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(54) HEAT PUMP DEFROST CONTROLLER

(57) A universal heat pump defrost controller device can be configured to determine when and for how long to cause a heat pump to enter defrost mode to remove ice from the outdoor heat exchanger coil. The defrost controller of this disclosure is configured to work with a variety of heat pumps which may implement a variety of defrost approaches, such as demand or timing. The arrangement and form factor of the defrost controller, along with break-away tabs, may allow the defrost controller to fit in the limited space available in many heat pumps. The simple dual display and controls of the device provide for intuitive configuration and troubleshooting during setup and installation.

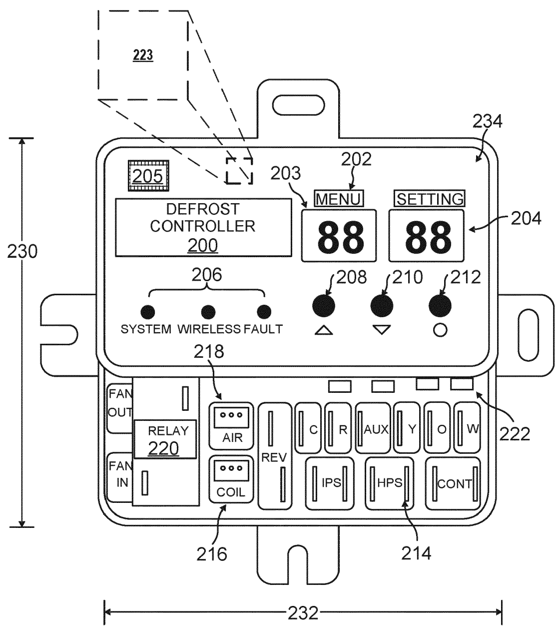

FIG. 2

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Description

TECHNICAL FIELD

[0001] The disclosure relates to heat pump defrost controllers.

BACKGROUND

[0002] A heating, ventilation, and air conditioning (HVAC) system that includes a heat pump typically includes an indoor and an outdoor heat exchanger coil. The heat exchanger coil may have a liquid, such as a refrigerant, running through piping, and when operating, the piping has air flowing over it. Because heat only flows from a high energy region to a low energy reason, a heat exchanger coil may extract energy from the air flowing through the coil if the coil is cooler than the surrounding air. In cooling mode, for example in summer in the northern hemisphere, the heat pump may be configured to cause the indoor coil to be cooler than indoor air passing through the indoor coil to remove heat from the air and cool the indoor space. In heating mode, the heat pump may configure the outdoor heat exchanger coil to be cooler than the outdoor air passing through it to extract energy from the outdoor air, transfer it to the indoor coil, and heat the indoor space.

[0003] Ambient air contains moisture, which may condense on the cooler heat exchanger coil. If the heat exchanger coil is cold enough, this moisture may form ice. Ice build-up inhibits airflow through the coil. In heating mode, even at relatively warm outside air temperatures, ice may still form on the outside heat exchanger coil. The ice should be removed or the heat pump may fail to heat the indoor space.

SUMMARY

[0004] In general, the disclosure is directed to a universal heat pump defrost controller device that is configured to determine when and for how long to cause a heat pump to enter defrost mode to remove ice from the outdoor heat exchanger coil. The defrost controller of this disclosure is configured to work with a variety of heat pumps which may implement a variety of defrost approaches. An example of defrost approach may include a timing cycle, which puts the heat pump in defrost mode periodically for a set time. Other examples of defrost approaches may include determining a temperature difference or a pressure difference between two or more areas of the heat pump and put the heat pump into defrost mode based on a temperature or pressure difference satisfying a predetermined threshold. Other examples of defrost approaches may include some combination of temperature or pressure sensing along with periodic timing.

[0005] The universal heat pump defrost controller of this disclosure is includes an intuitive display and user input with which a user may install the defrost controller on a heat pump and configure the controller to efficiently control the defrost cycle for a specific heat pump under specific conditions. A heat pump that does not defrost enough may limit air flow through the outdoor heat exchanger coil, reduce heat transfer efficiency and may cause stress on some heat pump components, such as the compressor. A heat pump that defrosts more than is needed uses additional energy, such as electricity, which may reduce the overall efficiency of the HVAC system as part of an overall system to control the environment of one or more spaces within a building. The universal heat pump defrost controller of this disclosure provides a defrost cycle control that is configurable to a particular heat pump approach, which may improve efficiency, equipment safety and reliability.

[0006] The details of one or more examples of the disclosure are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the disclosure will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0007]

FIG. 1 is a block diagram illustrating a climate control system including a heat pump with a defrost controller according to one or more techniques of this disclosure.

FIG. 2 is a conceptual diagram illustrating an example front view of a heat pump defrost controller according to one or more techniques of this disclosure.

FIG. 3 is a conceptual diagram illustrating an example isometric view of a heat pump defrost controller with break-away tabs according to one or more techniques of this disclosure.

FIG. 4A is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump with no low pressure switch.

FIG. 4B is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump the pressure switches in series with the contactor.

FIG. 4C is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump with pressure switches connected to the defrost control.

FIG. 4D is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump with a simple timer circuit.

FIG. 5A is a conceptual diagram illustrating an example coil temperature sensor.

FIG. 5B is a conceptual diagram illustrating an example coil temperature sensor connected to a heat exchanger coil.

