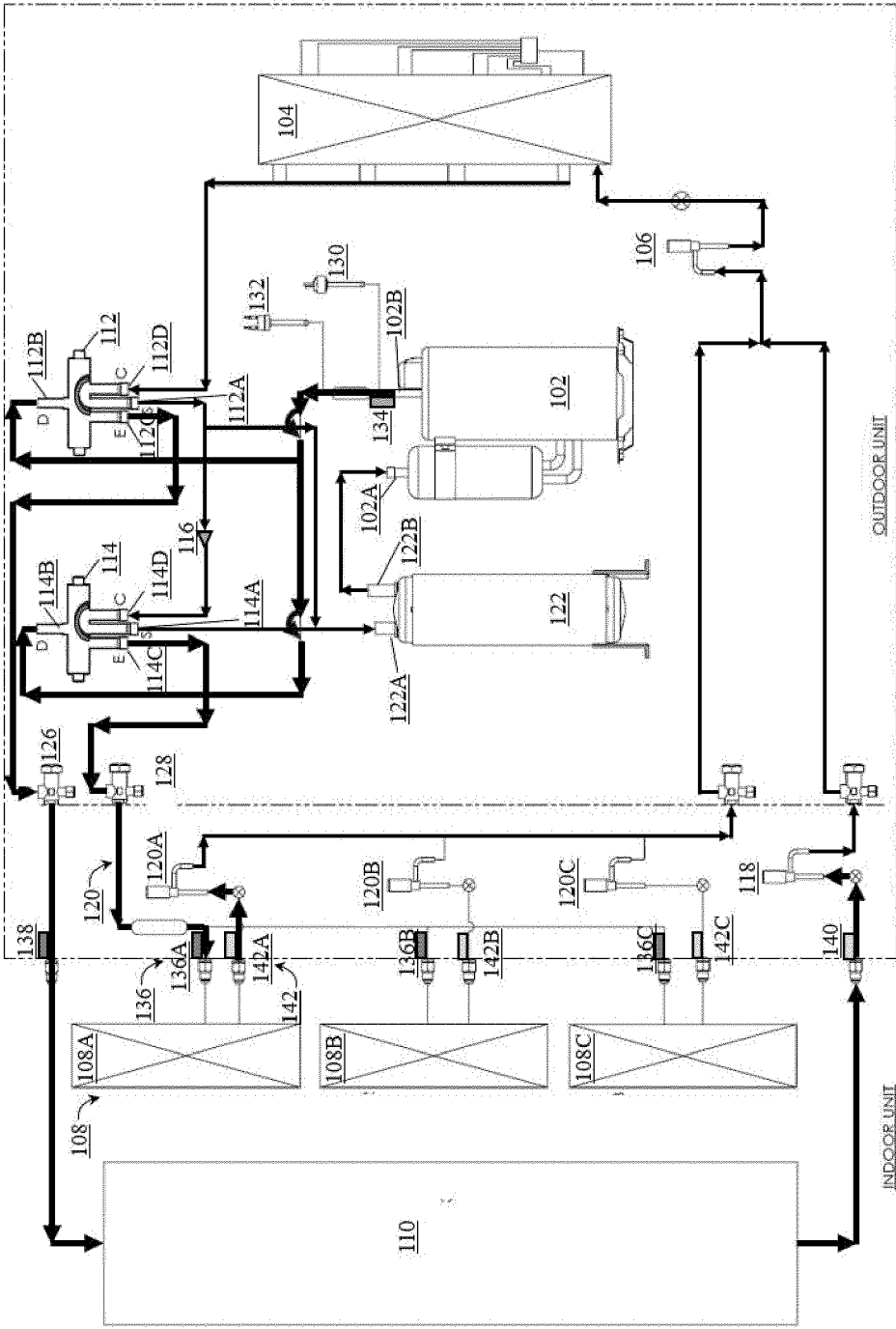


FIGURE 3

