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(54) Heat sink for a condensing unit and method of using same

(57) A condensing unit control module may be cooled using multiple methods of cooling. A first method of cooling can be used to cool the control module when a minimal or reduced amount of cooling is needed, and a second method of cooling can be used when the control module requires a larger or maximum amount of cooling. The first method of cooling may include the use of air cooling. The second method of cooling can be through working fluid cooling. The second cooling method can supplement the first cooling method as the cooling needs of the control module increase. The second cooling method can be activated based upon a temperature of a heat sink, a temperature of one or more components of the control module, operating conditions of a heat pump system, ambient conditions, and/or a temperature of the working fluid flowing throughout the heat pump system.

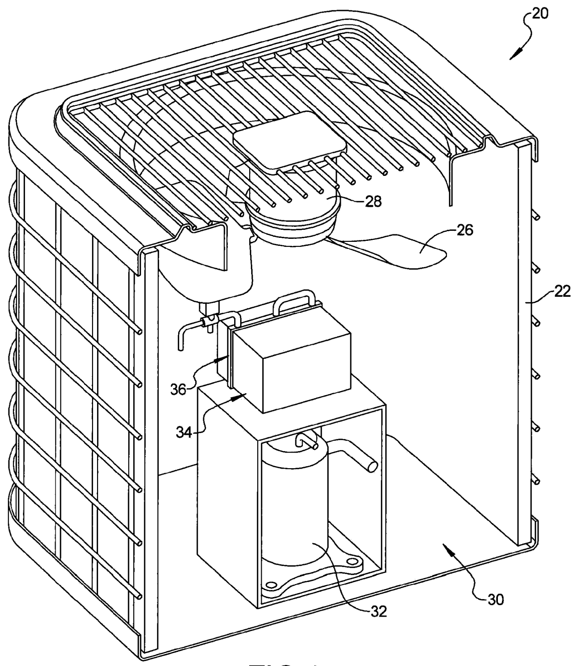

FIG 1

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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/618,244, filed on March 30, 2012. The entire disclosure of the above application is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to heating and air-conditioning systems and, more particularly, to cooling electrical components that drive the operation of the compressor.

BACKGROUND

[0003] This section provides background information related to the present disclosure and is not necessarily prior art.

[0004] Control modules, such as electronic devices, used in heating and air-conditioning systems often require a reliable means to cool their components. One such control module is a drive unit used with a variable-speed compressor.

[0005] The control module may be required to be cooled to within a specific temperature range or be maintained below a predetermined temperature to ensure adequate component life, performance, and reliability. The cooling needs of the control module can vary based on the operating condition of the heating and air-conditioning system. In situations where the cooling needs are not met, the temperature of the control module may reach a maximum operating temperature, which may trigger a sensor that shuts down the system operation, causing a nuisance trip in the drive.

SUMMARY

[0006] This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

[0007] In one form, the present disclosure provides a condensing unit that houses a compressor, a control module and a heat sink. The control module may control operation of the compressor. The heat sink may be in heat-transferring relation with the control module. The control module may be in heat-transferring relation with a first fluid and a second fluid. The first fluid may selectively flow through a fluid passageway in the heat sink. The second fluid may be a different substance than the first fluid and may be in selective convective heat-transferring relation with a heat-transferring member in heat-transferring relation with the heat sink.

[0008] In another form, the present disclosure provides a system that may include a compressor, a heat sink, a fluid conduit, at least one external heat-transferring member, and a control module. The heat sink may include a flow path therethrough. The fluid conduit may communicate with the heat sink flow path. The at least one external heat-transferring member may be in heat-transferring relation with the heat sink. The control module may be in heat-transferring relation with the heat sink. The control module may control operation of the compressor. The heat sink may transfer heat from the control module to a fluid flowing over the heat-transferring member and to a fluid flowing through the flow path.

[0009] In another form, the present disclosure provides a method of cooling a compressor control module. The method may include removing heat from the control module with a first cooling method that transfers heat to a first fluid. The method may also include selectively supplementing the first cooling method by removing heat from the control module with a second cooling method that transfers heat to a second fluid different than the first fluid while simultaneously removing heat with the first cooling method.

[0010] In another form, the present disclosure provides a method of cooling a compressor control module that may include inducing an airflow across a heat sink in heat-transferring relation to the control module. The method may also include transferring heat from the control module to the airflow through the heat sink. A working fluid may be selectively routed through a flow path in the heat sink in heat-transferring relation to the control module. Heat from the control module may be transferred to the working fluid when the working fluid is flowing through the heat sink.

[0011] In another form, the present disclosure provides a control module that can be cooled using multiple methods of cooling. A first method of cooling can be used to cool the control module when a minimal or reduced amount of cooling is needed, and a second method of cooling can be used when the control module requires a larger or maximum amount of cooling. The use of multiple methods of cooling the control module can be referred to as hybrid cooling. The first method of cooling the control module can be through the use of air cooling. The second method of cooling the control module can be through working fluid cooling. The air cooling can be used to provide a first level of cooling and the working fluid cooling can be utilized when a greater degree of cooling is required. The second cooling method can supplement the first cooling method as the cooling needs of the control module increase. The second cooling method can be activated based upon a temperature of a heat sink, a temperature of one or more components of the control module, operating conditions of a heat pump system, ambient conditions, and/or a temperature of a working fluid flowing throughout the heat pump system, by way of non-limiting example.

[0012] The invention provides a condensing unit housing a compressor, a control module controlling operation of said compressor, and a heat sink in heat-transferring relation with said control module, said control module being in heat-transferring relation with a first fluid and a second fluid, said first fluid selectively flowing through a fluid passageway in said heat sink, said second fluid being a different substance than said first fluid and in selective convective heat-transferring relation with a heat-transferring member in heat-transferring relation with said heat sink.

[0013] Optionally, the condensing unit further comprises: a condenser at least partially defining a cavity; a fan operable to direct a flow of said second fluid through said condenser, and wherein said compressor, said control module, said heat- transferring member and said heat sink are disposed in said cavity.

[0014] Optionally, said fan operates independently of an operating condition of said condenser.

[0015] Optionally, the condensing unit further comprises: a cooling module operable to selectively route said first fluid discharged by said compressor through said flow path to remove heat from said control module.

[0016] Optionally said cooling module includes a valve disposed in said fluid conduit that selectively allows said fluid conduit to direct said first fluid discharged by said compressor into said fluid passageway.

[0017] Optionally, said valve is an expansion device.

[0018] Optionally, said cooling module includes a temperature sensing device and said cooling module selectively routes said first fluid discharged by said compressor through said fluid passageway based on an output of said temperature sensing device.

[0019] Optionally, said cooling module includes a temperature responsive valve operable to selectively allow said first fluid discharged by said compressor into said fluid passageway based on a temperature sensed by said temperature responsive valve.

[0020] Optionally, an entirety of a flow of said first fluid discharged by said compressor can flow through said fluid passageway.

[0021] Optionally, the condensing unit further comprises a first fan, said first fan inducing a flow of said second fluid across said heat- transferring member.

[0022] Optionally, the condensing unit further comprises a condenser at least partially defining a cavity; a second fan operable to direct a flow of said second fluid through said condenser, and wherein said compressor, said control module, said heat- transferring member and said heat sink are disposed in said cavity and said flow of said second fluid induced by said second fan passes across said heat- transferring member, and said first fan and said second fan can be operated independently of one another.

[0023] the invention provides a method of cooling a compressor control module comprising: removing heat from the control module with a first cooling method that transfers heat to a first fluid; and selectively supplementing said first cooling method by removing heat from the control module with a second cooling method that transfers heat to a second fluid different than said first fluid while simultaneously removing heat with said first cooling method.

[0024] Optionally, said first fluid is ambient air and said second fluid is working fluid discharged by the compressor.

[0025] Optionally, selectively supplementing said first cooling method includes removing heat with said second method based on a temperature, said temperature including at least one of an ambient air temperature, a temperature of the control module, a temperature of working fluid discharged by the compressor, and a temperature of a heat sink in heat- transferring relation to the control module.

[0026] Optionally, removing heat with said first cooling method includes inducing an airflow through a condenser and over a heat sink in heat- transferring relation with the control module.

[0027] Optionally, removing heat with said first cooling method includes inducing an airflow over a heat sink in heat- transferring relation with the control module, the induced airflow being independent of an operating condition of a condenser.

[0028] Optionally, removing heat from the control module with said second cooling method includes routing at least a portion of working fluid discharged from the compressor through a flow path in a heat sink in heat- transferring relation to the control module.

[0029] Optionally, selectively supplementing includes removing heat from the control module with said second cooling method when the compressor is operating in a predetermined range.

[0030] The invention provides a method of cooling a compressor control module comprising: inducing an airflow across a heat sink in heat-transferring relation to the control module; transferring heat from the control module to the airflow through said heat sink; selectively routing a working fluid through a flow path in said heat sink in heat-transferring relation to the control module; and transferring heat from the control module to said working fluid when said working fluid is flowing through said heat sink.

[0031] Optionally, selectively routing includes selectively routing a condensed working fluid through said flow path in said heat sink.

[0032] Optionally, selectively routing includes selectively routing an entirety of a flow of working fluid discharged by the compressor through said flow path in said heat sink.

[0033] Optionally, selectively routing includes selectively routing said working fluid through said flow path based on a temperature of said working fluid.

[0034] Optionally, inducing said airflow includes inducing said airflow during an entire time the compressor is operating.

[0035] Optionally, inducing said airflow includes inducing said airflow to flow through a condenser within which the compressor and control module are disposed.

[0036] Optionally, inducing said airflow includes inducing said airflow with a fan that operates independently from operation of a condenser.

[0037] Optionally, selectively routing said working fluid includes using an expansion valve to selectively route and expand said working fluid in said flow path.

[0038] Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present teachings.

DRAWINGS

[0039] The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present teachings in any way.

