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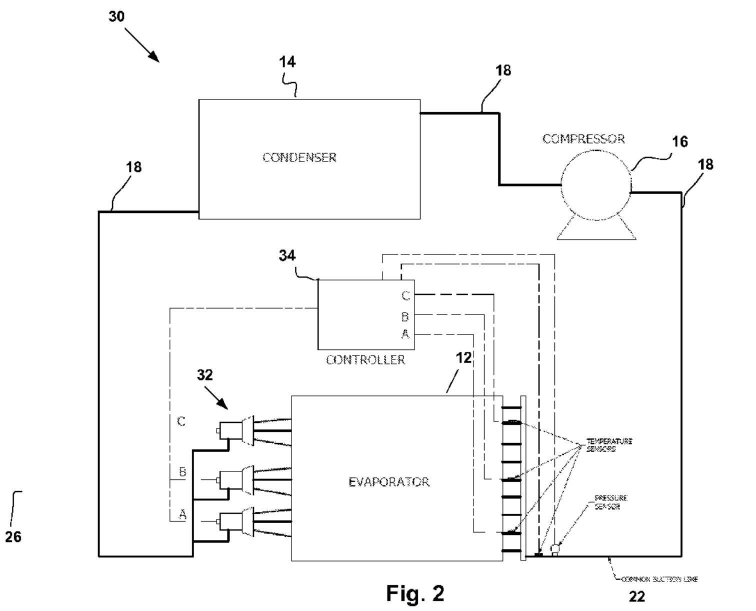

Fig. 2

(57) Abstract: A variable capacity evaporator system includes an evaporator having a plurality of independent circuits assembled as a unit, each circuit arranged in circuit groups and defining a fluid flow path, each circuit group including at least one circuit. The system further includes a plurality of flow control devices, each flow control device of the plurality of flow control devices in fluid communication with a respective circuit group and operative to vary a fluid flow through the respective circuit group, and a common header in fluid communication with a low-side each of the plurality of circuit groups. A controller is operatively coupled to each flow control device, the controller including logic configured to independently control each flow control device to regulate fluid flow through the respective circuit group based on a superheat at each circuit group and a superheat at the common header.

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VARIABLE CAPACITY EVAPORATOR

Related Application Data

This application claims priority of U.S. Provisional Application No. 61/811,974 filed on April 15, 2013, which is incorporated herein by reference in its entirety.

Field of Invention

The present invention relates to heating, ventilation, air conditioning and refrigeration (HVACR) systems, and more particularly to an evaporator that can be used in such systems.

Background

An air conditioning system can be used to control the temperature of a certain medium such as, for example, the air inside of a building. With reference to Fig. 1, an air conditioning system 10 generally includes an evaporator 12, a condenser 14, a compressor 16 and a series of lines 18 (*e.g.*, pipes, tubes, ducts) connecting these components together so that a refrigerant fluid can cycle there through. Typically, the evaporator 12 is located adjacent to or within the medium (*e.g.*, it is located inside the building) and the condenser 14 is located remote from the medium (*e.g.*, it is located outside of the building).

In an air conditioning system, refrigerant fluid enters the heat-absorbing component (e.g., evaporator 12) as a low pressure and low-temperature vapor-liquid. As the vapor-liquid passes through the heat-absorbing component, it is boiled into a low pressure gas state. From the heat-absorbing component, the fluid passes through the compressor 16, which increases the pressure and temperature of the gas. From the compressor 16, the high pressure and high temperature gas passes through the heat-rejecting component (e.g., condenser 14) whereat it is condensed to a liquid.

An air conditioning system will often include an expansion valve 20 immediately (or almost immediately) upstream of the heat-absorbing component. When the high pressure and high temperature liquid from heat-rejecting component passes through the expansion valve 20, the pressure of the fluid is reduced (*e.g.,* the expansion valve throttles the fluid) and fluid is converted to a low pressure and low temperature vapor/liquid state. This low pressure and low temperature vapor/liquid is received by the heat-absorbing component to complete the cycle.

The expansion valve 20 regulates fluid flow through the heat absorbing element by controlling the superheat in a common suction line 22 (which is located after all individual circuits exit the heat absorbing element and combine into a header) exiting the heat absorbing element. Control of flow through the heat absorbing element is performed by a controller 24 based on the average superheat at the header.

Heat absorbing elements, such as an evaporator 12, may be of a multi-circuit tube-and-fin coil configuration. Such evaporators typically include a plurality of coil circuits arranged in a parallel configuration. To use such evaporators, an air conditioning system will often also include a distributor 26 downstream of the expansion valve 20. A distributor commonly includes a mixing compartment whereat fluid is evenly distributed to a plurality of tubes which feed the multiple circuits of the heat-absorbing component.

Summary of Invention

Multi-circuit evaporators operate efficiently when used at or near their rated full-load capacity. However, as the load on the evaporator decreases and/or significantly varies, the efficiency of the evaporator also decreases.

A system and method in accordance with the present disclosure provide an evaporator assembly for heating, ventilation, air-conditioning and refrigeration systems that has variable capacity evaporator control. Using variable capacity evaporator control, the total cooling capacity of the evaporator coil can closely match the system demand (load) and thus accurate temperature and humidity control can be maintained over a wide operating range.

In one embodiment, an evaporator assembly includes an evaporator coil having a plurality of circuits, a distributor assembly having a plurality of distributors in fluid communication with respective circuits of the evaporator coil, and a controller for controlling flow of fluid through the plurality of distributors to vary the capacity of the evaporator coil by controlling the flow of fluid through the respective circuits.

According to one aspect of the invention, a variable capacity evaporator system includes: an evaporator including a plurality of independent circuits assembled as a unit, each circuit arranged in circuit groups and defining a fluid flow path, each circuit group including at least one circuit; a plurality of flow control devices, each flow control device of the plurality of flow control devices in fluid communication with a respective circuit group and operative to vary a fluid flow through the respective circuit group; a common header in fluid communication with a low-side each of the plurality of circuit groups; and a controller operatively coupled to each flow control device, the controller including logic configured to independently control each flow control device to regulate fluid flow through the respective circuit group based on a superheat at each circuit group and a superheat at the common header.

According to one aspect of the invention, the system includes a first plurality of temperature sensors, each temperature sensor of the first plurality of temperature sensors arranged to measure a low-side temperature of a respective circuit group.

According to one aspect of the invention, the system includes a pressure sensor arranged to measure a low-side pressure of a respective circuit group.

According to one aspect of the invention, the controller is communicatively coupled to the first plurality of temperature sensors and the pressure sensor to receive low-side temperature measurements and low-side pressure measurements therefrom, and the logic configured to independently control each flow control device based on a superheat at each circuit group and a superheat at the common suction line includes logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group.

According to one aspect of the invention, the logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group includes logic configured to: determine a saturation temperature corresponding to the low-side pressure for each circuit group; and calculate a superheat at each circuit group based on the measured low-side temperature for the respective circuit group and the saturation temperature for the respective circuit group.

According to one aspect of the invention, the logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group includes logic configured to command a flow control device for a respective circuit group to reduce fluid flow through the respective circuit group when the superheat at the respective group is less than a first prescribed value.