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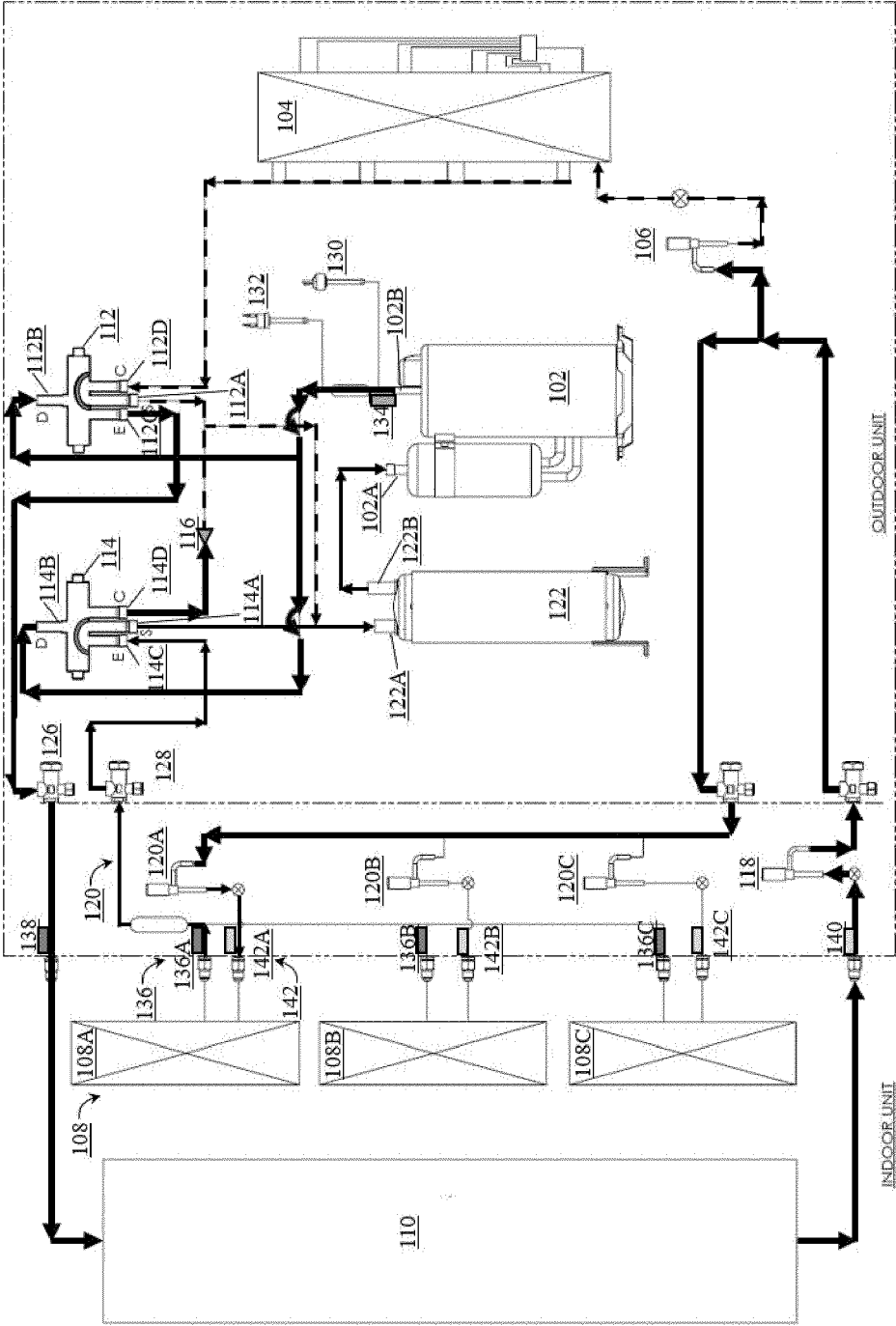