[0040] Figure 1 is a cut-away perspective view of a condensing unit having a compressor and control module therein that are cooled according to the present teachings;

[0041] Figure 2 is an enlarged perspective view of the compressor, the control module, and the cooling components of Figure 1;

[0042] Figure 3 is a perspective view of the control module with the cover removed;

[0043] Figure 4 is a schematic representation of a heating and air-conditioning system showing the working fluid cooling of the control module according to the present teachings;

[0044] Figures 5 and 6 are schematic representations of heating and air-conditioning systems including other working fluid cooling configurations according to the present teachings;

[0045] Figures 7 and 8 are schematic representations of a heating and air-conditioning system in the form of a heat pump shown in a cooling mode and a heating mode, respectively, and showing the working fluid cooling of the control module according to the present teachings;

[0046] Figure 9 is a graph illustrating a possible compressor-operating envelope and showing where the control module is air cooled and working fluid cooled according to the present teachings;

[0047] Figure 10 is a flowchart illustrating the hybrid cooling method according to the present teachings; and

[0048] Figure 11 is a schematic representation of a cooling module according to the present teachings.

DETAILED DESCRIPTION

[0049] Example embodiments are provided so that this disclosure will be thorough, and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[0050] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0051] When an element or layer is referred to as being "on," "engaged to," "connected to," or "coupled to" another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0052] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0053] Spatially relative terms, such as "inner," "outer," "beneath," "below," "lower," "above," "upper," and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0054] The following description is merely exemplary in nature and is not intended to limit the present teachings, application, or uses. It should be understood that throughout the drawings, corresponding reference numerals indicate like or corresponding parts and features (e.g., 20, 120, 220, etc.). As used herein, the term "module" may refer to an application-specific integrated circuit (ASIC), an electronic circuit, a processor (shared, dedicated, or group) and memory that executes one or more software or firmware programs, a combinational logic circuit, or other suitable components that provide the described functionality.

[0055] An exemplary condensing unit 20 utilizing the cooling techniques of the present teachings is shown in Figure 1. Condensing unit 20 is shown in a partially cutaway perspective view with various components, connections, and other features removed for simplicity. Condensing unit 20 includes a condenser 22 that extends around condensing unit 20. Condenser 22 includes one or more fluid conduits (not shown) from which a plurality of heat-transferring fins 60 extend. A fan 26 driven by an electric motor 28 can be disposed in an interior cavity 30 of condensing unit 20. Fan 26 can draw an airflow through condenser 22 to remove heat and condense the working fluid flowing through condenser 22. A compressor 32, such as a variable-speed compressor, can be disposed in interior cavity 30. For example, a control module 34 that controls operation of compressor 32 can be disposed in interior cavity 30 above compressor 32. Control module 34 can control the operation of compressor 32 to meet the demands of the heating and air-conditioning or heat pump system within which condensing unit 20 is used. Control module 34 is also referred to herein as the drive electronics. Control module 34 is in heat-transferring relation with a heat sink 36. The airflow induced by fan 26 flows across heat sink 36 to facilitate removal of heat from control module 34 via convection.

[0056] Referring now to Figures 2 and 3, details of compressor 32 and control module 34 are shown. Compressor 32 is operable to compress a working fluid from a suction pressure to a discharge pressure greater than the suction pressure. Working fluid enters compressor 32 at a suction pressure through suction inlet conduit 38 and is discharged from compressor 32 at the discharge pressure through discharge outlet conduit 40. Compressor 32 can take a variety of forms. For example, compressor 32 can be a variable-speed compressor that changes speed while in operation, thereby varying the capacity. Compressor 32 can be a scroll compressor, a reciprocating compressor, a screw compressor, a rotary compressor, and the like by way of non-limiting example.

[0057] Control module 34 can include a cover 44 which may be removed to access the internal components of control module 34, as shown in Figure 3. Control module 34 can include one or more circuit boards 46 and one or more electronic components 48 that enable control module 34 to perform its functions. It should be appreciated that the details of control module 34 shown in Figure 3 are merely exemplary in nature and that control module 34 can include additional or other components and/or modules, as needed, to provide the desired functionality.

[0058] A cooling module 50 can be used to command the cooling of control module 34. Cooling module 50 can be part of control module 34, as shown in Figures 3-8, or can be a separate module or component, as shown in phantom in Figure 4-8. Cooling module 50 can ascertain when cooling of control module 34 is needed and command the appropriate actions to achieve the desired cooling of control module 34, as described below.

[0059] Heat sink 36 can include a base 54 having a first surface 56 in heat-transferring relation with control module 34. A second surface 58 of base 54 can include a plurality of fins 60 that extend outwardly therefrom in heat-transferring relation. Fins 60 facilitate the transferring of heat via convection from heat sink 36 to an airflow induced by fan 26 flowing across fins 60. A fluid conduit 64 can extend through base 54 to provide additional cooling for heat sink 36. Fluid conduit 64 allows a working fluid to flow therethrough in heat-transferring relation with base 54 to remove heat therefrom. Fluid conduit 64 can extend through base 54 in a variety of orientations to facilitate heat transfer therebetween. For example, fluid conduit 64 can extend through base 54 in a serpentine manner, by way of non-limiting example. A valve/expansion device 66 (hereinafter valve) is disposed in fluid conduit 64 and is operable to control the flow of working fluid therethrough. Valve 66 can be operated by cooling module 50 or independently of cooling module 50. For example, in some embodiments cooling module 50 can send signals to valve 66 to open and close, as needed, to provide the desired cooling for control module 34, while in some embodiments valve 66 can be responsive to components independent of cooling module 34, such as a temperature sensor that causes valve 66 to open and close based on a sensed temperature. In some embodiments, the temperature sensor can be a component of cooling module 50, as shown in Figure 11. A return fluid conduit 68 communicates with fluid conduit 64 and directs working fluid exiting base 54 back to the working fluid flowing through the refrigerant system within which condensing unit 20 is utilized.

[0060] Heat sink 36 is operable to remove heat from control module 34 by air flowing over fins 60 and/or a working fluid flowing through fluid conduit 64. In this manner, two different methods of cooling can be realized. The two different cooling methods can be used independently of one another or can be used in conjunction with one another, as described below.

[0061] Referring now to Figure 4, a schematic representation of a heating and air-conditioning system 70 having a mechanization that enables working fluid to flow through heat sink 36 according to the present teachings is shown. In a typical heating and air-conditioning system, compressor 32 discharges high-pressure, high-temperature compressed working fluid through discharge conduit 40. The discharged working fluid flows through condenser 22 wherein the temperature is reduced and the working fluid can condense into a liquid. The working fluid exits condenser 22 through a conduit 72 and flows through an expansion device 74 which reduces the pressure of the working fluid. The low-pressure, low-temperature working fluid flows from expansion device 74 through fluid conduit 76 and into an evaporator 78. Within evaporator 78, the working fluid can absorb heat from a fluid flowing along evaporator 78, thereby increasing the temperature of the working fluid. The working fluid travels from evaporator 78 back into compressor 32 through suction conduit 38. The preceding explanation is a description of a typical vapor-compression cycle utilized in heating and air-conditioning systems. Thus, it should be appreciated that changes in the operation can be implemented without deviating from the present teachings.

[0062] In the mechanization shown in Figure 4, fluid conduit 64 communicates with conduit 72 to allow condensed working fluid to be expanded by valve 66 and flow through base 54 and remove heat from control module 34. Valve 66 can be selectively operated to allow working fluid in conduit 64 to flow through base 54. The working fluid flowing through valve 66 will be expanded wherein the pressure is lowered across valve 66. As a result, a reduced-pressure, low-temperature working fluid (either gas or liquid, or both) can flow through base 54 in heat-transferring relation with control module 34. The working fluid can thereby convectively absorb heat from base 54 and control module 34. The working fluid exiting base 54 flows through fluid conduit 68 and is supplied to suction conduit 38 for entering the suction side of compressor 32.

[0063] A temperature sensor 82 can be coupled to heat sink 36, such as to base 54, to provide a signal to cooling module 50 that is indicative of the temperature of heat sink 36. Cooling module 50 can use this signal to command operation of valve 66 to supply working fluid through base 54 to reduce the temperature thereof. In some embodiments, a temperature sensor 84 can be connected to control module 34 to provide a signal to cooling module 50 that is indicative of a temperature of control module 34. Cooling module 50 can then command operation of valve 66 based on the signal to allow working fluid to flow through base 54 and reduce the temperature of control module 34. In some embodiments, cooling module 50 can command operation of valve 66 based on the operating conditions of compressor 32. For example, when compressor 32 is in a low load operating state, cooling module 50 can maintain valve 66 closed as sufficient cooling can be achieved through the airflow over fins 60. When operation of compressor 32 is increased, cooling module 50 can command valve 66 to open to thereby allow working fluid to flow through base 54 and reduce the temperature of control module 34. The changing operation of compressor 32 can be based on the ambient conditions, by way of non-limiting example. Thus, in the mechanization shown in Figure 4, valve 66 can be opened and closed based on the temperature of heat sink 36, the temperature of control module 34, the operating conditions of compressor 32, and/or the ambient conditions. As shown in Figure 4, cooling module 50 can be integral with control module 34 or a separate module, as shown in phantom.

[0064] Air cooling of control module 34 can be provided by fan 26 of condensing unit 20 inducing an airflow across fins 60 and heat sink 36. Optionally, an airflow across fins 60 and heat sink 36 can be provided by a separate fan 86 which is independent of condenser fan 26. Fan 86 is shown in phantom in Figure 4 to indicate that fan 86 is optional. Fan 86 can be operated independently from fan 26 of condensing unit 20. Fan 86 can communicate with cooling module 50 and receive signals from cooling module 50 to command operation. In this manner, cooling module 50 can command independent operation of fan 86 to provide an airflow across fins 60 and heat sink 36. Thus, an independent fan 86 can be commanded to induce an airflow over fins 60 and heat sink 36 to provide air cooling of control module 34. It should be appreciated that in some embodiments both fan 26 and independent fan 86, when present, can be operated simultaneously to induce airflow over fins 60 and heat sink 36. Some embodiments (e.g., geothermal units) may include fan 86 and may not include fan 26.

[0065] Referring now to Figures 5 and 6, a heating and air-conditioning system 170 having another mechanization that enables the cooling of the heat sink 36 with the working fluid is shown. Heating and air-conditioning system 170 is similar to heating and air-conditioning system 70 discussed above. Therefore, only the differences associated with the mechanization for providing working fluid through base 54 of heat sink 36 is discussed.

[0066] In this mechanization, fluid conduit 164 receives expanded working fluid from fluid conduit 176 downstream of expansion device 74. A thermal valve 190 is disposed in fluid conduit 176 and coupled to fluid conduit 164. Thermal valve 190 is operable to allow all of the working fluid to either flow through fluid conduit 176, bypassing fluid conduit 164 and heat sink 36, or to flow through fluid conduit 164, heat sink 36, and fluid conduit 168 and rejoin fluid conduit 176 in a downstream location prior to evaporator 78.