According to one aspect of the invention, the logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group includes logic configured to command a flow control device for the respective circuit group to increase fluid flow through the respective circuit group when the superheat at the respective group is greater than a second prescribed value.

According to one aspect of the invention, the system includes a second temperature sensor arranged to measure a temperature within the header.

According to one aspect of the invention, the pressure sensor is arranged to measure a pressure within the header.

According to one aspect of the invention, the controller is communicatively coupled to the second temperature sensor and the pressure sensor to receive a temperature measurement and a pressure measurement therefrom, and the logic configured to independently control each flow control device includes logic configured to control each flow control device based on the measured header temperature and measured header pressure.

According to one aspect of the invention, the logic configured to control each flow control device based on the measured header temperature and measured header pressure includes logic configured to: determine a saturation temperature corresponding to the measured header pressure; and calculate a superheat at the header based on the measured header temperature and the saturation temperature corresponding to the measured header pressure.

According to one aspect of the invention, the logic configured to control each flow control device based on the measured header temperature and measured header pressure includes logic configured to override control based on superheat at each circuit group when the superheat at the header is less than a third prescribed value.

According to one aspect of the invention, the logic configured to override control based on superheat at each circuit group includes logic configured to command at least one flow control device to reduce fluid flow through the respective circuit group when the superheat at the header is less than the third prescribed value.

According to one aspect of the invention, a method for providing variable capacity to a heat exchanger having a plurality of independent circuits is provided. The method includes: arranging the plurality of circuits into circuit groups, each circuit group including at least one circuit of the plurality of circuits; and independently controlling fluid flow through each circuit group based on a superheat at each circuit group and a superheat at a common header in fluid communication with a low-side of each circuit group.

According to one aspect of the invention, independently controlling fluid flow though each circuit group includes independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group.

According to one aspect of the invention, independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group includes: determining a saturation temperature corresponding to the low-side pressure for each circuit group; and calculating a superheat at each circuit group based on the measured low-side temperature for the respective circuit group and the saturation temperature for the respective circuit group.

According to one aspect of the invention, independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group includes reducing fluid flow through the respective circuit group when the superheat at the respective group is less than a first prescribed value.

According to one aspect of the invention, independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group includes increasing fluid flow through the respective circuit group when the superheat at the respective group is greater than a second prescribed value.

According to one aspect of the invention, independently controlling fluid flow through each circuit group includes controlling fluid flow based on a measured header temperature and a measured header pressure.

According to one aspect of the invention, controlling fluid flow based on a measured header temperature and a measured header pressure includes: determining a saturation temperature corresponding to the measured header pressure; and calculating a superheat at the header based on the measured header temperature and the saturation temperature corresponding to the measured header pressure.

According to one aspect of the invention, controlling fluid flow based on a measured header temperature and a measured header pressure includes overriding control based on superheat at each circuit group when the superheat at the header is less than a third prescribed value.

According to one aspect of the invention, overriding control based on superheat at each circuit group includes reducing fluid flow through at least one circuit group when the superheat at the header is less than the third prescribed value.

According to one aspect of the invention, a variable capacity evaporator includes: a plurality of independent circuits arranged in circuit groups, each circuit group including at least one circuit; a plurality of sub-headers in fluid communication with respective ones of the plurality of circuit groups; a first plurality of temperature sensors, each temperature sensor of the first plurality of temperature sensors arranged to measure a temperature within a respective circuit; a common header in fluid communication with the plurality of sub-headers; and a second temperature sensor arranged to measure a temperature within the header.

According to one aspect of the invention, the evaporator includes a pressure sensor arranged to measure a pressure within the header.

According to one aspect of the invention, the evaporator includes a plurality of flow control devices, each flow control device of the plurality of flow control devices in fluid communication with a respective circuit group and operative to vary a fluid flow through the respective circuit group.

The foregoing and other features of the invention are hereinafter described in greater detail with reference to the accompanying drawings.

Brief Description of the Drawings

Fig. 1 is a schematic view of a typical air conditioning system. The evaporator is shown using a single refrigerant distributor and refrigerant flow is controlled by the electric expansion valve feeding the distributor. The controller sends signals to the electric expansion valve based on the superheat measurement calculated from the pressure and temperature readings on the common suction line after the evaporator header

Fig 2 is a schematic view of an air conditioning system including an exemplary variable capacity evaporator assembly according to the disclosure. Each electric expansion valve can be controlled independently. The control can be in response to a number of inputs, for example, the individual circuit superheat from each circuit group, the common suction superheat, or a combination of both.

Fig. 3 is a schematic illustration of a variable capacity evaporator assembly in accordance with the present disclosure.

Fig. 4 illustrates temperature and pressure sensor placement in both the individual circuits as well as at the common header in accordance with the present disclosure.

Fig. 5 is a top view of the variable capacity evaporator assembly of Fig. 3 illustrating the multi-circuit evaporator and multiple flow control devices.

Fig. 6 is a flow chart illustrating exemplary steps for operating the variable capacity heat exchanger assembly in accordance with the present disclosure.

Detailed Description

The inventive aspects in accordance with the present disclosure will be described in the context of an air conditioning system. It should be appreciated, however, that aspects of the present disclosure are not limited to an air conditioning system, but also can be applied to any HVACR application.

The present disclosure provides a system and method for providing a variable capacity evaporator. As will be described in more detail below, a heat exchanger system includes an evaporator having a plurality of individual circuits arranged in groups, and a plurality of flow control devices. Respective ones of the plurality of flow control devices are in fluid communication with respective ones of the groups of circuits. A controller is operatively coupled to the flow control devices, the controller configured to control the flow control devices to regulate the flow of refrigerant through the respective groups of circuits. In this manner, portions of the evaporator can be disabled and/or the flow through portions of the evaporator can be reduced, thereby closely matching the overall load on the evaporator and maintaining refrigerant velocity in the active circuits of the evaporator.

Each flow control device of the system can be controlled independently, and control can be in response to a number of inputs. For example, control of the flow control devices can be in response to the individual circuit superheat from each circuit group, the common suction superheat for all circuit groups, or a combination of both. In this manner, the flow through each circuit group can be varied from a completely off state (i.e., no fluid flow) to a completely on state (i.e., full fluid flow), and all variations there between. For example, the flow control devices can be independently controlled to shut off one third or two thirds of the heat exchanger coil, which can improve part load coil performance.

Improvement in system performance is at least in part due to maintaining the refrigerant velocity above a prescribed value, which promotes accurate superheat control even at extremely low loads. Conventional technology feeds all circuits at all times, even during periods of low loads. In such instances, refrigerant flow velocities drop and circuits can log with oil and refrigerant, resulting in a drop in heat transfer performance. As a result, superheat control becomes erratic due to slugs of liquid refrigerant entering the common suction header, which leads to instabilities in flow control. The variable capacity evaporator system in accordance with the present disclosure enables the total capacity of the coil to be closely matched to the load. As a result, accurate temperature and humidity control can be maintained over a wide operating range.