FIGURE 4

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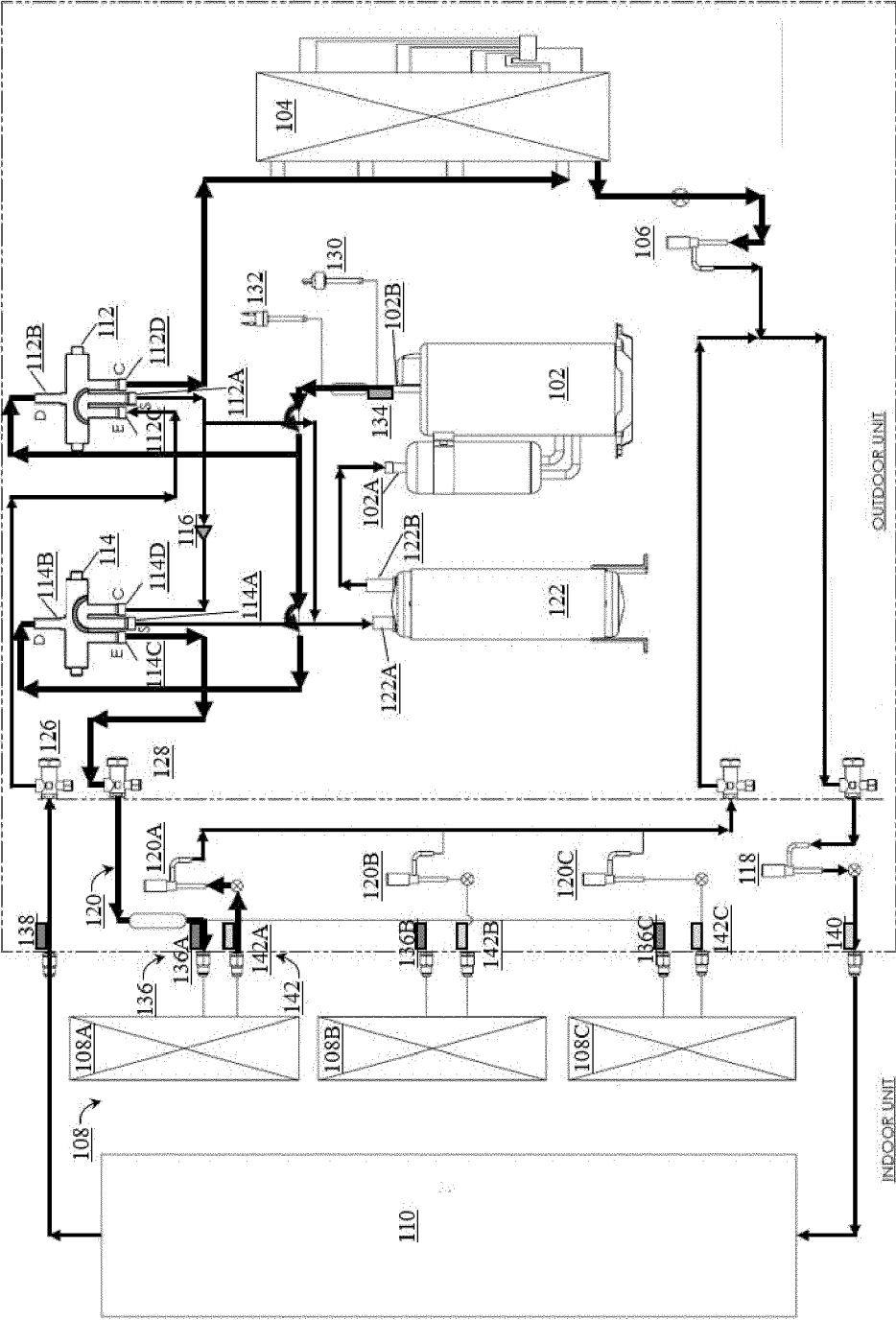