[0067] Valve 190 can direct the flow through fluid conduit 164 based on a temperature of the working fluid entering valve 190. That is, valve 190 can be a temperature-sensing valve that, upon detecting a temperature above a predetermined value, directs all of the flow through heat sink 36 to provide cooling for control module 34. For example, as shown in Figure 5, fluid conduits 164 and 168 are indicated in phantom, while fluid conduit 176 is entirely in solid. In this situation, all of the working fluid flows through fluid conduit 176 and does not flow through fluid conduits 164, 168 or heat sink 36. This operation corresponds to operation of control module 34 without being cooled by the working fluid. As shown in Figure 6, when valve 190 redirects the flow of the working fluid through fluid conduits 164, 168 (now shown in solid), the working fluid flows through base 54 of heat sink 36 to provide cooling to control module 34. The working fluid re-enters fluid conduit 176 after flowing through base 54. As such, a portion 176a of fluid conduit 176 is shown in phantom, thereby indicating that working fluid does not flow therethrough. In this manner, valve 190 can automatically adjust to enable working fluid to cool control module 34, as needed, based upon a temperature of the working fluid entering valve 190. Additionally, in this mechanization, an entirety of the expanded working fluid flows through base 54 of heat sink 36 when working fluid is being used to cool control module 34. Valve 190 can be a component of cooling module 50, as shown in phantom in Figure 5 and shown in solid in Figure 11.

[0068] Referring now to Figures 7 and 8, a heating and air-conditioning system 270 having another mechanization that enables the cooling of heat sink 36 with the working fluid is shown. Heating and air-conditioning system 270 is a heat pump system that is similar to heating and air-conditioning system 70 discussed above. Therefore, only the differences associated with the mechanization are discussed.

[0069] In this mechanization, heating and air-conditioning system 270 is in the form of a heat pump system and includes an outdoor heat exchanger 222, an indoor heat exchanger 278, first and second expansion devices 274a, 274b, and associated bypass conduits 272a, 272b with respective check valves 287a, 287b therein, and a reversing valve 288. Reversing valve 288 communicates with both suction conduit 238 and discharge conduit 240 to reverse the flow through heating and air-conditioning system 270 to switch between a cooling mode, as shown in Figure 7, and a heating mode, as shown in Figure 8. An outdoor conduit 289 extends between reversing valve 288 and outdoor heat exchanger 222. An indoor conduit 291 extends between reversing valve 288 and indoor heat exchanger 278.

[0070] In a first position of reversing valve 288, discharge conduit 240 communicates with outdoor conduit 289 while suction conduit 238 communicates with indoor conduit 291, as shown in Figure 7. In a second position of reversing valve 288, discharge conduit 240 communicates with indoor conduit 291 while suction conduit 238 communicates with outdoor conduit 289, as shown in Figure 8. The movement of reversing valve 288 between the first and second positions changes the operation of heating and air-conditioning system 270 from a cooling mode, as shown in Figure 7, to a heating mode, as shown in Figure 8. Movement of reversing valve 288 can be based on commands from control module 34, a thermostat (not shown) or a system controller (not shown).

[0071] Referring now to Figure 7, when heating and air-conditioning system 270 is in the cooling mode, reversing valve 288 is in the first position. In the first position, discharge conduit 240 communicates with outdoor conduit 289 to direct compressed working fluid to outdoor heat exchanger 222. In outdoor heat exchanger 222, the temperature of the working fluid is reduced and the working fluid can condense into a liquid. The working fluid exits outdoor heat exchanger 222 through conduit 272. In the cooling mode, expansion device 274a is closed and, as a result, working fluid flowing through conduit 272 flows through bypass conduit 272a and through check valve 287a. The working fluid may not experience any significant change in its state or properties when flowing through bypass conduit 272a and check valve 287a. After flowing through bypass conduit 272a, the working fluid re-enters conduit 272 and flows through expansion device 274b, which is active and reduces the pressure of the working fluid. The low-pressure, low-temperature working fluid flows from expansion device 274b into indoor heat exchanger 278 wherein the working fluid can absorb heat from a fluid flowing along indoor heat exchanger 278, thereby increasing the temperature of the working fluid. The working fluid is prevented from bypassing expansion device 274b through bypass conduit 272b due to the presence of check valve 287b and the pressure difference of the working fluid on either side thereof. Working fluid travels from indoor heat exchanger 278 to reversing valve 288 through conduit 291 and on into compressor 32 through suction conduit 238.

[0072] Referring now to Figure 8, operation of heating and air-conditioning system 270 in the heating mode is shown. In the heating mode, reversing valve 288 is in the second position such that discharge conduit 240 communicates with indoor conduit 291 and suction conduit 238 communicates with outdoor conduit 289. The discharged working fluid flows through discharge conduit 240, through reversing valve 288, and into indoor heat exchanger 278 through indoor conduit 291. In indoor heat exchanger 278, the temperature of the working fluid is reduced as heat is transferred from the working fluid to a fluid flowing along indoor heat exchanger 278, such as an airflow. The working fluid can condense into a liquid as its temperature is reduced in indoor heat exchanger 278. The working fluid exits indoor heat exchanger 278 through conduit 272. In the heating mode, expansion device 274b is closed and the working fluid flows through bypass conduit 272b and check valve 287b. The working fluid may not experience any significant change in its state or properties when flowing through bypass conduit 272b and check valve 287b. The working fluid continues to flow through conduit 272 and through expansion device 274a, which is active in the heating mode and reduces the pressure of the working fluid flowing therethrough. The working fluid flows from expansion device 274a into outdoor heat exchanger 222 through conduit 272. The working fluid is prevented from flowing through bypass conduit 272a due to the presence of check valve

287a and the pressure difference on either side thereof. The low-pressure, low-temperature working fluid flows from expansion device 274a through fluid conduit 272 and into outdoor heat exchanger 222. Within outdoor heat exchanger 222, the working fluid can absorb heat from a fluid flowing along outdoor heat exchanger 222, thereby increasing the temperature of the working fluid. The working fluid travels from outdoor heat exchanger 222 back into compressor 32 through outdoor conduit 289, reversing valve 288, and suction conduit 238.

[0073] In the mechanizations shown in Figures 7 and 8, fluid conduit 64 communicates with conduit 272 between expansion devices 274a, 274b. This positioning of fluid conduit 64 allows condensed working fluid to flow into fluid conduit 64 and be expanded by valve 66 and flow through base 54 and remove heat from control module 34, as described above with reference to the mechanization shown in Figure 4. When in the cooling mode, the working fluid in communication with fluid conduit 64 is in a condensed non-expanded state due to expansion device 274a being closed while expansion device 274b is active. When in the heating mode, the working fluid in communication with fluid conduit 64 is again in a condensed non-expanded state due to expansion device 274b being closed while expansion device 274a is active. Thus, the same type of cooling can be provided for control module 34, as described above with reference to the mechanization shown in Figure 4, regardless of heating and air-conditioning system 270 being operated in the cooling mode or heating mode.

[0074] According to the present teachings, control module 34 can be cooled by airflow induced by fan 26, fan 86 (when present), and by working fluid flowing through base 54 of heat sink 36. Typically, control module 34 will be air cooled by air flowing across fins 60 of heat sink 36. When the air cooling is insufficient to maintain control module 34 below a predetermined temperature or within a predetermined temperature-operating range, the cooling can be supplemented by providing working fluid to base 54 to provide additional cooling for control module 34. The conditions under which additional cooling is provided by the working fluid can vary based upon the needs of control module 34 and the desired operation of compressor 32 and the system within which compressor 32 is utilized. For example, the use of air cooling and working fluid cooling can be dictated by the current compressor 32 operating condition within an operating envelope 92, such as that shown in graph 93 of Figure 9. In graph 93, the saturated evaporator temperature is shown along the horizontal axis while the saturated condenser temperature is shown along the vertical axis. A line 95 extends between the horizontal and vertical axes. The area below line 95, above the vertical axis, and to the left of the horizontal axis represents the operating envelope 92 within which compressor 32 may operate.

[0075] Within operating envelope 92, control module 34 can be cooled by air cooling and, in some areas, supplemented with additional cooling provided by the working fluid. A transition line 96 can divide the operating envelope into a first area 97, wherein control module 34 is cooled solely by air cooling, and a second area 98, wherein the cooling of control module 34 is supplemented with additional cooling provided by working fluid flowing through heat sink 36. Second area 98 is indicated in cross-hatching in Figure 9. The location and shape of transition line 96 can vary based upon the desired operation of compressor 32, the operational-temperature range of control module 34 and/or the desired operation of the system within which condensing unit 20 is operating. For example, in some embodiments, the transition line 96 can be based upon a condenser temperature of 140°F, as shown in Figure 9. When this is the case, the working fluid can be supplied to base 54 of heat sink 36 whenever the condenser temperature is 140°F or greater. When the temperature drops below 140°F, the working fluid flow through base 54 is ceased and cooling can be provided entirely by air cooling. In some embodiments (e.g., a geothermal unit), the operating envelope 92 may be than described above. For example, the transition line 96 may be at a temperature lower than 140°F. In such embodiments, independent fan 86 may be used to assist in cooling heat sink 36.

[0076] The use of the working fluid to provide additional cooling to control module 34 adds an efficiency loss to the system within which compressor 32 is operating. To reduce the efficiency loss, in some embodiments the working fluid can be supplied to base 54 of heat sink 36 only in situations requiring the additional cooling. Additionally, in some embodiments the use of the working fluid can be limited to ranges that do not affect the efficiency rating of compressor 32 and/or the system within which compressor 32 is utilized. For example, the efficiency rating of compressor 32 and/or the system within which it is utilized can be limited to specific operating points, such as points 99a, 99b shown in Figure 9. These rating points can be industry-derived standards for rating the efficiencies of the compressor and/or heating and air-conditioning systems. The use of supplemental cooling provided by directing working fluid through base 54 of heat sink 36 can affect the efficiency. Therefore, the supplemental cooling provided by the working fluid can be limited to areas in operating envelope 92 within which compressor rating points 99a, 99b do not occur. For example, as shown in Figure 9, both rating points 99a, 99b are in first area 97, wherein the entire cooling of control module 34 is provided by airflow across fins 60. Thus, by limiting the use of working fluid to provide cooling for control module 34 to areas within which the compressor rating points do not exist, such as in second area 98, the use of the working fluid to cool control module 34 does not affect the system rating. Additionally, the use of working fluid to cool control module 34 can allow control module 34 to operate at a lower temperature, thereby possibly allowing the use of less-expensive components for control module 34.