FIG. 6 is a conceptual diagram illustrating an example air temperature sensor.

FIG. 7 is a conceptual diagram illustrating an example display sequence shown by a defrost controller according to one or more techniques of this disclosure.

FIG. 8 is a conceptual diagram illustrating example displays that may be shown on the menu and setting display of the defrost controller according to one or more techniques of this disclosure.

FIG. 9 shows an example setup processing using dual displays in accordance with the techniques of this disclosure.

DETAILED DESCRIPTION

[0008] In general, the disclosure is directed to a universal heat pump defrost controller device that is configured to determine when and for how long to cause a heat pump to enter defrost mode to remove ice from the outdoor heat exchanger coil. The defrost controller of this disclosure is configured to work with a variety of heat pumps which may implement a variety of defrost approaches. An example of a defrost approach may include a timing cycle, which puts the heat pump in defrost mode periodically for a set time. Other examples of defrost approaches include determining a temperature difference or a pressure difference between two or more areas of the heat pump and put the heat pump into defrost mode based on a temperature or pressure difference satisfying a predetermined threshold. Other examples of defrost approaches include some combination of temperature or pressure sensing along with periodic timing.

[0009] The universal heat pump defrost controller of this disclosure is includes an intuitive display and user input with which a user may install the defrost controller on a heat pump and configure the controller to efficiently control the defrost cycle. The universal heat pump defrost controller of this disclosure provides a defrost cycle control that is configurable to a particular heat pump approach, which may improve efficiency, equipment safety and reliability.

[0010] In some examples, the defrost controller on an existing heat pump installation may malfunction or fail. To replace a defective defrost controller, given the wide variety of heat pump models and manufacturers, a repair technician may either need to carry a large number and variety of replacement parts on the repair truck or delay a repair until the replacement model of defrost controller is delivered to the repair site. A repair technician may instead carry a few universal defrost controllers that can be used on a variety of heat pump models. Installing a replacement defrost controller may require a significant amount of field configuration to work properly with the existing heat pump. In some examples, even replacing a defrost controller with the exact replacement part may require a significant amount of field configuration to account for changes in climate from default settings for the defrost controller.

[0011] Heat pump controllers, and heat pumps, from different manufacturers may operate at different temperatures, place their sensors in different locations, and have differing rates of frost accumulation. The large amount of variation may require in depth knowledge by the repair technician to properly configure the heat pump controller. Some examples of existing heat pump controllers have no display and may either be non-configurable or offer very little configurability. Some examples of universal defrost controllers, while capable of replacing many models, may be difficult to setup or require a great amount of heat pump appliance knowledge to configure properly. In this disclosure a repair technician may also be referred to as an installer.

[0012] In contrast, the universal heat pump defrost controller of this disclosure includes a controllable display on the defrost controller and may also include wireless connectivity to configure the controller via communication with a computing device. For example, the defrost controller of this disclosure includes a display for showing operating temperatures, which may show the installer normal/current operating temperatures of the appliance to help in troubleshooting and configuration. The defrost controller of this disclosure may display key parameters, such as outdoor air temperature and outdoor coil temperature so the installer can easily see the operating conditions to help the installer troubleshoot a malfunctioning or poorly configured appliance.

[0013] FIG. 1 is a block diagram illustrating one example of a climate control system including a heat pump with a defrost controller according to one or more techniques of this disclosure. Other examples of a climate control system using a heat pump may include more or fewer components than shown in FIG. 1.

[0014] Climate control system 100 is an example of a forced air system that may be used to control the temperature of an enclosed space, such as an office building, home, or other similar space. Example climate control system 100 includes a forced air heating, ventilation and air conditioning (HVAC) system 102, HVAC controller 116, thermostat 118, heat pump 130 and defrost controller 120.

[0015] HVAC system 102 is configured to draw return air 104 from one or more enclosed spaces, which may be indoor spaces. HVAC system 102 heats, cools or just circulates the air back to living spaces 106. HVAC system 102 includes a blower 112 mechanically connected to blower motor 114, heat exchanger 110, and one or more auxiliary heat exchangers 108. In this disclosure, for simplicity, the heated and cooled spaces will be referred to as living spaces.

[0016] Blower motor 104 drives blower 112 via a belt, or some other mechanical connection. Blower 112 forces air through heat exchanger 110, auxiliary heat exchanger 108 and to living spaces 106, which draws return air 104 from return air ducts in the living spaces.

[0017] Heat exchanger 110 is an indoor heat exchanger connected via plumbing to an outdoor heat exchanger in heat pump 130. In cooling mode, heat exchanger 110 transfers energy from the air to liquid refrigerant in the coils of heat exchanger 110, thereby cooling the air sent to living spaces 106. In heating mode, heat exchanger 110 transfers energy from outside air passed through the outdoor heat exchanger coil in heat pump 130 (not shown in FIG. 1), thereby heating the air sent to living spaces 106.

[0018] Auxiliary heat exchanger 108 is used to heat the air sent to living spaces 106 when heat pump 130 does not provide adequate heat, such as during a defrost cycle, or if the outside air temperature (OAT) is too cold for heat pump 130 to function. Examples of auxiliary heat exchanger 108 may include an electric heating unit, such as a resistance heater, a heat exchanger connected to a gas or other type of furnace.