FIGURE 5

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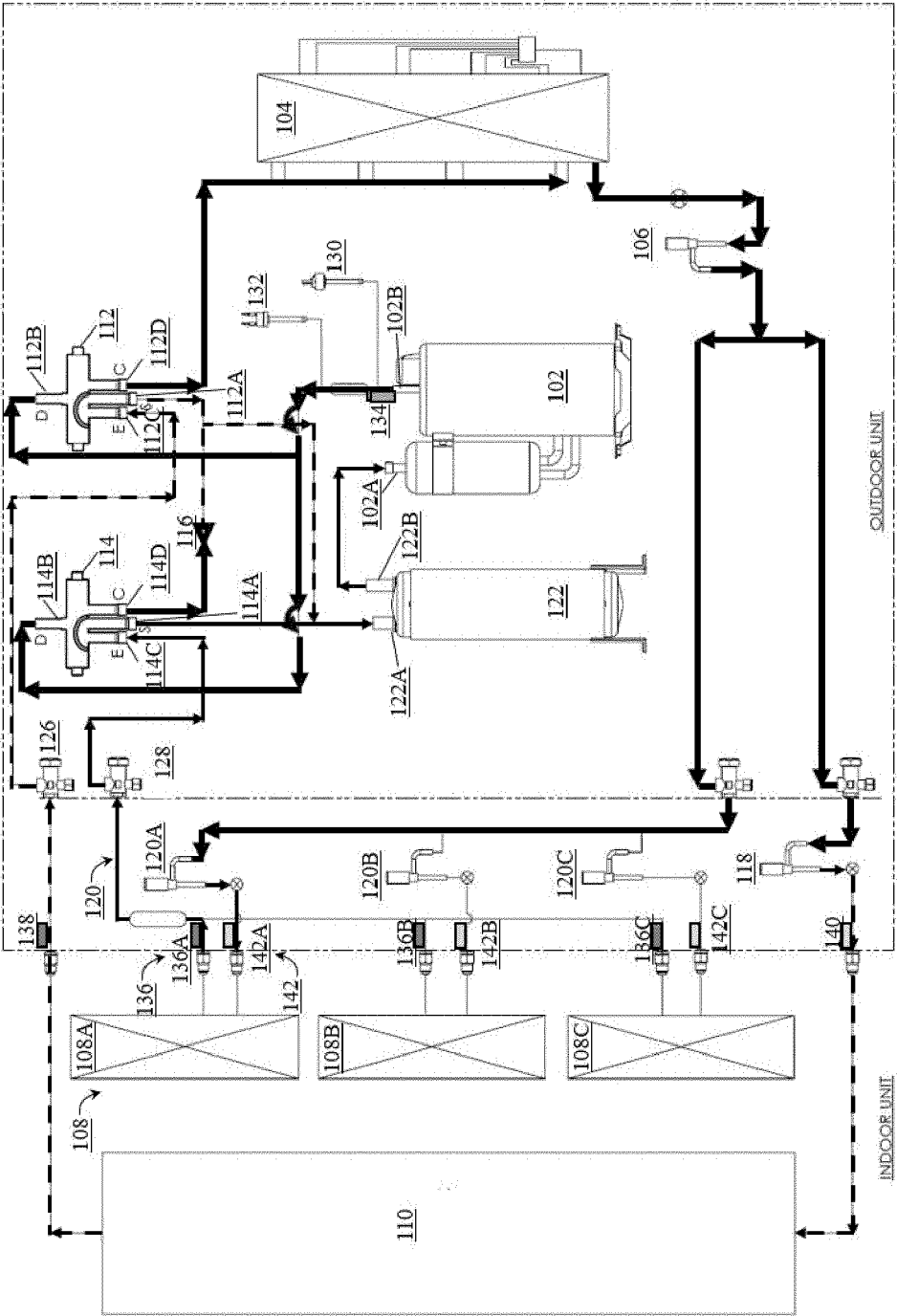