Some of the benefits of the variable capacity evaporator system over existing technology include: (1) the ability to independently control refrigerant flow into predetermined sections of an evaporator coil; (2) maintaining refrigerant velocities in the active circuits of the evaporator coil even at extremely low load conditions; (3) preventing or reducing logging circuits with excess refrigerant and oil (4) improving superheat control by reducing slugging that can cause erratic superheat readings by the temperature sensors; (5) the ability to close off predetermined sections of a evaporator coil to defrost that section while still in cooling mode thereby saving energy; and (6) superheat remains steady even at extremely low loads and prevent liquid slugging thereby protecting the refrigerant compressor from damage.

Referring now to the drawings, and initially to Fig. 2, an air conditioning system 30 according to the present invention is schematically shown. The air conditioning system 30 can be used to control the temperature of a certain medium (*e.g.,* air inside a building) and generally comprises an evaporator 12, a condenser 14, and a compressor 16. The evaporator 12 includes a plurality of independent circuits through which a refrigerant may flow. A plurality of lines 18 *(e.g.*, pipes, tubes, ducts) connect these components so that refrigerant fluid can cycle there through. The evaporator 12 can be located within the medium (*i.e.,* it can be located inside the building) and the compressor can be located remote from the medium (*i.e.,* it can be located outside of the building).

In accordance with the present disclosure, the air conditioning system 30 includes a plurality of flow control devices 32 (expansion-distribution assemblies 32) located adjacent to the end of the evaporator 12 that act at its inlet when fluid travels in the first (*i.e.*, forward and/or cooling) direction, each of the first plurality of flow control devices in fluid communication with a respective group of circuits of the evaporator 12. An exemplary flow control device that may be used in the system in accordance with the present disclosure is described in U.S. Application No. 12/817,972 filed on June 17, 2010, the contents of which is hereby incorporated by reference in its entirety.

As described in more detail below, a controller 34 is operatively coupled to the plurality of expansion-distribution assemblies 32, the controller 34 configured to independently control the flow of fluid through the respective groups of circuits in the evaporator 12. More specifically, the controller 34 controls each expansion-distribution assembly 32 based on a superheat for each circuit group A, B, C of the evaporator 12, wherein the superheat for each circuit group is based on a pressure measurement obtained from a common pressure sensor (located a common suction line) and a temperature measurement obtained from a sensor corresponding to the respective group. Further, a control override function is implemented based on the overall superheat for the combined evaporator circuits (i.e., the superheat at the common suction line), the overall superheat derived from the pressure measurement at the common suction line and a temperature measurement obtained from temperature sensor at the common suction line.

Referring now to Fig. 3, an exemplary embodiment of a variable capacity evaporator system 200 in accordance with aspects of the present disclosure is shown. The variable capacity evaporator system includes an evaporator 12 having plurality of independent circuits 202. Each circuit 202, which includes a respective inlet and outlet at the evaporator, forms an independent flow path for a fluid (e.g., a refrigerant) passing through the evaporator 12.

The individual circuits 202 may be formed as groups, where each group includes at least one circuit 202 and preferably a plurality of circuits 202. In the example shown in Fig. 3, three groups of circuits 202 are formed (group A, Group B and Group C), each group having six circuits 202. The system 200 also includes a plurality of flow control devices 32 (e.g., expansion-distribution assembly 32), each flow control device 32 in fluid communication with a circuit inlet within a common group. In the exemplary embodiment, each flow control device 32 includes six circuits and, thus, the three flow control device 32 can feed an eighteen circuit heat exchanger coil. It is noted, however, that the number of flow control devices 32 and the number of individual circuits 204 can vary by application, and each group need not have the same number of circuits. Additionally, while the preferred embodiment utilizes flow control device 32 in the form of the expansion-distribution assembly 32, other types of flow control devices may be used without departing from the scope of the invention. For example, instead of using the expansion-distribution assembly 32, multiple electronic expansion valves can be paired with standard refrigerant distributors. A fluid inlet 204 is in fluid communication with the flow control devices 30 for providing refrigerant thereto, and a common header 206 is in fluid communication with each circuit 202, for example, via sub-headers 204 for receiving fluid exiting the circuits 202.

With additional reference to Figs. 4 and 5, the system 200 further includes a first plurality of temperature sensors 208. More specifically, each circuit group has associated therewith a first temperature sensor 208 used to calculate superheats for group A, B and C. The low-side inlets or outlets of each circuit 202 within a group, for example, may be combined in a respective sub-header 212. As used herein, the term sub-header refers to a common manifold that receives and is in fluid communication with the circuits of a common circuit group. A first temperature sensor 208 then may be operatively coupled to a respective sub-header 212 so as to obtain temperature measurements for the low-side of each group A, B and C. Further, the sub-headers 212 for each circuit group A, B and C may be combined in the common header 206. As used herein, the term header refers to a manifold that receives and is in fluid communication with the sub-headers. A second temperature sensor 214 and a pressure sensor 216 can be arranged at the common header 206 to measure the low-side (suction) temperature and pressure for the entire evaporator 12.

The first temperature sensors 208 for each group A, B and C (and/or for each circuit 202), the second temperature sensor 214 and the pressure sensor 216 for the common header 206, and the flow control devices 32 are each communicatively coupled to the controller 34. As will be described in more detail below, the controller 34 utilizes the data provided by the temperature and pressure sensors, and generates a control signal that independently controls each flow control device 32 so as to regulate fluid flow through the respective circuit groups A, B and C.

By adjusting the flow rate of each flow control device 32, fluid flow through the each circuit group A, B and C can be controlled independent of fluid flow through the other circuit groups. The specific configuration (grouping) of the circuits with respect to each flow control device is flexible and allows a variety of different configurations to provide the desired performance by the designer.

The variable capacity evaporator system 200 can provide cooling control over an extremely wide operating range and has the ability to accurately control temperature and humidity when using appropriate control logic. Moreover, the variable capacity evaporator system 200 enables portions of the evaporator coil to defrost while the other portions of the evaporator coil remains in cooling mode, thereby saving energy.

With additional reference to Fig. 6, illustrated are logical operations to implement an exemplary method of controlling flow through an evaporator 12 to provide variable capacity evaporator system in accordance with the present disclosure. Although Fig. 6 shows a specific order of executing functional logic blocks, the order of executing the blocks may be changed relative to the order shown. Also, two or more blocks shown in succession may be executed concurrently or with partial concurrence. Certain blocks also may be omitted. In addition, any number of functions, logical operations, commands, state variables, semaphores or messages may be added to the logical flow for purposes of enhanced utility, accounting, performance, measurement, troubleshooting, and the like. It is understood that all such variations are within the scope of the present invention.