[0019] In the example of FIG. 1, HVAC controller 116 receives a signal from thermostat 118 and sends a signal to defrost controller 120 as well as control signals to HVAC system 102. In other examples, thermostat 118 may directly connect to HVAC system 102 and defrost controller 120. Thermostat 118 may send a call for heat or call for cold to HVAC controller 116, which may in turn send signals to heat pump 130 and HV AC system 102 to circulate cold or warm air to living spaces 106. HVAC controller may also send and receive signals from defrost controller 120 to control the defrost cycle of heat pump 130.

[0020] Defrost controller 120 is configured to operate with a variety of different heat pumps 130 operating in a variety of different climates. In some examples, defrost controller 120 may include one or more circuit boards, a display, input controls and a wireless communication interface. The one or more circuit boards may include a number of electrical connection terminals used to connect control or sensing signals between the components of heat pump 130 and defrost controller 120. Defrost controller 120 may also have connection terminals to communicate with HVAC controller 116 and/or directly with thermostat 118. Defrost controller 120 may also include one or more mounting tabs to mechanically secure defrost controller 120 to heat pump 130.

[0021] Defrost controller 120 may include one or more processors to execute the functions of the defrost controller. Examples of the one or more processors in defrost controller 120 may include any one or more of a microcontroller (MCU), e.g. a computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals, a microprocessor (μP), e.g. a central processing unit (CPU) on a single integrated circuit (IC), a controller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a system on chip (SoC) or equivalent discrete or integrated logic circuitry. A processor may be integrated circuitry, i.e., integrated processing circuitry, and that the integrated processing circuitry may be realized as fixed hardware processing circuitry, programmable processing circuitry and/or a combination of both fixed and programmable processing circuitry.

[0022] In some examples, defrost controller 120 may initiate defrost in heat pump 130 based on defrost controller 120 operating in timing mode or demand mode. In one example of a timing mode, a first timer may measure an accumulated run time on the compressor, such as thirty, forty-five, ninety minutes or other configurable time interval. When the accumulated compressor run time reaches the configured time interval, the defrost controller initiates a defrost mode for a set length of time. The interval may be configured based on the model and type of heat pump as well as the location of the heat pump. For example, in dry, arid climate, the interval may be set longer than the interval in more humid regions. The installer may configure the time interval, the defrost mode run time and other timing using the display on defrost controller 120, or via a wireless or wired connection to a computing device.

[0023] Demand mode may be based on a pressure difference or a temperature difference. A pressure difference system may consider that that ice on the coil may result in an increase in the pressure differential across the outdoor heat exchanger coil. A defrost controller operating in pressure demand mode may compare the pressure on both sides (input and output) of the outdoor coil. When the difference between the two pressures reaches a preset level, defrost controller 120 may initiate a defrost.

[0024] In temperature demand mode, defrost controller 120 may measure the temperature of the piping in the outdoor heat exchanger coil of heat pump 130 as well as the outside air temperature. As ice builds up on the coil, the refrigerant may not absorb as much heat from the outdoor air and the coil gets colder. In other words, as ice accumulates, this ΔT may increases because the coil temperature drops. Processing circuitry of defrost controller 120 may initiate a defrost when the temperature sensors indicate a preset ΔT limit has been satisfied.

[0025] Measuring the temperature at different points on the coil may affect the temperature difference input and therefore the operation defrost controller 120. Many outside factors, such as wind, dirt, and mechanical problems may affect the control threshold. The demand mode configuration of defrost controller 120 of this disclosure determines when to initiate a defrost based on the configured temperature set point and other factors. For example, processing circuitry within defrost controller 120 may include instructions to automatically detect when heat pump 130 is in heating vs cooling mode. For example, by sensing the temperature of the heat pump coil, defrost controller 120 may determine if heat pump 130 is heating or cooling based on the temperature rise of the outdoor coil. An outdoor coil rising in temperature may indicate cooling mode. An outdoor coil dropping in temperature may indicate heating mode. Defrost functionality may be automatically enabled when coil temperature is detected in the applicable range. During setup of controller 120, an installer may configure defrost controller 120 the reversing valve system type for the particular heat pump 130. For example, heat pump 130 may energize the reversing valve when in cooling mode (O) or may energize the reversing valve when in heating mode (B).

[0026] In some examples, other timers may be used in demand mode. A minimum defrost interval timer may disable the temperature or pressure imitated defrost until a minimum interval from the previous defrost cycle has expired. A fail-safe timer may be incorporated to limit the maximum length of a defrost cycle. This timer may be used as a backup in case the coil sensor fails and does not terminate defrost.

[0027] FIG. 2 is a conceptual diagram illustrating an example front view of a heat pump defrost controller according to one or more techniques of this disclosure. Defrost controller 200 is an example of defrost controller 120 described above in relation to FIG. 1 and includes the same characteristics and functions.

[0028] Defrost controller 200 is configured with a square form factor, in which the vertical dimensions 232 are approximately equal to the horizontal dimensions 230. Also, the size of defrost controller 200 is small, when compared to other examples of defrost controllers. Defrost controller 200 is intended as a replacement for original equipment manufacturer (OEM) defrost controllers or other universal controllers. Other components and various wires and cable assemblies. it can be very difficult to find room to install any new devices or kits in an existing heat pump, such as heat pump 130 described above in relation to FIG. 1. Because the space available on most heat pumps is limited, the small relative size and square form factor of defrost controller 200 provide advantages over other types of defrost controllers. Defrost controller 200 may be installed in a heat pump with limited space and in either a horizontal or vertical rotation to be compatible with a wide variety of heat pumps. Defrost controller 200 includes menu display 202 and setting display 204, indicator lights 206, controls 208, 210 and 212, circuit board 222 on which are mounted temperature sensor connectors 216 and 218, other connectors 214 and relay 220. In some examples, circuit board 222 may also include processing circuitry 223, shown as a dashed line image.