FIGURE 6

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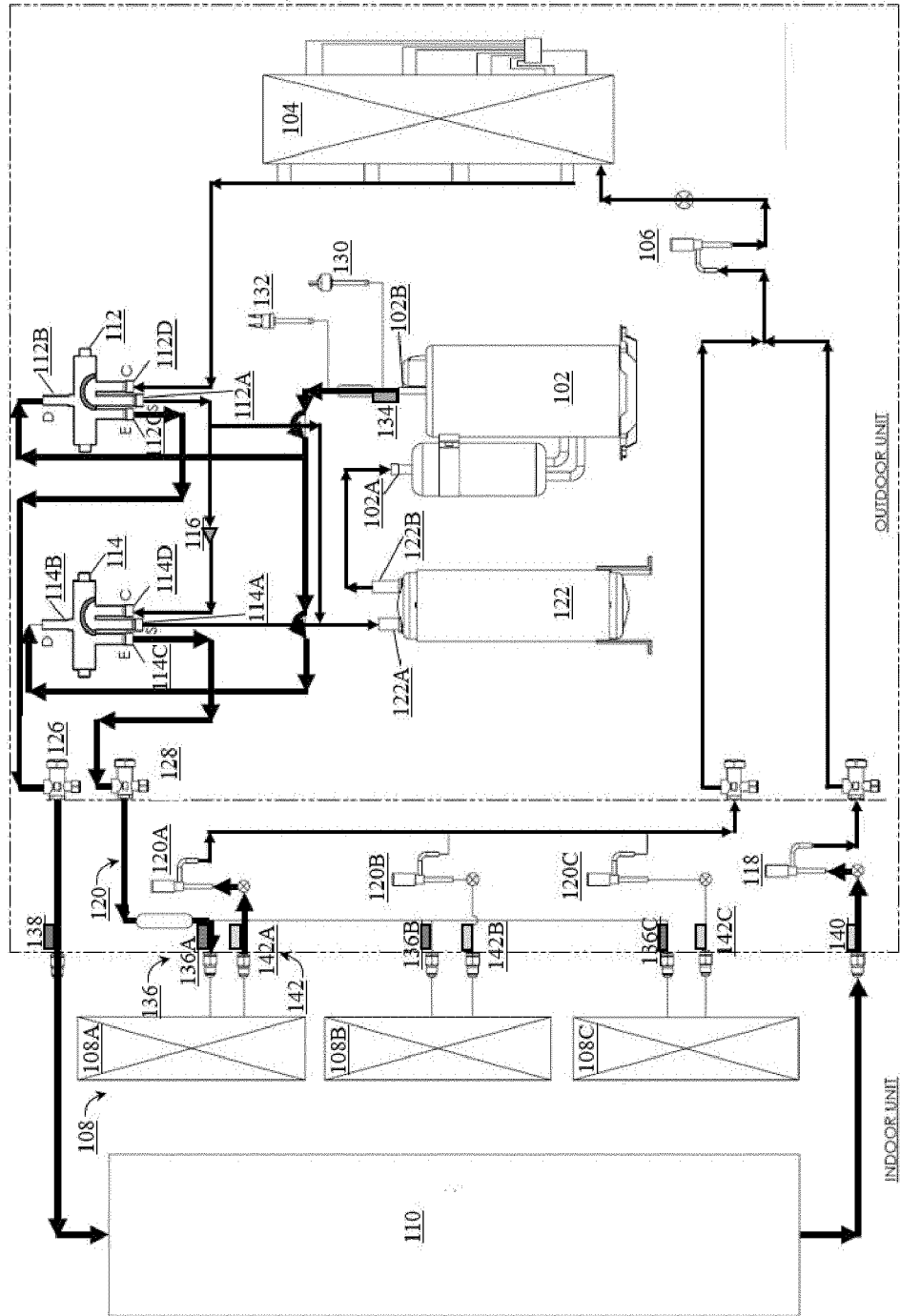