[0077] It should be appreciated that compressor operating envelope 92 is merely exemplary in nature and just one possible arrangement for dividing operating envelope 92 into first and second areas 97, 98 within which different cooling methods, according to the present teachings, are used is illustrated. Other operating envelopes having differing transition lines and differing first and second areas 97, 98 can be utilized, as desired, to achieve a desired cooling for control module 34.

[0078] Referring now to Figure 10, a method of implementing the cooling of a control module 34, according to the present teachings, is shown. The method begins with the initiating of compressor 32 operation, as indicated in block 200. With the initial startup of the compressor 32, control module 34 is air cooled, as indicated in block 202. This can be accomplished by fan 26 and/or fan 86 (when present) inducing airflow across fins 60 of heat sink 36.

[0079] While control module 34 is being air cooled, control monitors the status, as indicated in block 204. Cooling module 50 can monitor the status. The types of information monitored can include the temperature of control module 34, the temperature of heat sink 36, the demand placed on compressor 32, and/or environmental conditions, by way of non-limiting example. In some embodiments, the temperature of the condensed working fluid downstream of expansion device 74 is monitored, such as with valve 190 in the configuration shown in Figures 5 and 6.

[0080] A determination is made if supplemental cooling is needed, as indicated in block 206. If supplemental cooling is not needed, control moves to block 208 and monitors the status. If supplemental cooling is needed, control module 34 is cooled with working fluid, as indicated in block 210. Specifically, in the configurations shown in Figures 4, 7, and 8, cooling module 50 commands valve 66 to open, thereby allowing working fluid to flow through fluid conduit 64 and base 54 of heat sink 36 to remove heat from control module 34. In the case of the configuration shown in Figures 5 and 6, valve 190 can automatically open upon sensing a temperature of the working fluid flowing thereto above a predetermined temperature. The opening of control valve 190 thereby directs the working fluid through fluid conduit 164 and base 54 of heat sink 36 to remove heat from control module 34.

[0081] While control module 34 is being cooled with working fluid, the status is monitored by cooling module 50, as indicated in block 208. In block 212, a determination of the need for supplemental cooling is ascertained. The determination of whether supplemental cooling is needed can be done by cooling module 50 and can be based on the same considerations discussed above with reference to block 206. If supplemental cooling is needed, control returns to block 210 and either initiates cooling of control module 34 with working fluid, if not already occurring, or continues to cool control module 34 with working fluid, if already occurring. If supplemental cooling is not needed, flow of working fluid to base 54 of heat sink 36 is stopped, as indicated in block 213. In the configurations shown in Figures 4, 7, and 8, this can be accomplished by cooling module 50 commanding valve 66 to close, thereby stopping flow of working fluid through heat sink 36. In the configuration shown in Figures 5 and 6, this can be accomplished by valve 190 sensing the temperature of the working fluid having dropped below a predetermined temperature and stopping the flow of working fluid through heat sink 36.

[0082] With the flow of working fluid to heat sink 36 stopped, control determines if compressor 32 is still operating, as indicated in block 214. If compressor 32 is still operating, control returns to block 202 and continues to air cool control module 34. If compressor 32 is no longer operating, control moves to block 216 and the method ends.

[0083] Thus, the method of the present teachings can utilize air- cooling and/or other fluid- cooling to cool control module 34 and, as needed, supplement the cooling by supplying working fluid to base 54 of heat sink 36 to provide additional cooling for control module 34. The conditions under which the cooling of control module 34 is supplemented with the working fluid can be selected to achieve a desired operational- temperature of control module 34 and can be selected to occur during conditions that do not include the system rating zone. Additionally, the use of the working fluid to supplement the cooling can occur during high- load or high- ambient conditions. By limiting the periods of use of the working fluid to cool control module 34, increased efficiency can be achieved over that when working fluid is used to continuously cool control module 34. Additionally, the use of the two stages of cooling can reduce the quantity of air cooling necessary to maintain control module 34 in a desired operational- temperature range. The ability to provide supplemental cooling may allow the use of components in control module 34 that have a lower cost due to the reduced required operational- temperature range of the components.

[0084] While the present teachings have been described with reference to specific examples, mechanizations, and methods, it should be appreciated that changes in these configurations, mechanizations, and methods can be implemented without deviating from the present teachings. For example, the configuration of condensing unit 20 can vary from that shown. Additionally, the mechanizations shown in Figures 4-8 can be altered to change the locations of fluid conduits 64, 164, 68, 168 to provide the desired interconnections to the heating and air-conditioning system. Additionally, the temperatures and operating conditions at which supplemental cooling is provided by the working fluid can vary from that shown above. Accordingly, such variations and changes are to be regarded as being within the spirit and scope of the present teachings.

Claims

1. A condensing unit housing a compressor, a control module for controlling operation of said compressor, and a heat sink in heat-transferring relation with said control module, said control module being in heat-transferring relation with a first fluid and a second fluid, said first fluid being arranged to selectively flow through a fluid passageway in said heat sink, said second fluid being a different substance than said first fluid and in selective convective heat-transferring relation with a heat-transferring member in heat-transferring relation with said heat sink.

2. The condensing unit of claim 1, further comprising:

a condenser at least partially defining a cavity;
a fan operable to direct a flow of said second fluid through said condenser, and
wherein said compressor, said control module, said heat-transferring member and said heat sink are disposed in said cavity;
optionally wherein said fan operates independently of an operating condition of said condenser.

3. The condensing unit of claim 1 or claim 2, further comprising a cooling module operable to selectively route said first fluid discharged by said compressor through said flow path to remove heat from said control module.

4. The condensing unit of claim 3, wherein said cooling module includes one, some or all of:

(a) a valve disposed in said fluid conduit that selectively allows said fluid conduit to direct said first fluid discharged by said compressor into said fluid passageway; optionally wherein said valve is an expansion device;
(b) a temperature sensing device, wherein said cooling module is operable to selectively route said first fluid discharged by said compressor through said fluid passageway based on an output of said temperature sensing device;
(c) a temperature responsive valve operable to selectively allow said first fluid discharged by said compressor into said fluid passageway based on a temperature sensed by said temperature responsive valve.

5. The condensing unit of any one of the preceding claims, wherein an entirety of a flow of said first fluid discharged by said compressor can flow through said fluid passageway.

6. The condensing unit of any one of the preceding claims, further comprising a first fan, said first fan inducing a flow of said second fluid across said heat-transferring member.

7. The condensing unit of claim 6, further comprising a condenser at least partially defining a cavity;
a second fan operable to direct a flow of said second fluid through said condenser, and
wherein said compressor, said control module, said heat-transferring member and said heat sink are disposed in said cavity and said flow of said second fluid induced by said second fan is arranged to pass across said heat-transferring member, and said first fan and said second fan can be operated independently of one another.

8. A method of cooling a compressor control module comprising:

removing heat from the control module with a first cooling method that transfers heat to a first fluid; and
selectively supplementing said first cooling method by removing heat from the control module with a second cooling method that transfers heat to a second fluid different than said first fluid while simultaneously removing heat with said first cooling method.

9. The method of claim 8, wherein said first fluid is ambient air and said second fluid is working fluid discharged by the compressor.

10. The method of claim 8 or claim 9, wherein selectively supplementing said first cooling method includes removing heat with said second method based on a temperature, said temperature including at least one of an ambient air temperature, a temperature of the control module, a temperature of working fluid discharged by the compressor, and a temperature of a heat sink in heat-transferring relation to the control module;
and/or wherein selectively supplementing includes removing heat from the control module with said second cooling method when the compressor is operating in a predetermined range.

11. The method of any one of claims 8-10, wherein removing heat with said first cooling method includes inducing an airflow through a condenser and over a heat sink in heat-transferring relation with the control module;
and/or wherein removing heat with said first cooling method includes inducing an airflow over a heat sink in heat-transferring relation with the control module, the induced airflow being independent of an operating condition of a condenser.

12. The method of any one of claims 8-11, wherein removing heat from the control module with said second cooling method includes routing at least a portion of working fluid discharged from the compressor through a flow path in a heat sink in heat-transferring relation to the control module.

13. The method of any one of claims 8-12, wherein said first cooling method comprises:

inducing an airflow across a heat sink in heat-transferring relation to the control module;
transferring heat from the control module to the airflow through said heat sink;

wherein said second cooling method comprises:

selectively routing a working fluid through a flow path in said heat sink in heat-transferring relation to the control module; and
transferring heat from the control module to said working fluid when said working fluid is flowing through said heat sink.

14. The method of claim 13, wherein selectively routing includes one some or all of:

(a) selectively routing a condensed working fluid through said flow path in said heat sink;
(b) selectively routing an entirety of a flow of working fluid discharged by the compressor through said flow path in said heat sink;
(c) selectively routing said working fluid through said flow path based on a temperature of said working fluid;
(d) using an expansion valve to selectively route and expand said working fluid in said flow path.

15. The method of claim 13 or claim 14, wherein inducing said airflow includes inducing said airflow during an entire time the compressor is operating;
and/or wherein inducing said airflow includes inducing said airflow to flow through a condenser within which the compressor and control module are disposed;
and/or wherein inducing said airflow includes inducing said airflow with a fan that operates independently from operation of a condenser.