[0029] The connectors on circuit board 222 are arranged to be all together and below control and indicator panel 234 of defrost controller 200. Control and indicator panel 234 may also be referred to as user interface 234. In some examples the connectors on circuit board 222, such as other connectors 214 may be spade connectors or other type of quick connect electrical connectors. Having all the connectors, each connector with a clear label, in one location below control and indicator panel 234, may provide advantages over other examples of defrost controllers that have difficult to read labels, and may have wiring connections coming from different locations and out of different directions from the circuit board. In contrast, the arrangement of the electrical connectors of defrost controller 200 may simplify installation and thereby reduce installation time, minimize confusion, rework and troubleshooting. In some examples, other connections 214 may include connections to power the reversing valve or to power the auxiliary heat or some portion of the auxiliary heat while the heat pump is in defrost. Defrost controller 200 may be configured to automatically turn on auxiliary heat when in defrost, or rely on the thermostat to call for auxiliary heat as needed.

[0030] Some examples of other connectors 214 may be seen in the table below

Table 1 - Connections

Name	Function
R	Hot (24V in some examples)
C (COM)	Common
W	Aux/emergency heat request from thermostat-W requests will cause the AUX output to be energized.
Y	Compressor request from thermostat or HVAC controller-Y requests will cause the COMPR and FAN terminals to be energized.
O	Reversing valve request from thermostat or HVAC controller - controls the status of the RV output. May connect to either O or B wire of a heat pump.
HPS (or HPC) (2 terminals)	High pressure cutout/switch- these terminals must be shorted for compressor operation.
LPS (or LPC) (2 terminals)	High pressure cutout/switch- these terminals must be shorted for compressor operation.

(continued)

Name	Function
AUX	Output to auxiliary/emergency heat -energized during a defrost cycle or when requested by W input.
CONT (2 terminals)	Output to compressor contactor-energized by Y request. The CONT terminal may also be labeled as a COMPR terminal.
REV (or RV) (2 terminals)	Output to reversing valve. Energized by 0 input and as required by a defrost cycle.

[0031] Air temperature sensor connector 218 may receive the OAT from a temperature probe (not shown in FIG. 2). Coil temperature sensor connection 216 may receive the temperature of the outdoor heat exchanger coil (not shown in FIG. 2). Processing circuitry of defrost controller 200 (not shown in FIG. 2) may use the temperature information to execute the temperature demand mode functions described above in relation to FIG. 1. In some examples, connecting one or more temperature sensors may automatically configure defrost controller 200 to perform certain functions. For example, processing circuitry of defrost controller 200 may implement the most sophisticated defrost algorithm as determined by the sensors connected to it. In the example of both sensors (air and coil temperatures) are in place, the processing circuitry may implement temperature demand defrost mode. In the example of only the coil sensor in place (air temperature sensor omitted), the processing circuitry may implement a hybrid timed mode in which a period of time while the coil is below some threshold temperature may be used as the defrost trigger. As one example defrost controller 200 may defrost after 30 minutes of runtime below 35degF is detected.

[0032] Defrost controller 200 may be configured to automatically switch between operating modes. For example. In the event that the air temperature sensor fails, defrost controller 200 may be configured to automatically switch from temperature demand mode to timed mode. The air temperature sensor may fail for example, if the sensor becomes disconnected or damaged, such as because of weather. Processing circuitry within defrost controller 200 may detect the status of the air temperature sensor, or some other sensor, e.g. that the sensor is malfunctioning or providing signals that indicate a malfunction. Similarly, the processing circuitry may detect that a sensor has been disconnected or is in some other inactive status.

[0033] Relay 220 may control a fan or blower used to move outside air through the outside heat exchanger (not shown in FIG. 2). In some examples, a fan may be installed on top of a heat pump, such as heat pump 130 depicted in FIG. 1. The fan may pull outside air through the coils of the outside heat exchanger and out through the top of the heat pump. In some examples, processing circuitry in defrost controller 200 may cause relay 220 to shut off the fan during a defrost.

[0034] In some examples, the circuit board layout of defrost controller 200 may be configured to allow for a variety of configurations while maintaining a reduced cost when compared to other examples of defrost controllers. Circuit board 222 may include the main functions of defrost controller 200, such as the processor, display driver, and connections. To maintain a small form factor, a second circuit board (not shown in FIG. 2) may be stacked on top of circuit board 222 and include other optional functions. The second circuit board may include a wireless function in some examples, a wired communication connection in other examples, a variety of options for indicator lights 206 and so on. In this manner, defrost controller 200 may be manufactured with the same main circuit board used in all variations, and one or more different second circuit boards that include additional options, which may reduce the cost of manufacturing.