FIGURE 7

100

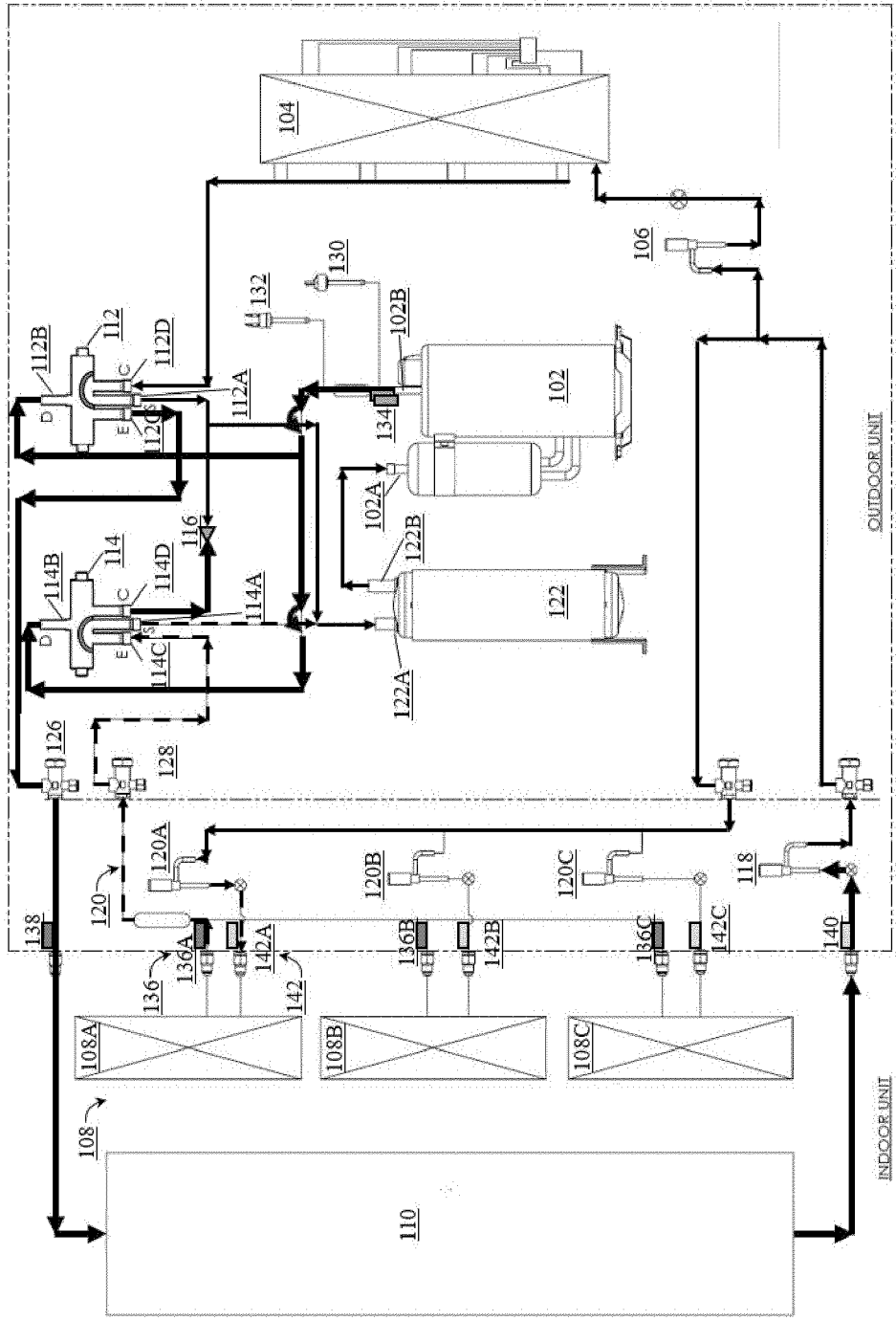


FIGURE 8