Beginning at block 302, the pressure at the header 210 is obtained, for example, using the pressure sensor 216. As noted above, the header 206 is the common suction line (low-side) for all circuits 202 of the evaporator 12. Thus, the pressure measured by the pressure sensor 216 effectively is the average pressure within the evaporator 12. Next at block 304 the saturation temperature at the header 206 is obtained based on the measured header pressure. For example, using the measured pressure at the header 206, a temperature/pressure chart is accessed to convert the pressure measurement to header saturation temperature. Such temperature/pressure chart may be stored in memory of the controller 34 as a database, for example. Alternatively, the temperature/pressure chart may be stored remotely and accessible by the controller 34, for example, via a network or internet connection. At block 306 the temperature at the header 206 is measured using temperature sensor 214, and at block 308 the superheat for the header 206 is calculated by taking the difference between the temperature measured at the header 206 and the determined saturation temperature.

At block 312, the superheat at the header 206 is compared to an override value. The override value corresponds to a minimum superheat at the header 206. If the superheat at the header 206 is less than the override value, then control based on superheat at each individual sub-header 212 is overridden and control of all flow control valves 30 is based simply on the superheat at the header 206. The specific value for the override value may be application specific. Preferably, the override value is between 5 degrees and 8 degrees Fahrenheit. If the superheat at the header 206 is not less than the override value, then the method moves to block 314 a counter N is initialized.

The counter N represents the particular circuit group for the variable capacity evaporator system 200. Thus, if the system 200 has three circuit groups, a value of 1 can correspond to a first circuit group (group A), a value of 2 can correspond to a second circuit group (group B) and a value of 3 can correspond to a third circuit group (Group C). Next at block 316 the low-side pressure for circuit group N is obtained via measurement by pressure sensor 216 located at the header 206 (or from a pressure sensor for a specific circuit of the circuit group – not shown), and at block 318 the saturation temperature at the sub-header 212 for circuit group N is determined based on the temperature/pressure chart described above. Next at block 320 the temperature at the sub-header for group N is measured using the temperature sensor 208 corresponding to circuit group N (or from a temperature sensor for a specific circuit of the circuit group), and at block 322 the superheat at the sub-header 212 for circuit group N is determined by taking the difference between the measured temperature and the saturation temperature for group N.

At block 324 the superheat at the sub-header 212 for circuit group N is compared to a superheat setpoint. The superheat setpoint may be application specific. Preferably, the superheat setpoint is between 8 degrees and 10 degrees Fahrenheit. If the calculated superheat at the sub-header 212 for circuit group N is less than the superheat setpoint, then at block 328 the flow control device 32 corresponding to circuit group N is commanded to reduce the flow through the circuit group, thereby tending to cause the superheat for the circuit group to rise. However, if the calculated superheat at the sub-header 212 for circuit group N is greater than the superheat setpoint, then at block 330 the flow control device 32 corresponding to circuit group N is commanded to increase the flow through the circuit group, thereby tending to cause the superheat for the circuit group to decrease.

The particular amount in which the flow control device 32 is commanded to increase or decrease flow through the respective circuit group is application specific, and may be based on environmental parameters (e.g., temperature, humidity, etc.), the size of the space that is being conditioned by the system 200, the capacity of the system 200, etc. Each flow control device 32 is controlled by a respective controller, which may include a proportional controller (P), a proportional plus integral controller (PI) or a proportional plus integral plus derivative controller (PID). Further, while not specifically shown in Fig. 6 it will be appreciated that if the calculated superheat for circuit group N is equal to the superheat setpoint then flow is maintained at its last state (i.e., the flow is not increased or decreased).

Once the flow has been increased, decreased or maintained, at block 332 the counter N is incremented and at block 334 the counter N is compared to a maximum value to determine if all circuit groups have been processed. In the exemplary system shown in Fig. 2, there are three circuit groups and thus the process is repeated three times (i.e., once for each circuit group). If all circuit groups have not been processed, then the method moves back to block 316 and blocks 316-334 are repeated. If all circuit groups have been processed the method moves back to block 302 and the entire process repeats.

Moving back to block 312, if the superheat at the header 206 is less than the override value, the method bypasses blocks 312-334 and instead executes blocks 336-344. More specifically, at block 336 the counter N is initialized (e.g., set to a value of 1), and then at block 338 it is determined if the flow control device 32 corresponding to circuit group N is at a minimum flow rate (e.g., has the flow control device 32 been commanded to inhibit or otherwise minimize flow through circuit group N?). If the flow control device corresponding to circuit group N is not at a minimum flow rate, then at block 340 the flow control device corresponding to circuit group N is commanded to reduce flow through the respective circuit group. Like above, the particular amount in which the flow is reduced is application specific. Once the flow has been reduced, the method moves back to block 302 and the process repeats.

Moving back to block 338, if the flow control device corresponding to circuit group N is at a minimum flow rate, then at block 342 the counter N is incremented (thus reflecting the next circuit group), and at block 344 a check is performed to determine if all circuit groups have been processed. If all circuit groups have not been process then the method moves back to block 338 and the flow for the next circuit group is analyzed. However, if all circuit groups have been processed then the method moves back to block 302 and the process repeats.

The variable capacity evaporator system in accordance with the present disclosure provides improved efficiency relative to conventional systems. Further, since individual circuits within the evaporator can be shut down, defrost operations can be carried out without interrupting operation of the heating/cooling system.

Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

Claims

What is claimed is:

1. A variable capacity evaporator system, comprising:

an evaporator including a plurality of independent circuits assembled as a unit, each circuit arranged in circuit groups and defining a fluid flow path, each circuit group including at least one circuit;

a plurality of flow control devices, each flow control device of the plurality of flow control devices in fluid communication with a respective circuit group and operative to vary a fluid flow through the respective circuit group;

a common header in fluid communication with a low-side each of the plurality of circuit groups; and

a controller operatively coupled to each flow control device, the controller including logic configured to independently control each flow control device to regulate fluid flow through the respective circuit group based on a superheat at each circuit group and a superheat at the common header.

2. The system according to claim 1, further comprising a first plurality of temperature sensors, each temperature sensor of the first plurality of temperature sensors arranged to measure a low-side temperature of a respective circuit group.

3. The system according to any one of claims 1-2, further comprising a pressure sensor arranged to measure a low-side pressure of a respective circuit group.

4. The system according to claim 3, wherein the controller is communicatively coupled to the first plurality of temperature sensors and the pressure sensor to receive low-side temperature measurements and low-side pressure measurements therefrom, and the logic configured to independently control each flow control device based on a superheat at each circuit group and a superheat at the common suction line includes logic configured to control each flow control device based on the measured low-side temperature for the

respective circuit group and measured low-side pressure for the respective circuit group.

5. The system according to claim 4, wherein the logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group includes logic configured to:

determine a saturation temperature corresponding to the low-side pressure for each circuit group; and

calculate a superheat at each circuit group based on the measured low-side temperature for the respective circuit group and the saturation temperature for the respective circuit group.

6. The system according to claim 5, wherein the logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group includes logic configured to command a flow control device for a respective circuit group to reduce fluid flow through the respective circuit group when the superheat at the respective group is less than a first prescribed value.

7. The system according to any one of claims 5-6, wherein the logic configured to control each flow control device based on the measured low-side temperature for the respective circuit group and measured low-side pressure for the respective circuit group includes logic configured to command a flow control device for the respective circuit group to increase fluid flow through the respective circuit group when the superheat at the respective group is greater than a second prescribed value.