[0035] Menu display 202 and setting display 204, in the example of FIG. 2, are seven-segment light emitting diode (LED) displays. In other examples, other types of displays may be used, including a liquid crystal display (LCD), or other types of displays. Menu display 202 and setting display 204 are the same type of off-the-shelf display, which provides an advantage over other types of displays. Using an off-the-shelf display may reduce costs by not using a customized display. Also, using the same type of display for both menu display 202 and setting display 204 may reduce manufacturing cost by reducing the number and types of components that need to stocked in a production facility. Having two discrete displays with separation 203 between them may make the overall user interface easier to follow and less confusing. The separation may, for example, be plastic or some other color or material that contrasts with the color and material of menu display 202 and setting display 204. In one example implementation, menu display 202 displays a menu item, and setting display 204 displays the setting for that menu item.

[0036] Indicator lights 206 may include one or more indicators that provide information to an installer. In the example of FIG. 2, indicator lights 206 include a system light, a wireless light and a fault light. In other examples, indicator lights 206 may include more or fewer lights and have different functions than those depicted in FIG. 2. For example, a defrost controller without a wireless capability may not include the wireless indicator light. As another example a green indicator in the system light may indicate proper system power and operation. A red indicator light in the fault light may indicate a system fault. The installer may use controls 208, 210 and 212 as well as menu display 202 and setting display 204 to review and troubleshoot a fault indication or other diagnostic information. Alternatively, an installer may communicate with defrost controller 200 via a wireless connection to a computing device.

[0037] In some examples defrost controller 200 may include an optical indicator 205. Examples of optical indicator 205 may include a QR code, barcode or similar optical indicator. In some examples, an installer may initiate a wireless connection with defrost controller 200 by reading optical indicator 205 using, for example a mobile computing device. Optical indicator 205 may provide connection and identification information for defrost controller 200 to a software product executing on the mobile computing device.

[0038] In operation, both menu display 202 and setting display 204 may depict either numbers or characters. In some examples, menu display 202 may depict the category or mode and setting display 204 may depict the value or setting of the category or mode. In other examples, menu display 202 and setting display 204 may be combined to display a set of characters or numbers. An installer may configure defrost controller to operate with a particular heat pump by selecting a category in menu display 202 by changing the value in menu display 202 with the controls, such as up button 208, down button 210 and select button 212. The installer may read the value of the selected category in setting display 204. The installer may further change the value of the selected category by pressing up button 208, down button 210 and select button 212 as appropriate. In some examples, pressing combinations of buttons, or pressing and holding one or more buttons for a selected period of time may perform other functions. For example, pressing an holding the select button for a period of time may reset a category value to a default value. In other words, processing circuitry in defrost controller 200 receives input from up button 208, down button 210 and select button 212 and causes menu display 202 and setting display 204 to depict the appropriate value. Some examples of categories that may be found in the table below.

Table 2 - Example Categories of Settings

Category	Description	Value
1	Defrost Enable Temperature. Coil temperature where defrost functionality is active.	Temperature in degrees
2	Termination Temperature. Coil temperature where defrost is terminated.	Temperature in degrees
3	Defrost Cycle Time Time the coil temperature is below the Defrost Enable Temperature before a defrost is triggered if in timed mode (no outdoor air sensor present).	Time in minutes
4	Short Cycle Delay Time Minimum off time between compressor cycles.	Time in minutes
5	Reversing Valve System Type 0-reversing valve energized in cool. B- reversing valve energized in heat.	O or B
6	Reverse Delay 0-30 seconds 30seconds Compressor off time when switching between heating and defrost modes. Setting this to 0 will shorten the overall defrost time, but may result in objectionably loud noises when entering/exiting defrost (depending on compressor type).	Time in seconds
7	Maximum Defrost Time The maximum amount of time a defrost cycle can last. A defrost cycle may be terminated earlier if the coil reaches the Termination Temperature, but a defrost cycle should never last longer than this time.	Time in minutes
8	Aux Heat Lockout Temperature W requests will be ignored if the outdoor temperature is higher than this set temperature. The Aux heat output will still function normally during a defrost cycle regardless of this setting.	Temperature in degrees
9	Compressor Lockout Temperature - Y requests will be ignored if the outdoor temperature is lower than this temperature.	Temperature in degrees
10	Temperature selection (Fahrenheit or Celsius)	F or C

[0039] Some other options that may be configured include:

- Compressor Disable Temperature - compressor operation prohibited below a predetermined temperature
- Aux Heat Disable Temperature - auxiliary heat operation prohibited above this temperature
- Reversing Valve Travel Time - delay between reversing the valve and deenergizing the compressor
- Refrigerant Reversing Delay - time the compressor is held OFF following reversal, which may reduce noise.
- Short Cycle Delay - the minimum time the compressor must be off before allowing restart
- Defrost Temperature - coil temperature threshold used for defrost determination
- Cycle Time - time the coil can be below Defrost Temperature before a defrost is triggered
- Max Defrost Time - maximum allowable length of a defrost cycle

[0040] In one example, menu display 202 and setting display 204 may be configured to blink, with blinking indicating which of the two is active. In this context, active means which of menu display 202 and setting display 204 corresponds to the parameter being changed, such as whether a category or menu level is being changed (e.g., menu display 202) or a value/setting for the category or menu level (e.g., setting display 204) is being changed. An installer may, for example, push the up/down buttons to choose which category they want to change (the left menu display 202 numbers will blink), and then press select to enter that menu level. The menu number on menu display 202 then stops blinking and the setting icon (setting display 202) starts blinking. The installer can then press the up/down arrows to adjust the setting (i.e. 30, 60, 90 minute timer, etc) for that menu item. The value for the menu item will be shown on setting display 202. By pressing select, the installer can lock in the setting and go back to the main menu. The installer can press and hold select to complete setup.