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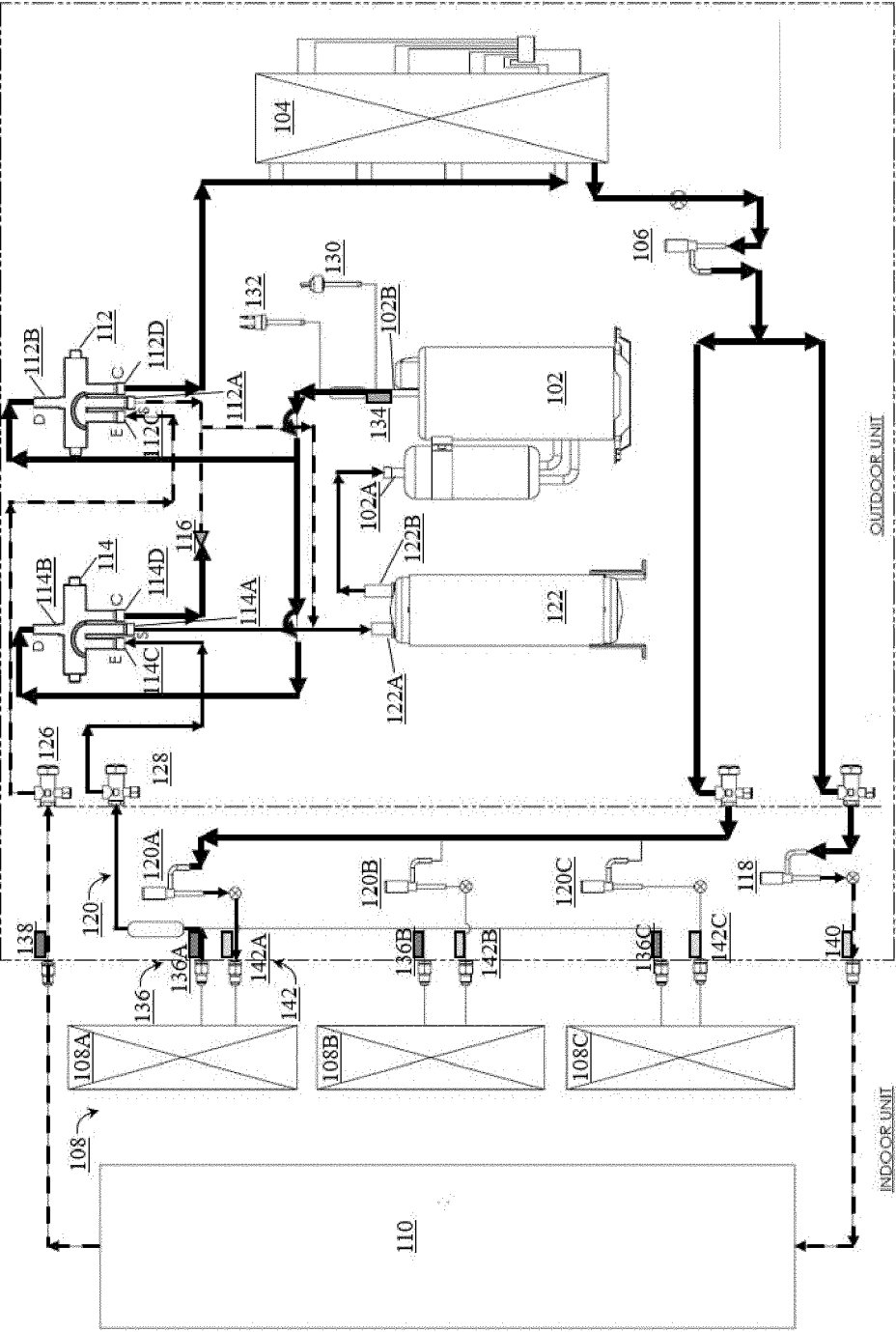