8. The system according to any one of claims 1-8, further comprising a second temperature sensor arranged to measure a temperature within the header.

9. The system according to claim 8, wherein the pressure sensor is arranged to measure a pressure within the header.

10. The system according to claim 9, wherein the controller is communicatively coupled to the second temperature sensor and the pressure sensor to receive a temperature measurement and a pressure measurement therefrom, and the logic configured to independently control each flow control device includes logic configured to control each flow control device based on the measured header temperature and measured header pressure.

11. The system according to claim 10, wherein the logic configured to control each flow control device based on the measured header temperature and measured header pressure includes logic configured to:

determine a saturation temperature corresponding to the measured header pressure; and

calculate a superheat at the header based on the measured header temperature and the saturation temperature corresponding to the measured header pressure.

12. The system according to claim 11, wherein the logic configured to control each flow control device based on the measured header temperature and measured header pressure includes logic configured to override control based on superheat at each circuit group when the superheat at the header is less than a third prescribed value.

13. The system according to claim 12, wherein the logic configured to override control based on superheat at each circuit group includes logic configured to command at least one flow control device to reduce fluid flow through the respective circuit group when the superheat at the header is less than the third prescribed value.

14. A method for providing variable capacity to a heat exchanger having a plurality of independent circuits, the method comprising:

arranging the plurality of circuits into circuit groups, each circuit group including at least one circuit of the plurality of circuits; and

independently controlling fluid flow through each circuit group based on a superheat at each circuit group and a superheat at a common header in fluid communication with a low-side of each circuit group.

15. The method according to claim 14, wherein independently controlling fluid flow though each circuit group comprises independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group.

16. The method according to claim 15, wherein independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group comprises:

determining a saturation temperature corresponding to the low-side pressure for each circuit group; and

calculating a superheat at each circuit group based on the measured low-side temperature for the respective circuit group and the saturation temperature for the respective circuit group.

17. The method according to any one of claims 15-16, wherein independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group comprises reducing fluid flow through the respective circuit group when the superheat at the respective group is less than a first prescribed value.

18. The method according to any one of claims 15-17, wherein independently controlling fluid flow based on a measured low-side temperature for the respective circuit group and a measured low-side pressure for the respective circuit group comprises increasing fluid flow through the respective circuit group when the superheat at the respective group is greater than a second prescribed value.

19. The method according to any one of claims 14-18, wherein independently controlling fluid flow through each circuit group includes controlling fluid flow based on a measured header temperature and a measured header pressure.

20. The method according to claim 19, wherein controlling fluid flow based on a measured header temperature and a measured header pressure comprises:

determining a saturation temperature corresponding to the measured header pressure; and

calculating a superheat at the header based on the measured header temperature and the saturation temperature corresponding to the measured header pressure.

21. The method according to claim 20, wherein controlling fluid flow based on a measured header temperature and a measured header pressure comprises overriding control based on superheat at each circuit group when the superheat at the header is less than a third prescribed value.

22. The method according to claim 21, wherein overriding control based on superheat at each circuit group comprises reducing fluid flow through at least one circuit group when the superheat at the header is less than the third prescribed value.

23. A variable capacity evaporator, comprising:

a plurality of independent circuits arranged in circuit groups, each circuit group including at least one circuit;

a plurality of sub-headers in fluid communication with respective ones of the plurality of circuit groups;

a first plurality of temperature sensors, each temperature sensor of the first plurality of temperature sensors arranged to measure a temperature within a respective circuit;

a common header in fluid communication with the plurality of sub-headers; and

a second temperature sensor arranged to measure a temperature within the header.

24. The variable capacity evaporator according to claim 23, further comprising a pressure sensor arranged to measure a pressure within the header.

25. The variable capacity evaporator according to any one of claims 23-24, further comprising a plurality of flow control devices, each flow control device of the plurality of flow control devices in fluid communication with a respective circuit group and operative to vary a fluid flow through the respective circuit group.

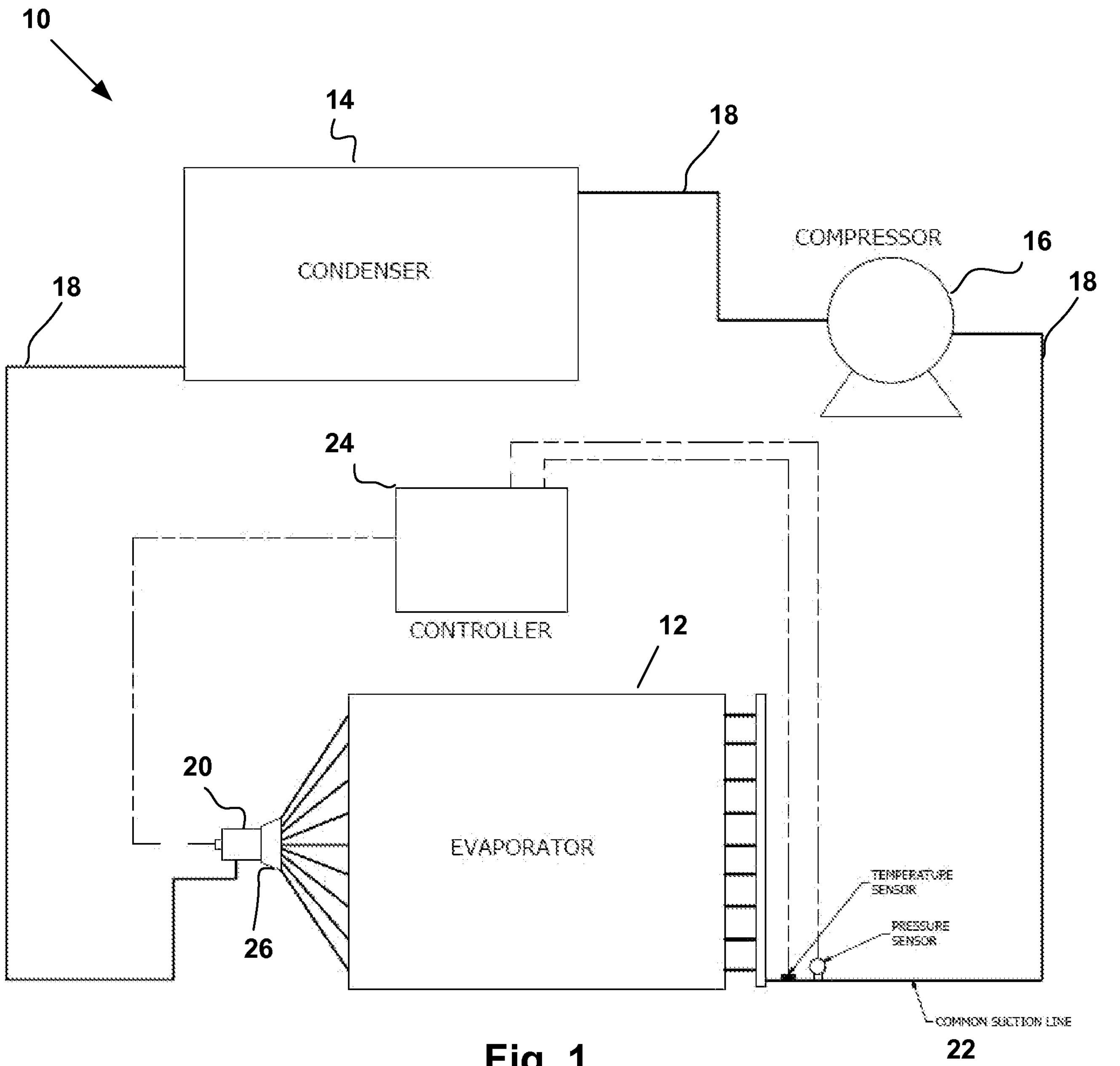
10
14
18
CONDENSER
COMPRESSOR
16
18
18
24
CONTROLLER
12
20
EVAPORATOR
TEMPERATURE SENSOR
PRESSURE SENSOR
26
COMMON SUCTION LINE
22