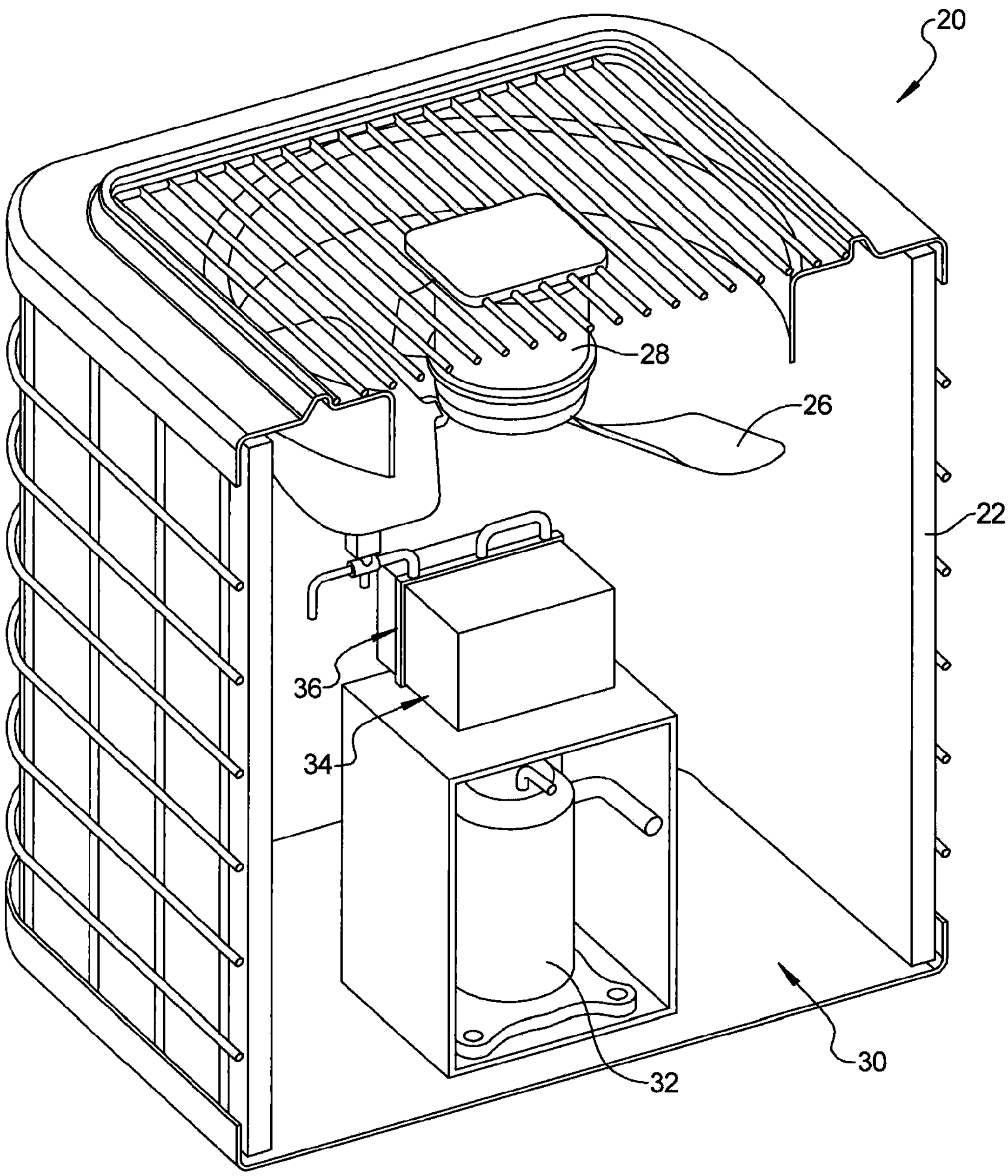


FIG 1

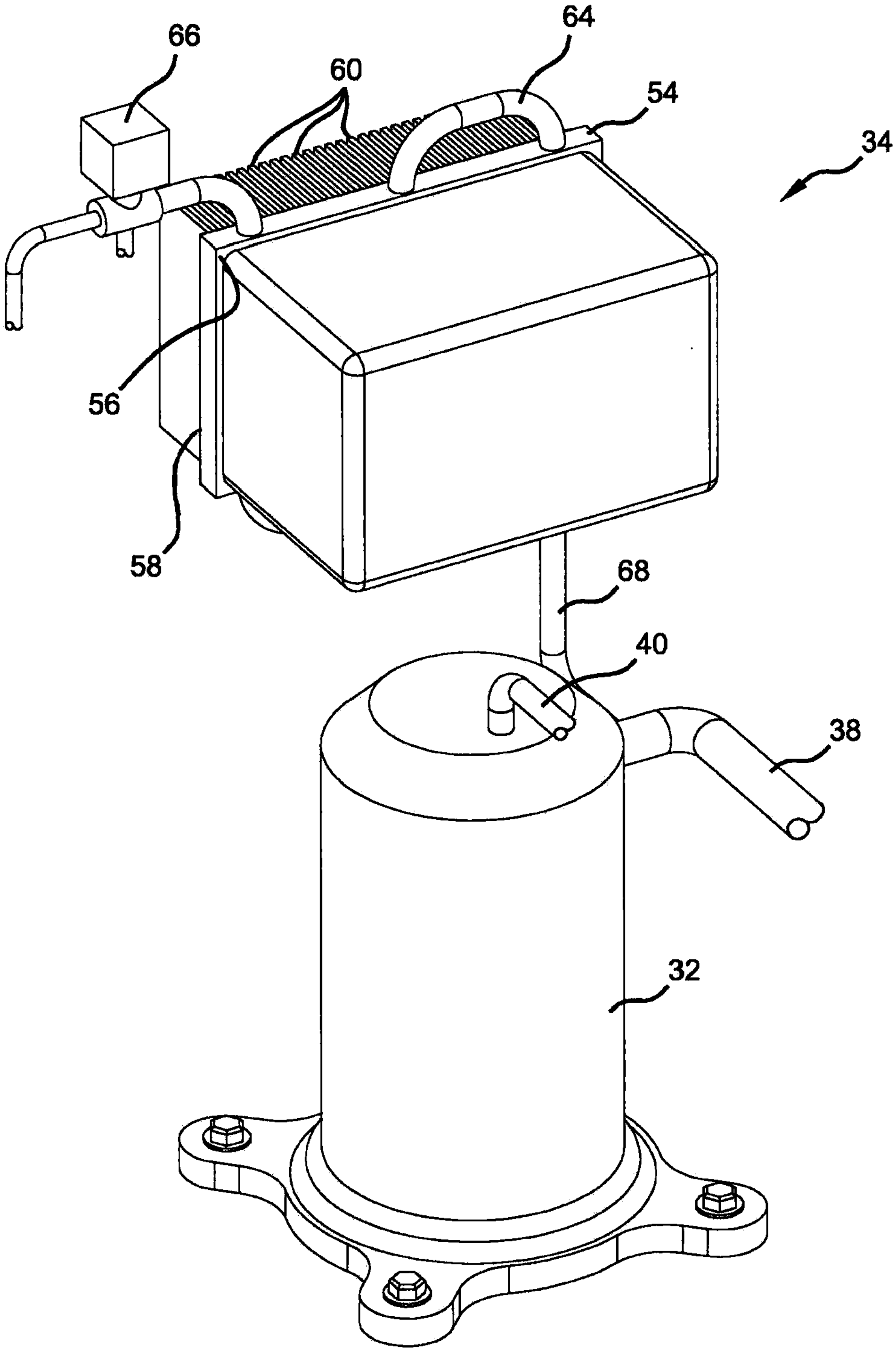


FIG 2

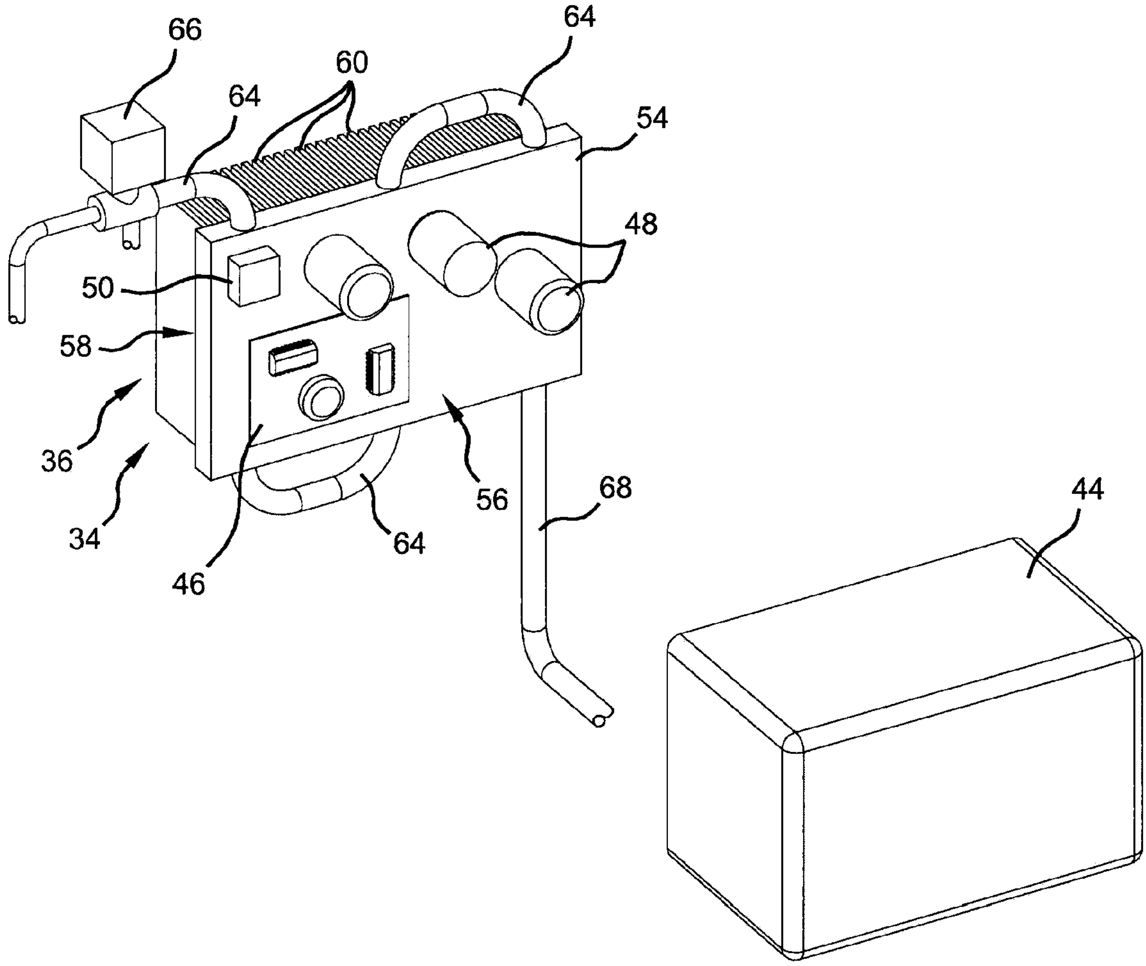


FIG 3

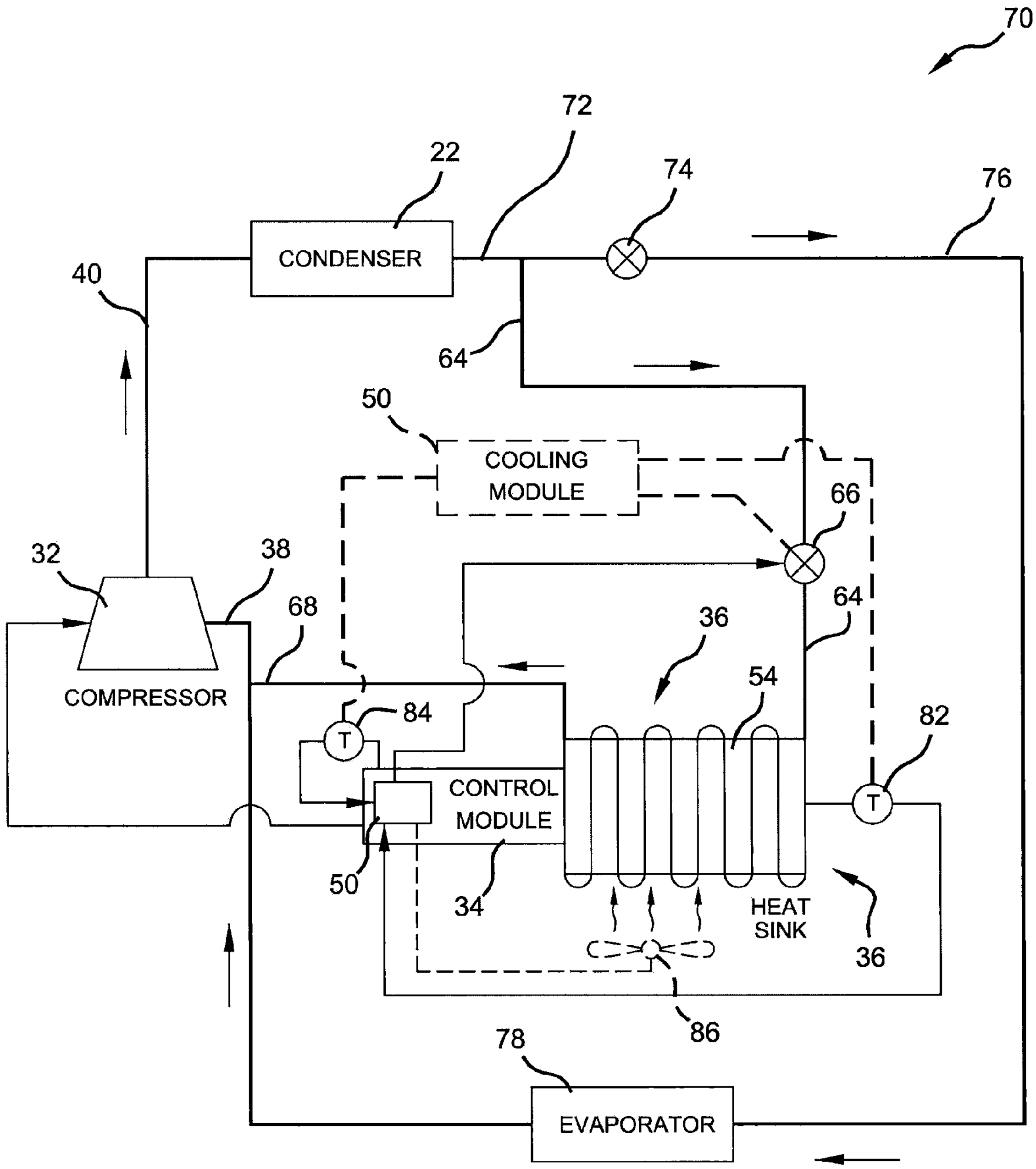
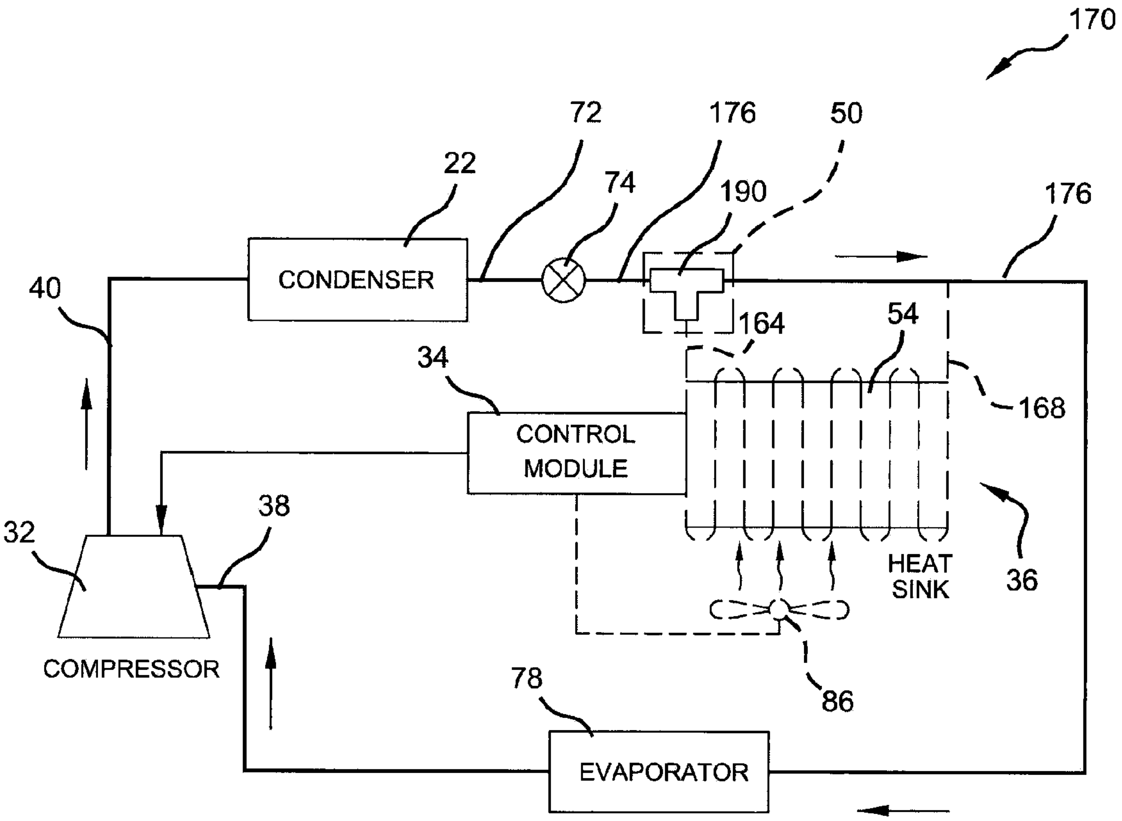

70
72
22
74
76
CONDENSER
40
64
50
COOLING