FIGURE 9

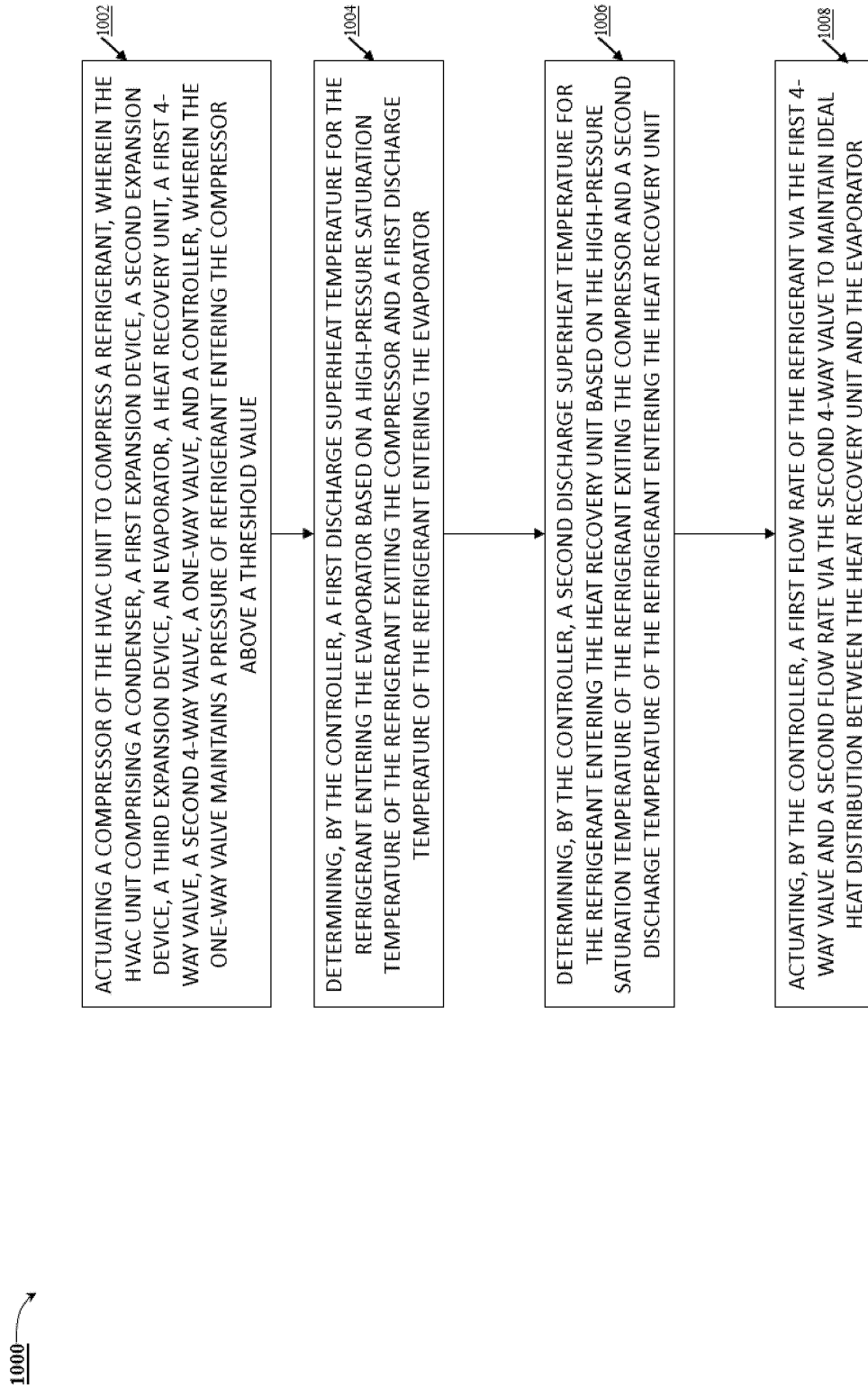


FIGURE 10



PARTIAL EUROPEAN SEARCH REPORT

Application Number

under Rule 62a and/or 63 of the European Patent Convention.
This report shall be considered, for the purposes of
subsequent proceedings, as the European search report

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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 2013/145785 A1 (NOBUHIRO NAKAGAWA [JP]) 13 June 2013 (2013-06-13) * paragraphs [0036] - [0052]; figure 1 * -----	1-6, 9-12	INV. F25B13/00 F25B49/02 F25B41/22
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A	WO 2021/039087 A1 (DAIKIN IND LTD [JP]) 4 March 2021 (2021-03-04) * paragraphs [0021] - [0062]; figure 1 * -----	1-6, 9-12	
			TECHNICAL FIELDS SEARCHED (IPC)
			F25B

INCOMPLETE SEARCH

The Search Division considers that the present application, or one or more of its claims, does/do not comply with the EPC so that only a partial search (R.62a, 63) has been carried out.

Claims searched completely :

Claims searched incompletely :

Claims not searched :

Reason for the limitation of the search:

see sheet C

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Place of search	Date of completion of the search	Examiner
Munich	4 October 2022	Amous, Moez
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document		

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**INCOMPLETE SEARCH
SHEET C**

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Claim(s) completely searchable:

1-6, 9-12

Claim(s) not searched:

7, 8, 13, 14

Reason for the limitation of the search:

Rule 62a EPC

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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		WO 2021039087 A1	04-03-2021

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