Fig. 1

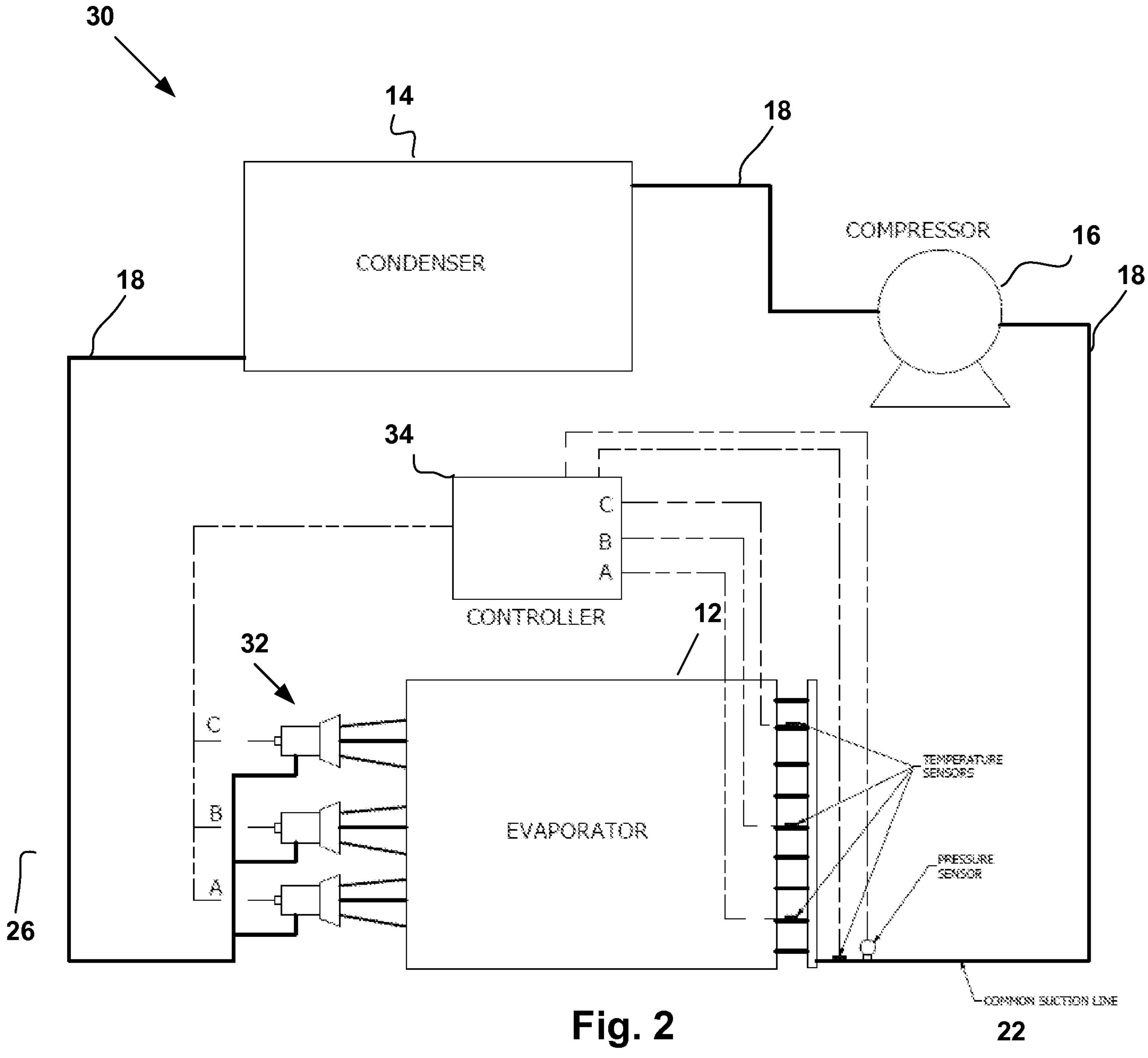
30
14
18
CONDENSER
COMPRESSOR
16
18
18
34
C
B
A
CONTROLLER
12
32
C
B
A
EVAPORATOR
TEMPERATURE SENSORS
PRESSURE SENSOR
26
COMMON SUCTION LINE
22