MODULE
66
32
38
68
36
64
54
COMPRESSOR
84
T
82
T
CONTROL
MODULE
50
34
HEAT
SINK
36
86
78
EVAPORATOR

FIG 4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COMPRESSOR
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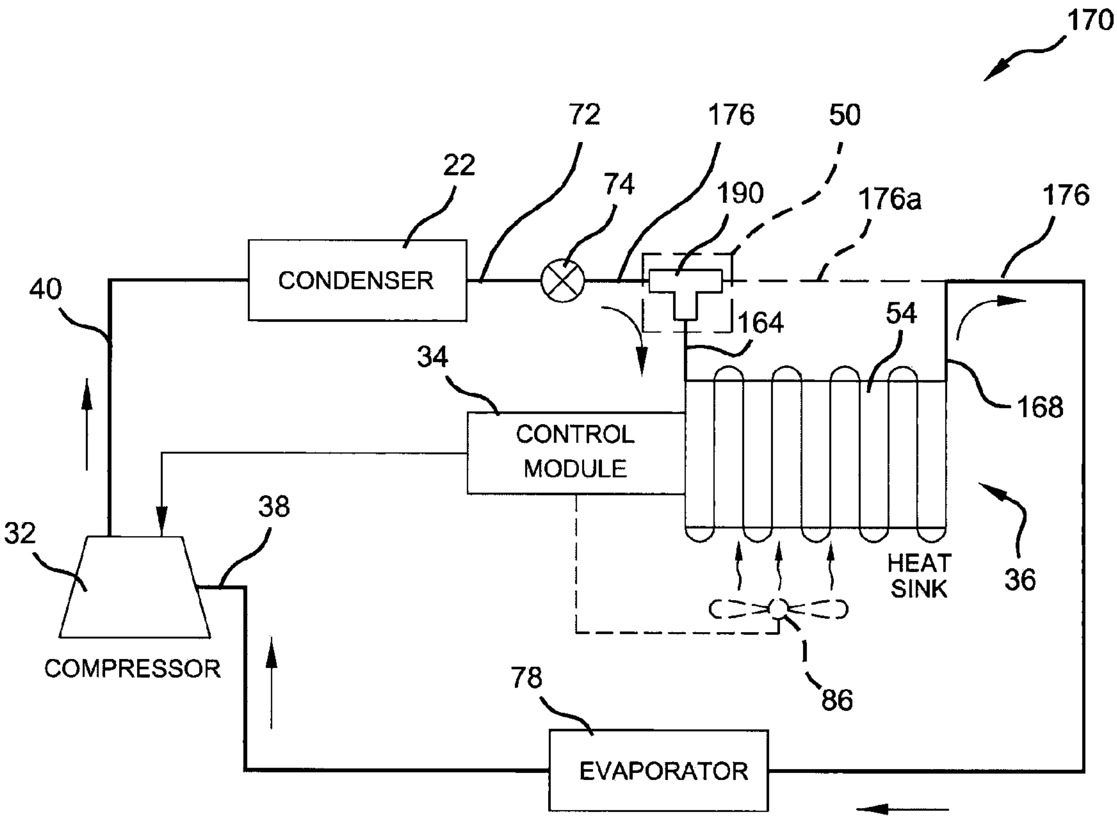
EVAPORATOR