[0041] Defrost controller 200 may be configured to display the coil and air temperatures on the onboard display(s). It is also conceivable that the temperatures may be transmitted wirelessly through Bluetooth or WiFi for example, to be displayed or analyzed on a remote device. It is also conceivable that additional parameters be displayed such as refrigerant temperature delta across the coil, air temperature delta across the coil, refrigerant pressure, etc. Displaying temperatures helps the installer troubleshoot a malfunctioning or poorly configured appliance. Since the two key parameters (outdoor temperature and coil temperature) are displayed, the installer can easily see the operating conditions.

[0042] FIG. 3 is a conceptual diagram illustrating an example isometric view of a heat pump defrost controller with break-away tabs according to one or more techniques of this disclosure. Defrost controller 300 is an example of defrost controller 130 and defrost controller 200 described above in relation to FIGS. 1 and 2 respectively and includes the same functions and characteristics.

[0043] Defrost controller 300 includes control and indicator panel 334, relay 320, other connectors 314, and mounting tabs 240 and 242A and 242B. Control and indicator panel 334 includes menu display 302, setting display 304, and controls 308 as described above in relation to FIG. 2. The example of control and indicator panel 334 only includes two indicator lights 306, a system light and a fault light. Control and indicator panel 334 may also be referred to as user interface 334.

[0044] As described above in relation to FIG. 2, defrost controller 300 is intended as a replacement for an OEM defrost controllers or another universal controller. Because the space available on most heat pumps is limited, the small relative size and square form factor of defrost controller 300 may provide advantages over other types of defrost controllers. Additionally, it may be desirable for the installer to only use two mounting tabs to attach defrost controller 300 to a heat pump, such as heat pump 130 described above in relation to FIG. 1. Mounting tabs 242A and 242B as well as mounting tab 240 and a fourth mounting tab not visible in FIG. 3, but shown in FIG. 2, may be removed to fit in the tight space available on the heat pump. Defrost controller 200 may be mounted either horizontally or rotated to be mounted vertically.

[0045] Each mounting tab e.g. 240, 242A, 242B includes a thinned or weak region 245 to make it easier to remove one or more of the mounting tabs. In some examples region 245 may be scored or reduced in material thickness such as by a V-shaped or other shaped groove. A mounting tab that may interfere with installation may be broken off cleanly, in a manner that does not damage the housing 305 of the device, such as by using pliers or hands to bend the mounting tab. In this manner, defrost controller 300 may be securely mounted in a variety of heat pumps to withstand vibration that may be caused by the heat pump compressor, fan or other components, yet be compatible with the limited space available inside a heat pump. Thus, defrost controller 300 represents an example of a defrost controller that can include four mounting tabs connected to the housing 305. At the time of install, an installer may be able to easily remove any of the four mounting tabs in order to achieve a better placement or fit when mounting the defrost controller inside a heat pump.

[0046] FIGS. 4A - 4D are a schematic wiring diagrams of a heat pump defrost controller according to one or more techniques of this disclosure. Defrost controllers 400A - 400D are examples of defrost controller 130 and defrost controller 200 described above in relation to FIGS. 1 and 2 respectively and includes the same functions and characteristics. The connection terminals depicted in FIG. 4A - 4D are similar to those described above in relation to FIG. 2 and Table 1.

[0047] FIG. 4A is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump with no low pressure switch. The high pressure switch (HPC) connections on defrost controller 400A connect to the high pressure switch on the heat pump. The low pressure switch (LPC) connections are shorted.

[0048] FIG. 4B is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump the pressure switches in series with the contactor. The compressor connection (COMPR) connects to the series connected high pressure switch, low pressure switch and contactor on the heat pump. The high pressure switch (HPC) connections are shorted to each other and the ow pressure switch (LPC) connections are shorted to each other. The example of FIG. 4B also has no connection to the defrost control.

[0049] FIG. 4C is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump with pressure switches connected to the defrost control. In the example of FIG. 4C, the high pressure switch (HPC) connections on defrost controller 400C connect to the high pressure switch on the heat pump. The low pressure switch (LPC) connections on defrost controller 400C connect to the low pressure switch on the heat pump.

[0050] FIG. 4D is a schematic wiring diagram of a heat pump defrost controller installed in a heat pump with a simple timer circuit. In the example of FIG. 4D, the Y connector of defrost controller 400D connects to the series connected high pressure switch, low pressure switch and contactor on the heat pump. The high pressure switch (HPC) connections are shorted to each other and the low pressure switch (LPC) connections are shorted to each other. In the example of FIG. 4D, the reversing delay and the short cycle delay described above in relation to FIG. 2, may be configured for a very short or to zero delay. In other examples, with the pressure switches not in series with the contactor, the high pressure switch (HPC) connections on defrost controller 400C may connect to the high pressure switch on the heat pump. The low pressure switch (LPC) connections on defrost controller 400C may connect to the low pressure switch on the heat pump. In the example of FIG. 4D, the coil sensor may be used to determine whether the reversing valve is set for heating mode or cooling mode.