Fig. 2

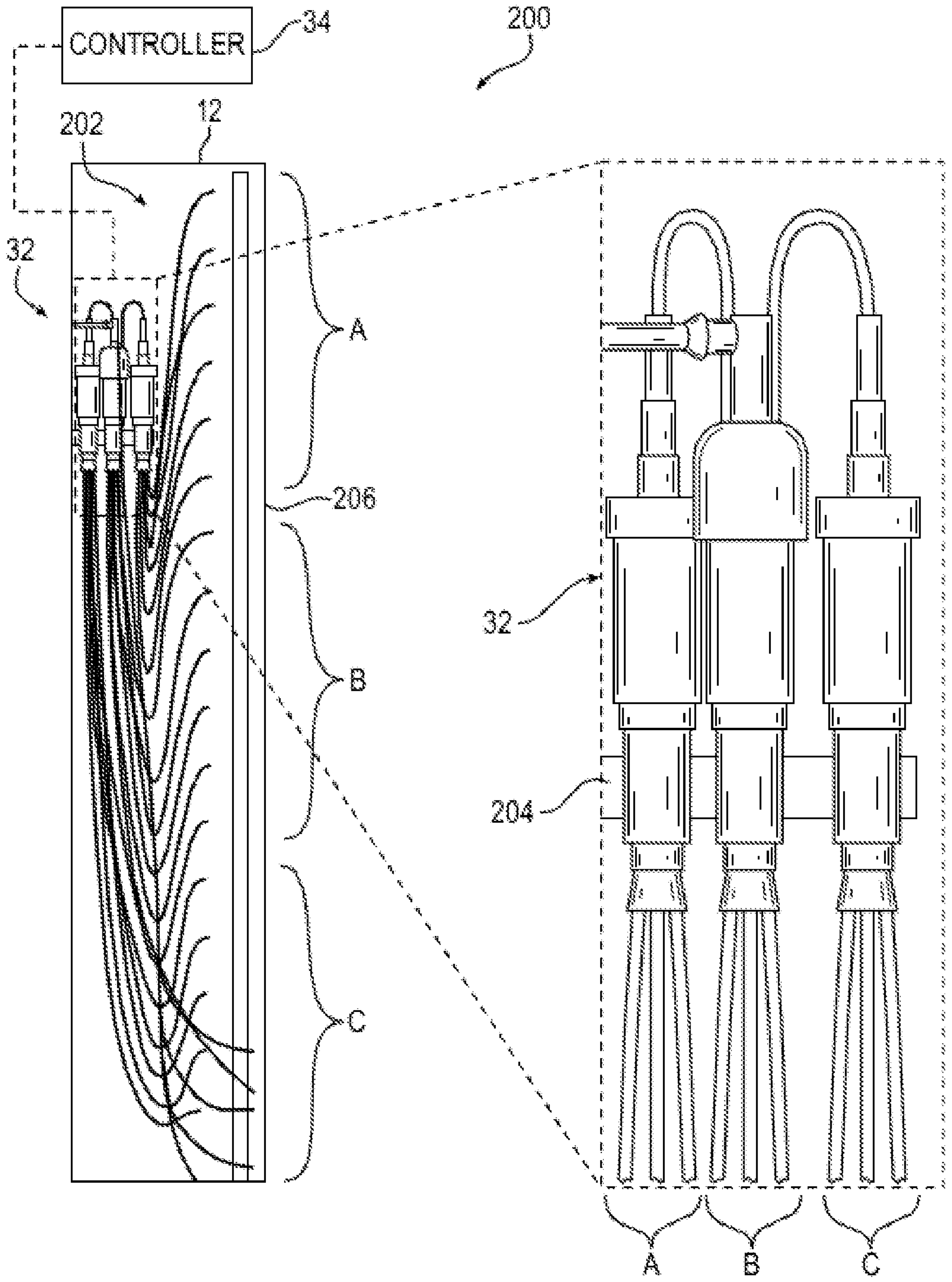

FIG. 3

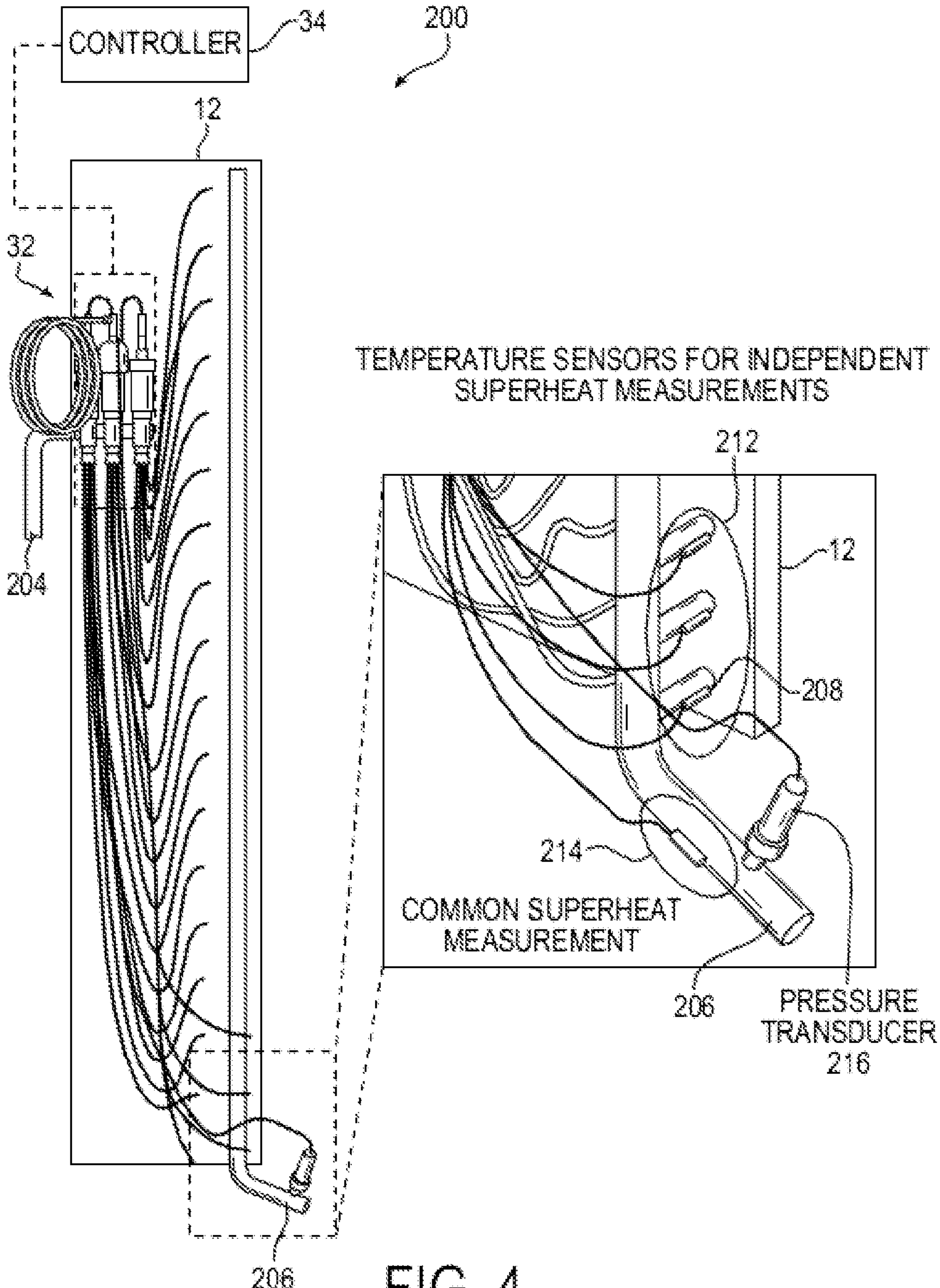
CONTROLLER
34
200
12
32
204
206
TEMPERATURE SENSORS FOR INDEPENDENT SUPERHEAT MEASUREMENTS
212
12
208
214
COMMON SUPERHEAT MEASUREMENT
206
PRESSURE TRANSDUCER 216