FIG 5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SINK
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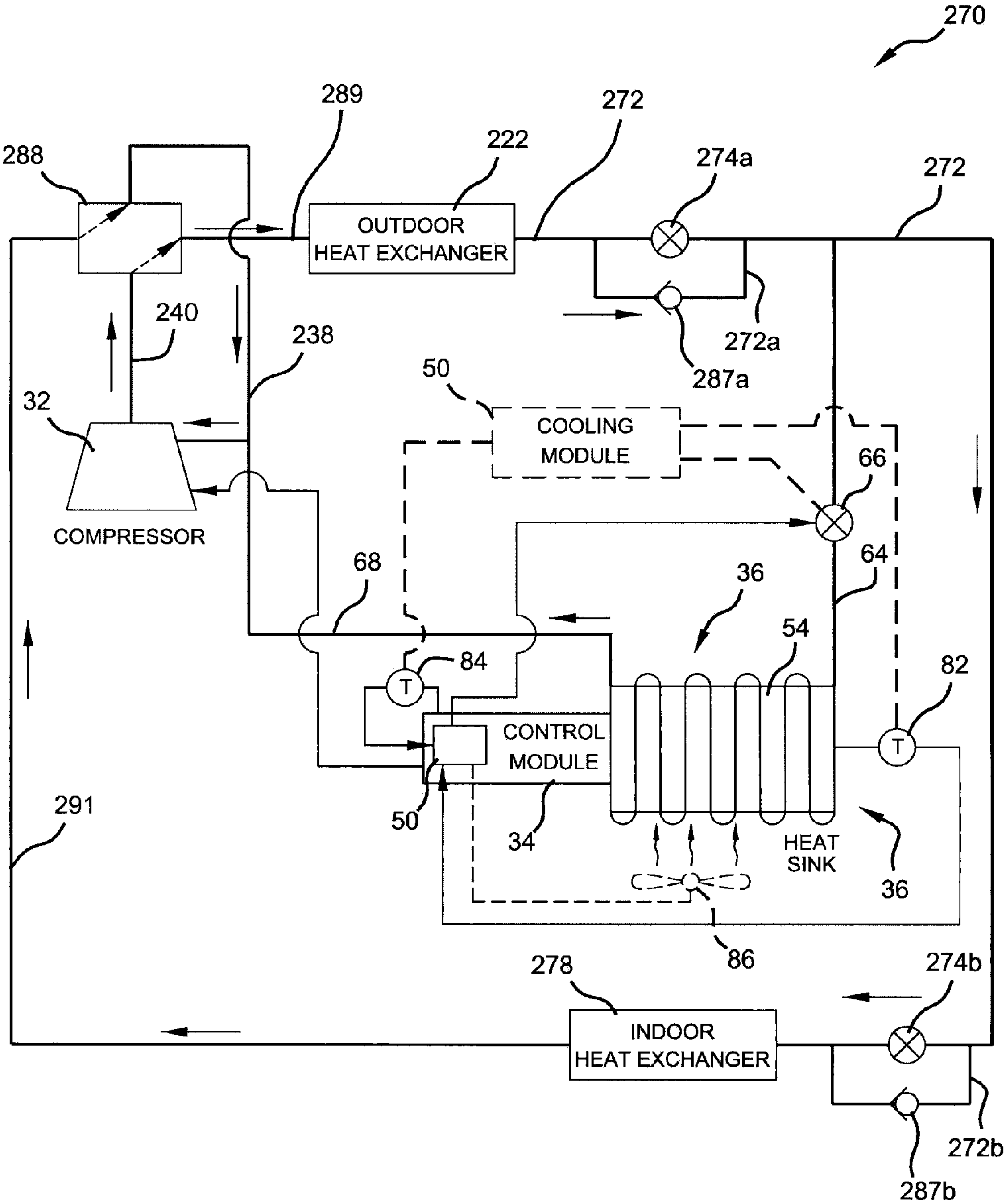
COMPRESSOR
78
86
EVAPORATOR

FIG 6


270
289
272
222
274a
272
288
OUTDOOR
HEAT EXCHANGER
240
272a
238
287a
50
32
COOLING
MODULE
66
COMPRESSOR
68
36
64
54
84
82
T
CONTROL
MODULE
T
291
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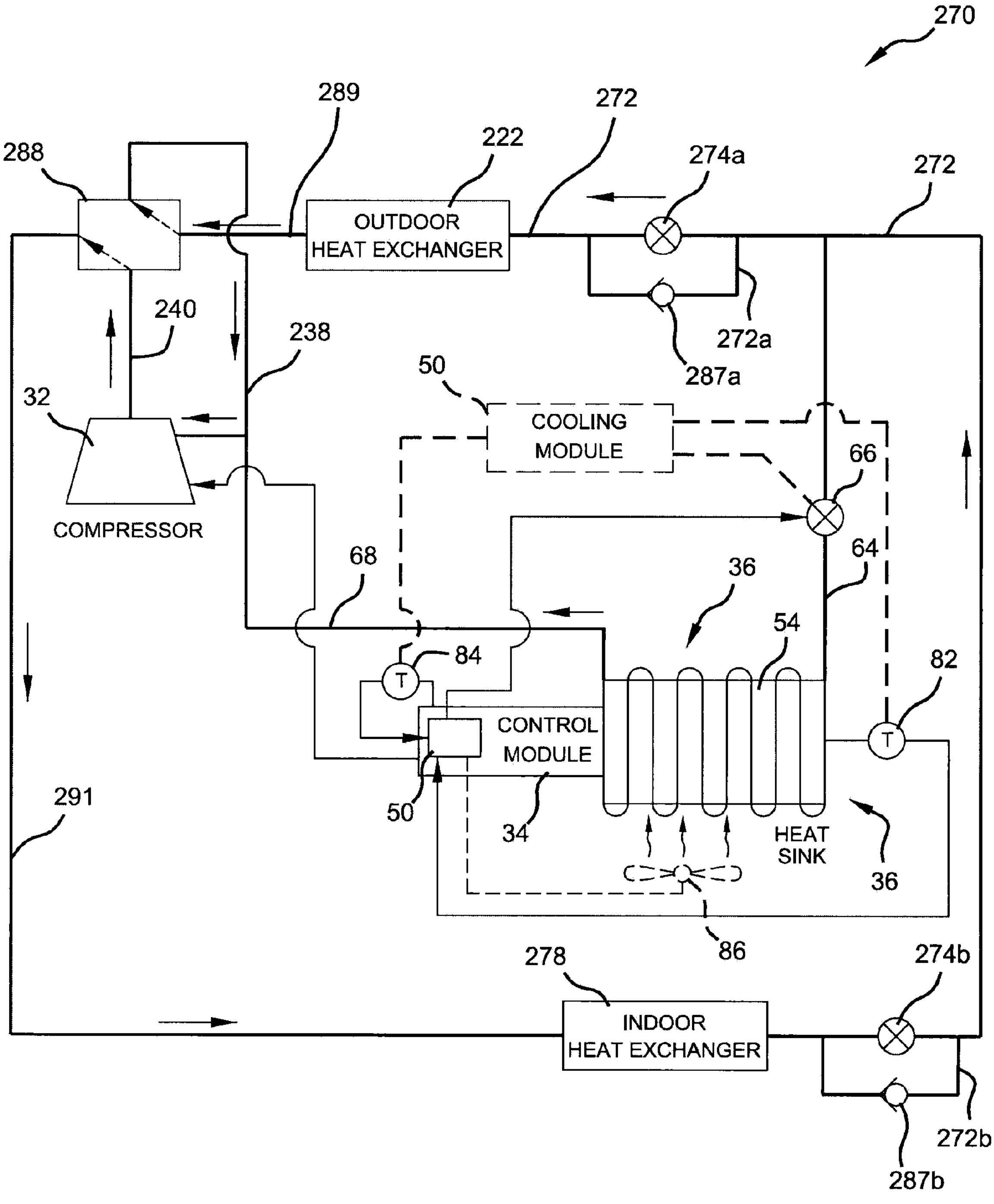
34
HEAT
SINK
36
86
278
274b
INDOOR
HEAT EXCHANGER
272b
287b

FIG 7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274a
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HEAT EXCHANGER
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COMPRESSOR
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HEAT
SINK
36
86
278
274b
INDOOR
HEAT EXCHANGER
272b
287b

FIG 8

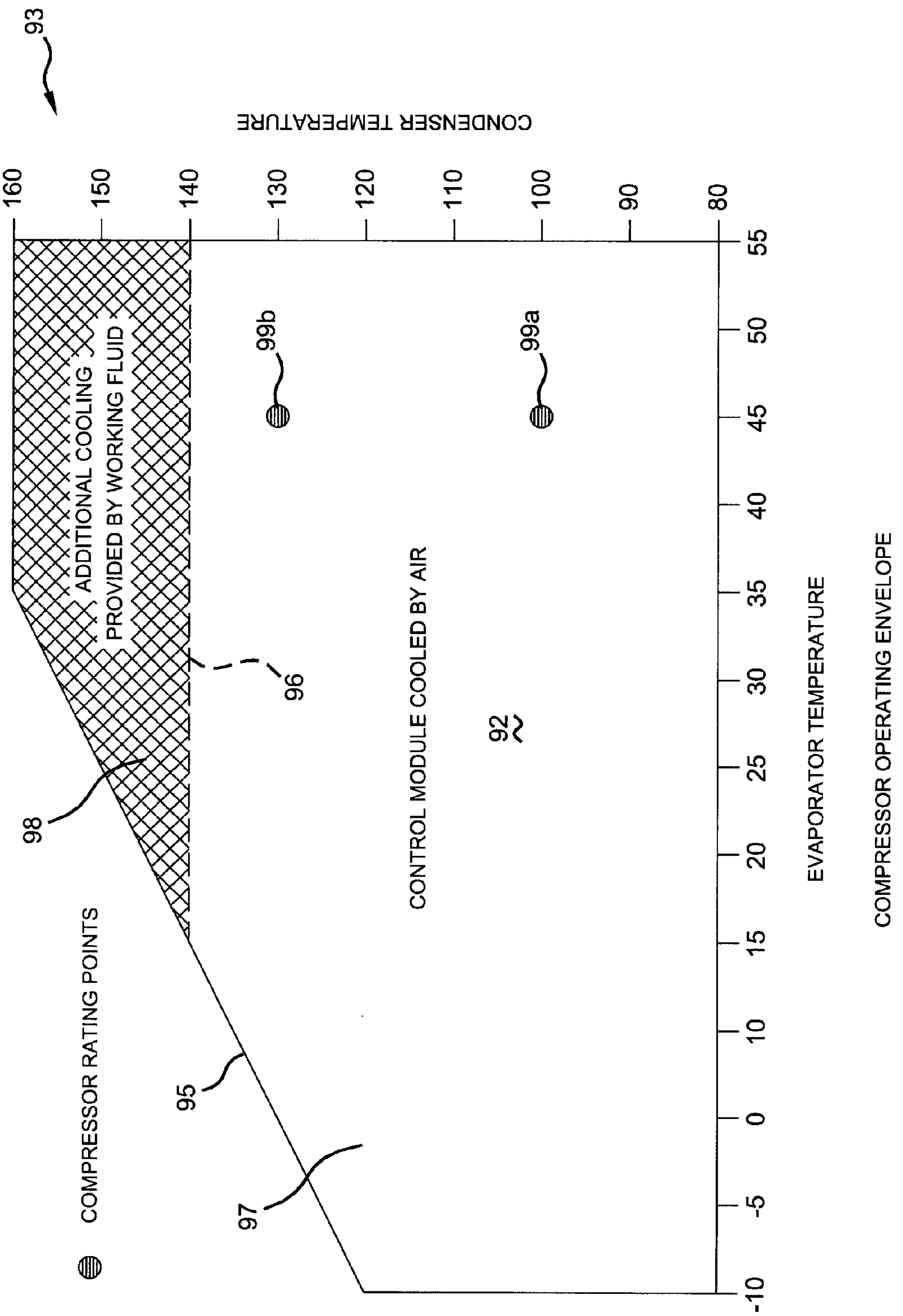
93
CONDENSER TEMPERATURE
160
150
140
130
120
110
100
90
80
-10
-5
0
5
10
15
20
25
30
35
40
45
50
55
EVAPORATOR TEMPERATURE
COMPRESSOR OPERATING ENVELOPE
COMPRESSOR RATING POINTS
ADDITIONAL COOLING
PROVIDED BY WORKING FLUID
CONTROL MODULE COOLED BY AIR
92
95
96
97
98
99a
99b