[0051] FIG. 5A is a conceptual diagram illustrating an example coil temperature sensor. may connect to coil temperature sensor connection 216, described above in relation to FIG. 2. Coil temperature sensor 500 includes a temperature sensor at clip 502A and a connection 504, configured to mate with coil temperature sensor connection 216 depicted in FIG. 2.

[0052] In operation, processing circuitry within a defrost controller, such as defrost controller 200 described above in relation to FIG. 2, may receive a signal from coil temperature sensor 500 indicating the coil temperature to the processing circuitry. The processing circuitry may use the signal in determining the temperature difference between the coil and the outside air temperature to initiate a defrost cycle. In some examples, processing circuitry within the defrost controller may include instructions to automatically detect when heat pump is in heating or in cooling mode. For example, by sensing the temperature of the heat pump coil, the defrost controller may determine if heat pump is heating or cooling based on the temperature rise of the outdoor coil. An outdoor coil dropping in temperature may indicate heating mode. Defrost functionality may be automatically enabled when coil temperature is detected in the applicable range.

[0053] FIG. 5B is a conceptual diagram illustrating an example coil temperature sensor connected to a heat exchanger coil. Coil sensor clip 502B is an example of coil sensor clip 502A described above in relation to FIG. 5A. The location of coil sensor clip 502B on outside heat exchanger coil 506 may affect the configuration and the operation of a defrost controller of this disclosure. In some examples, and installer may place the sensor on the coil where the OEM sensor thermostat was located. The original settings for proper adjustment of the termination and enable temperatures on the defrost controller may be used if coil sensor clip 502B is placed in the same location as the OEM sensor. However, in other examples, the installer may utilize the configuration features of the defrost controller of this disclosure to ensure proper operation of the temperature sensing.

[0054] In some examples the location of the OEM sensor may be inaccessible or difficult to access. An installer may place the new coil sensor clip 502B on the coil loop nearest the expansion valve where refrigerant is entering the outside heat exchanger coil during the heating mode. This location may give the largest temperature difference between the air temperature and the coil temperature. The installer may utilize the configuration features of the defrost controller of this disclosure to configure the defrost controller for the new sensing setup.

[0055] FIG. 6 is a conceptual diagram illustrating an example air temperature sensor according to one or more techniques of this disclosure. Air temperature sensor 600 may be used to initiate a defrost cycle when a defrost controller of this disclosure is in the demand temperature mode.

[0056] Air temperature sensor 600 may include sensor 604 and connection 602. Connection 602 may be configured to mate with air temperature sensor connector 218 described above in relation to FIG. 2. Processing circuitry in the defrost controller may receive a signal from air temperature sensor connector 218 and determine the OAT based on the signal. The processing circuitry may initiate a defrost cycle based on a temperature difference between the OAT and the outside coil temperature satisfying a threshold. Use of the air sensor may be desirable because the defrost controller may reduce the number of unnecessary defrosts that are common among defrost timers and therefore improve efficiency of the heat pump.

[0057] FIG. 7 is a conceptual diagram illustrating an example display sequence shown by a defrost controller according to one or more techniques of this disclosure. Once the power is connected to a defrost controller of this disclosure, the menu display and setting display may cycle through the examples depicted in FIG. 7. In some examples the menu display and setting display may cycle through normal operating screens showing the current mode and the values of the two temperature sensors. The menu display and setting display of FIG. 7 are examples of menu display 202 and setting display 204 described above in relation to FIG. 2.

[0058] Mode screen 700 shows that the defrost controller is indicating the heat pump is in OFF mode. Other examples of current mode of operation may include heat, cool, delay and other similar modes.

[0059] Outdoor air temperature screen 702 displays the sensed OAT, for example as sensed by air temperature sensor 600 described above in relation to FIG. 6. The menu screen displays the character A, indicating air temperature and the setting display indicates 56 degrees. Temperature displays may be in Fahrenheit or in Celsius, depending on the configuration of the temperature display setting.

[0060] Coil temperature screen 704 displays the sensed outside heat exchanger coil temperature, for example as sensed by coil temperature sensor 500 described above in relation to FIGS. 5A and 5B. The menu screen displays the character C, indicating coil temperature and the setting display indicates 47 degrees.

[0061] FIG. 8 is a conceptual diagram illustrating example displays that may be shown on the menu and setting display of the defrost controller according to one or more techniques of this disclosure. The displays of FIG. 8 are examples of the display function described above in relation to FIG. 2 and Table 2.

[0062] A defrost controller may be placed in TEST mode (802), which may be used for a variety of functions, including to verify the function of the compressor, fan, and reversing valve and similar tests. During configuration, an installer may verify or set the termination temperature (804), which is indicated by the category 2, and the value of 90 degrees.

[0063] In some examples, for values that require three digits, the category may shift to the left-most position in the menu display, and the remaining digits shown in both the menu display and settings display. For example, a termination temperature of 103 degrees may be displayed as shown by 806. In other examples, the defrost controller display may use two-digit hexadecimal numbering to indicate the value or the category. As shown by 808, the termination temperature is shown in hexadecimal 67, which is equivalent to decimal 103 degrees. In other examples, the seven-segment displays may indicate any fault codes, fault history, and similar indications.

[0064] FIG. 9 shows an example setup processing using dual displays in accordance with the techniques of this disclosure. The example of FIG. 9 is another example of the display function described above in relation to FIG. 8.