FIG. 4

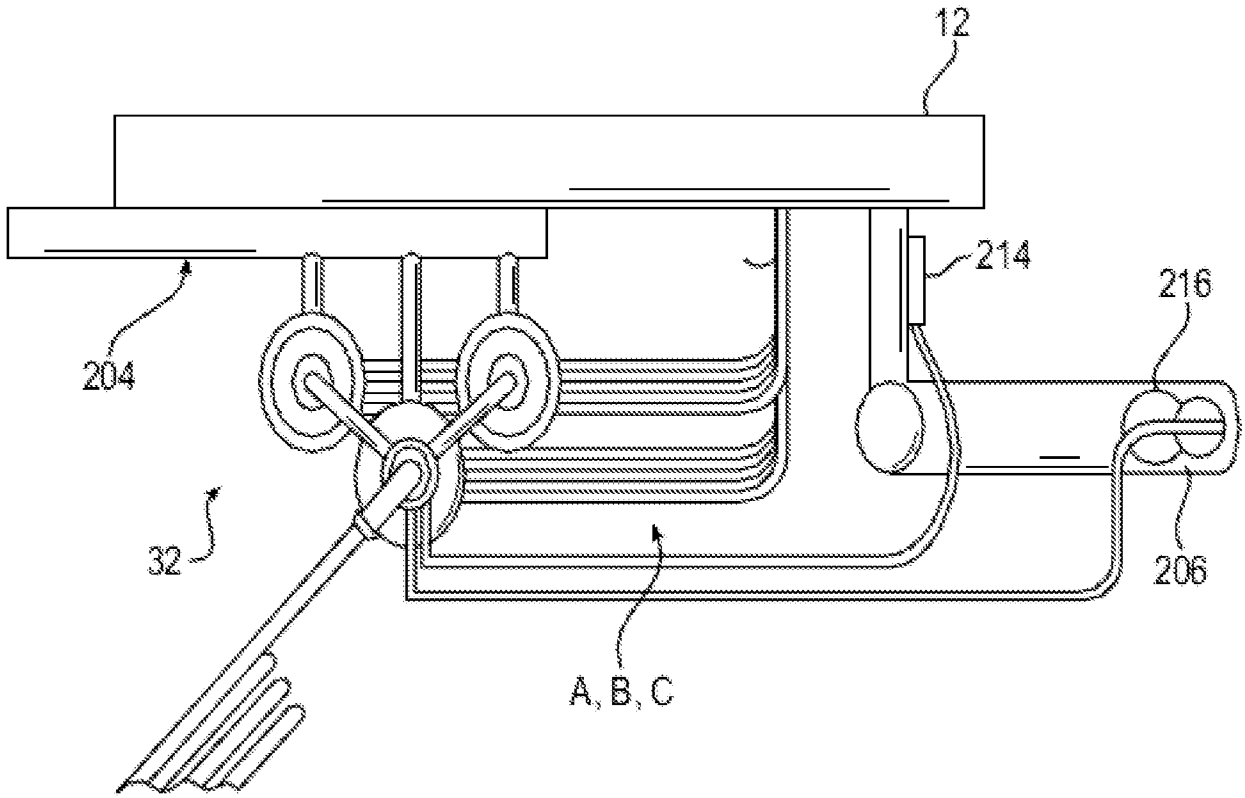

FIG. 5

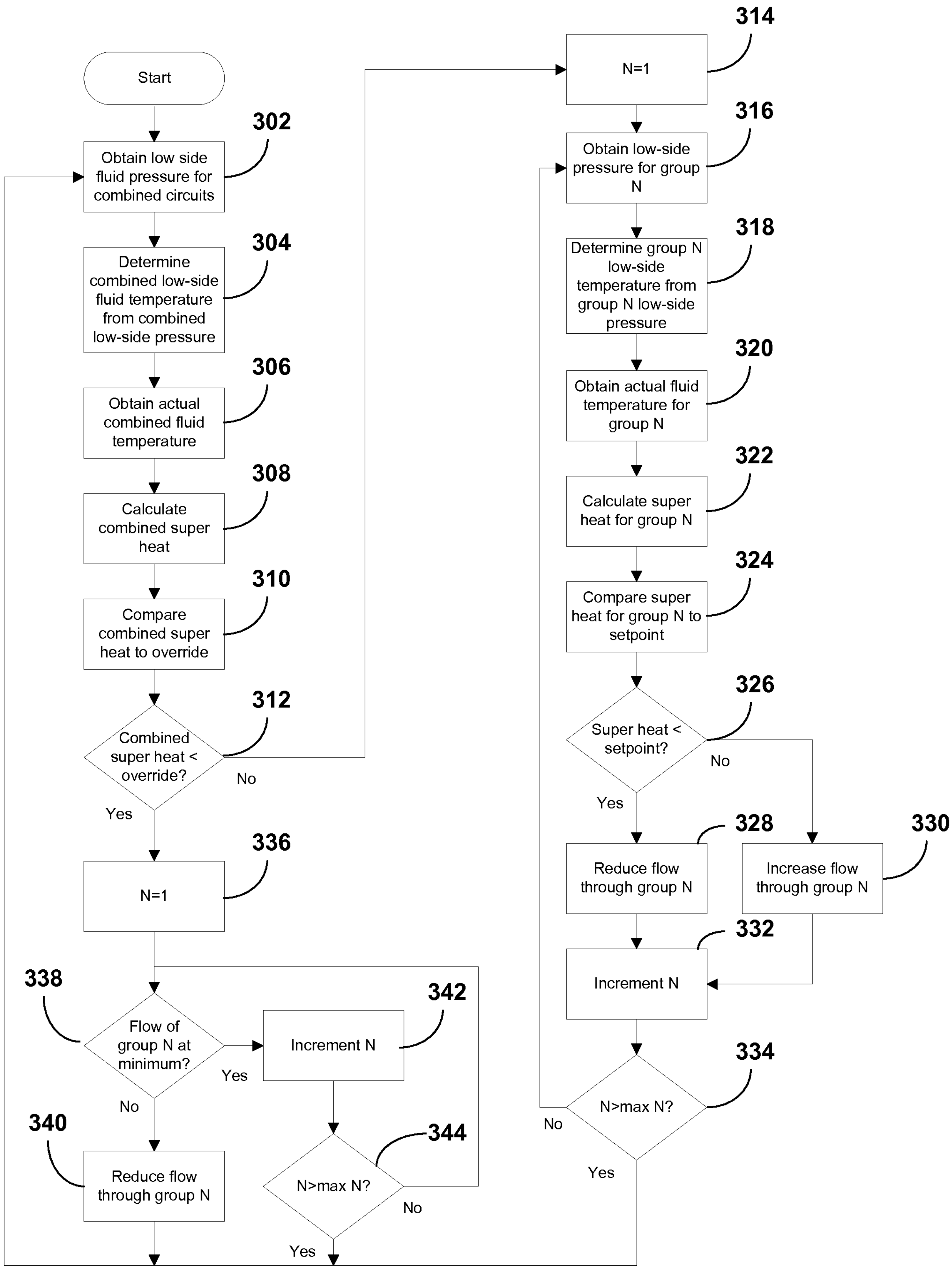
Start
302
Obtain low side fluid pressure for combined circuits
304
Determine combined low-side fluid temperature from combined low-side pressure
306
Obtain actual combined fluid temperature
308
Calculate combined super heat
310
Compare combined super heat to override
312
Combined super heat < override?
No
Yes
336
N=1
338
Flow of group N at minimum?
Yes
No
342
Increment N
344
N>max N?
No
Yes
340
Reduce flow through group N
314
N=1
316
Obtain low-side pressure for group N
318
Determine group N low-side temperature from group N low-side pressure
320
Obtain actual fluid temperature for group N
322
Calculate super heat for group N
324
Compare super heat for group N to setpoint
326
Super heat < setpoint?
No
Yes
328
Reduce flow through group N
330
Increase flow through group N
332
Increment N
334
N>max N?
No
Yes

Fig. 6