FIG 9

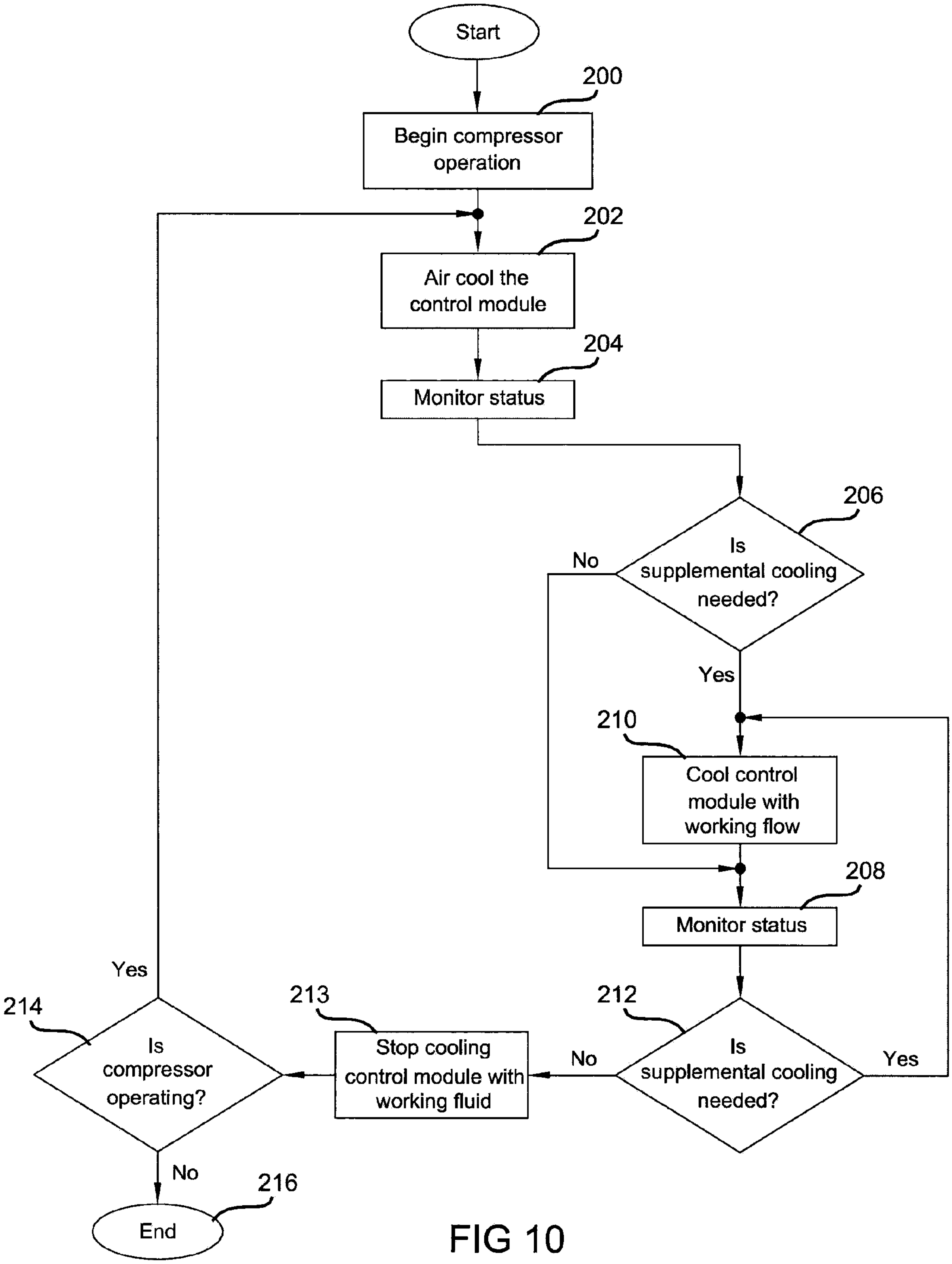
Start
200
Begin compressor operation
202
Air cool the control module
204
Monitor status
206
Is supplemental cooling needed?
No
Yes
210
Cool control module with working flow
208
Monitor status
212
Is supplemental cooling needed?
Yes
No
213
Stop cooling control module with working fluid
214
Is compressor operating?
Yes
No
216
End

FIG 10

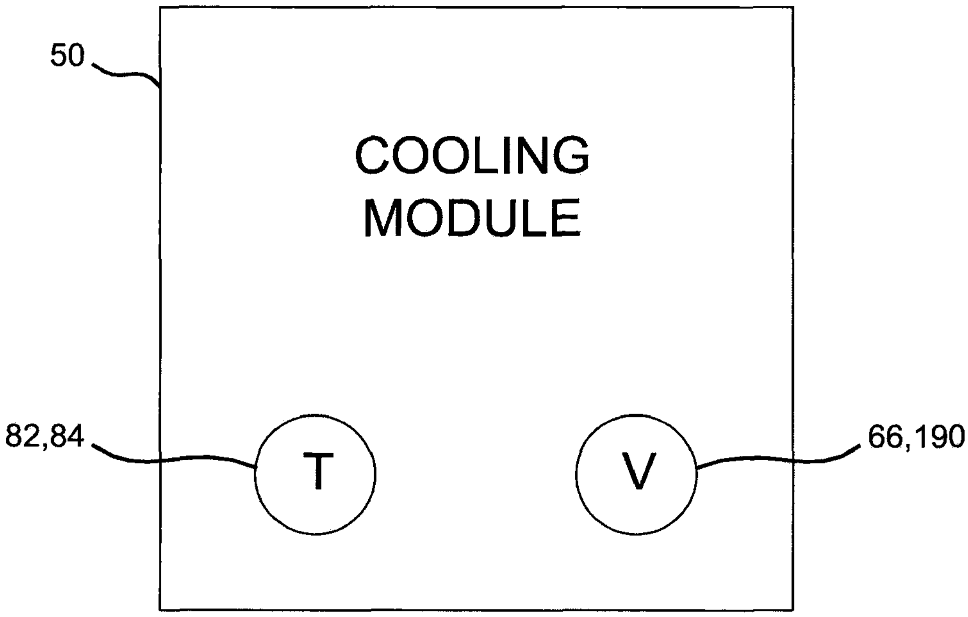

FIG 11

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EUROPEAN SEARCH REPORT

Application Number
EP 13 16 1753

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 Y	JP H06 159738 A (DAIKIN IND LTD) 7 June 1994 (1994-06-07) * abstract; figure 3 *	1-15 1-15	INV. F24F1/24 F25B31/00 F25B49/02
X Y	JP 2009 264699 A (DAIKIN IND LTD) 12 November 2009 (2009-11-12) * abstract; figure All *	1-15 1-15	
X Y	JP H11 23075 A (DENSO CORP) 26 January 1999 (1999-01-26) * the whole document *	1-15 1-15	
X Y	JP H05 322224 A (MITSUBISHI ELECTRIC CORP) 7 December 1993 (1993-12-07) * abstract *	1-15 1-15	
Y	WO 2011/083756 A1 (DAIKIN IND LTD [JP]; KIDO NAOHIRO [JP]; MAEDA TOSHIYUKI [JP]) 14 July 2011 (2011-07-14) * the whole document *	1-15	
Y	JP 2011 033340 A (DAIKIN IND LTD) 17 February 2011 (2011-02-17) * abstract *	1-15	TECHNICAL FIELDS SEARCHED (IPC) F24F F25B
Y	JP 2010 266132 A (MITSUBISHI HEAVY IND LTD) 25 November 2010 (2010-11-25) * abstract *	1-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	4 July 2013	Valenza, Davide

1

CATEGORY OF CITED DOCUMENTS

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04-07-2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP H06159738 A	07-06-1994	NONE	
JP 2009264699 A	12-11-2009	NONE	
JP H1123075 A	26-01-1999	NONE	
JP H05322224 A	07-12-1993	JP 2765365 B2	11-06-1998
		JP H05322224 A	07-12-1993
WO 2011083756 A1	14-07-2011	CN 102713462 A	03-10-2012
		EP 2522931 A1	14-11-2012
		US 2012279251 A1	08-11-2012
		WO 2011083756 A1	14-07-2011
JP 2011033340 A	17-02-2011	JP 5126343 B2	23-01-2013
		JP 2011033340 A	17-02-2011
JP 2010266132 A	25-11-2010	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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Patent documents cited in the description

- US 61618244 A **[0001]**