[0065] The example of FIG. 9 shows several examples of how the user interface may appear during setup or operation. Controls may include a button (910) for entry, selection etc. one or more buttons (906) for changing selected values, indicators for OK (902), alert or caution (904) and error (908). The user interface may also display a dual set of digits. For setup, the left pair of digits (912) may represent the current setting being configured. The right pair of digits (914) may represent the options for that setting. The digit pair that is blinking (e.g. 916, 918) may indicate where the current focus is. The button (910) to the right of the digits may be also configured to toggle the focus, e.g. between the left and the right set of digits.

Claims

1. A device comprising:

a housing (305);
processing circuitry (223) positioned within the housing;
a user interface (334), comprising a display and controls operatively coupled to the processing circuitry, and
a plurality of electrical connectors (214) operatively coupled to the processing circuitry and supported by the housing,

wherein a first connector (AUX) of the plurality of connectors is configured to provide power to an auxiliary heat exchanger and a second connector (218, 216) of the plurality of connectors is configured to receive a signal from a temperature sensor, and
wherein the plurality of connectors is arranged adjacent to the user interface and each connector of the plurality of connectors is aligned in the same direction,

wherein the processing circuitry is configured to control a defrost cycle for a heat pump based on the configuration of the heat pump.

2. The device of claim 1, wherein the processing circuitry is configured to control the defrost cycle in a timing mode, wherein the processing circuitry is configured initiate a defrost cycle based on an accumulated run time of the heat pump, and wherein the defrost cycle comprises a defrost mode.

3. The device of claim 1, wherein the processing circuitry is configured to control the defrost cycle in a demand mode, wherein the processing circuitry controls the heat pump to enter a defrost mode based on a signal from one or more sensors.

4. The device of claim 3, wherein the one or more sensors comprises the temperature sensor, wherein the temperature sensor is configured to send a signal to the processing circuitry indicating a temperature of a coil of the heat pump.

5. The device of claim 4, wherein the processing circuitry is configured to imitate the defrost cycle based on a period of time while the coil is below a threshold coil temperature.

6. The device of claim 4,
wherein the temperature sensor is a first temperature sensor, the one or more sensors further comprising a second temperature sensor configured to indicate an outside air temperature to the processing circuitry, and
wherein the processing circuitry is configured to initiate the defrost cycle based on a difference between the indicated coil temperature and the indicated outside air temperature.

7. The device of claim 6, wherein the processing circuitry comprises a fail-safe timer configured to limit a length of time of the defrost cycle.

8. The device of claim 3,
wherein the one or more sensors comprises a first pressure sensor located at a first position on the heat pump and a second pressure sensor located a second position on the heat pump, and
wherein the processing circuitry is configured to initiate a defrost cycle based on a pressure difference between the first pressure sensor and the second pressure sensor satisfying a predetermined pressure threshold.

9. The device of claim 8, wherein the first pressure sensor is located at an input side of an outdoor coil of the heat pump and the second pressure sensor is located at an output side of the outdoor coil of the heat pump.

10. The device of claim 1, wherein the processing circuitry is configured to automatically switch between a first operating mode and a second operating mode.

11. The device of claim 1, further comprising a main circuit board and a second circuit board, wherein the second circuit board includes one or more additional options for the device.

12. A system comprising:

a heating, ventilation and air conditioning, HVAC, system (102);
a heat pump (130) comprising a heat exchanger coil (506) and coupled to the HVAC system;
an HVAC controller (116) configured to control the HVAC system to circulate cold or warm air; and
a defrost controller (120, 200, 300) configured to communicate with the HVAC controller, the defrost controller comprising:

a housing (305);
processing circuitry (223) positioned within the housing;
a user interface (334), comprising a display and controls operatively coupled to the processing circuitry, and
a plurality of electrical connectors (214) operatively coupled to the processing circuitry and supported by the housing,

wherein a first connector (AUX) of the plurality of connectors is configured to provide power to an auxiliary heat exchanger and a second connector (218, 216) of the plurality of connectors is configured to receive a signal from a temperature sensor, and
wherein the plurality of connectors is arranged adjacent to the user interface and each connector of the plurality of connectors is aligned in the same direction,

wherein the processing circuitry is configured to control a defrost cycle for the heat pump based on the configuration of the heat pump.

13. The system of claim 12, wherein the processing circuitry is configured to control the defrost cycle in a timing mode,

wherein the processing circuitry is configured initiate a defrost cycle based on an accumulated run time of the heat pump, and wherein the defrost cycle comprises a defrost mode.

14. The system of claim 12, wherein the processing circuitry is configured to control the defrost cycle in a demand mode, wherein the processing circuitry controls the heat pump to enter a defrost mode based on a signal from one or more sensors.

15. A method comprising:

operating, by processing circuitry, a defrost controller in a demand mode during a first time,

wherein the defrost controller is configured to control a defrost cycle for a heat pump based on the configuration of the heat pump;
wherein the processing circuitry is configured to initiate a defrost mode of the defrost cycle based on a difference between a first measurement of a first sensor and a second measurement of a second sensor satisfying a measurement threshold;

operating, by processing circuitry, a defrost controller in a timing mode during a second time different from the first time, wherein during the second time, determining, by the processing circuitry, that the first sensor is not providing the first measurement or the second sensor is not providing the second measurement.

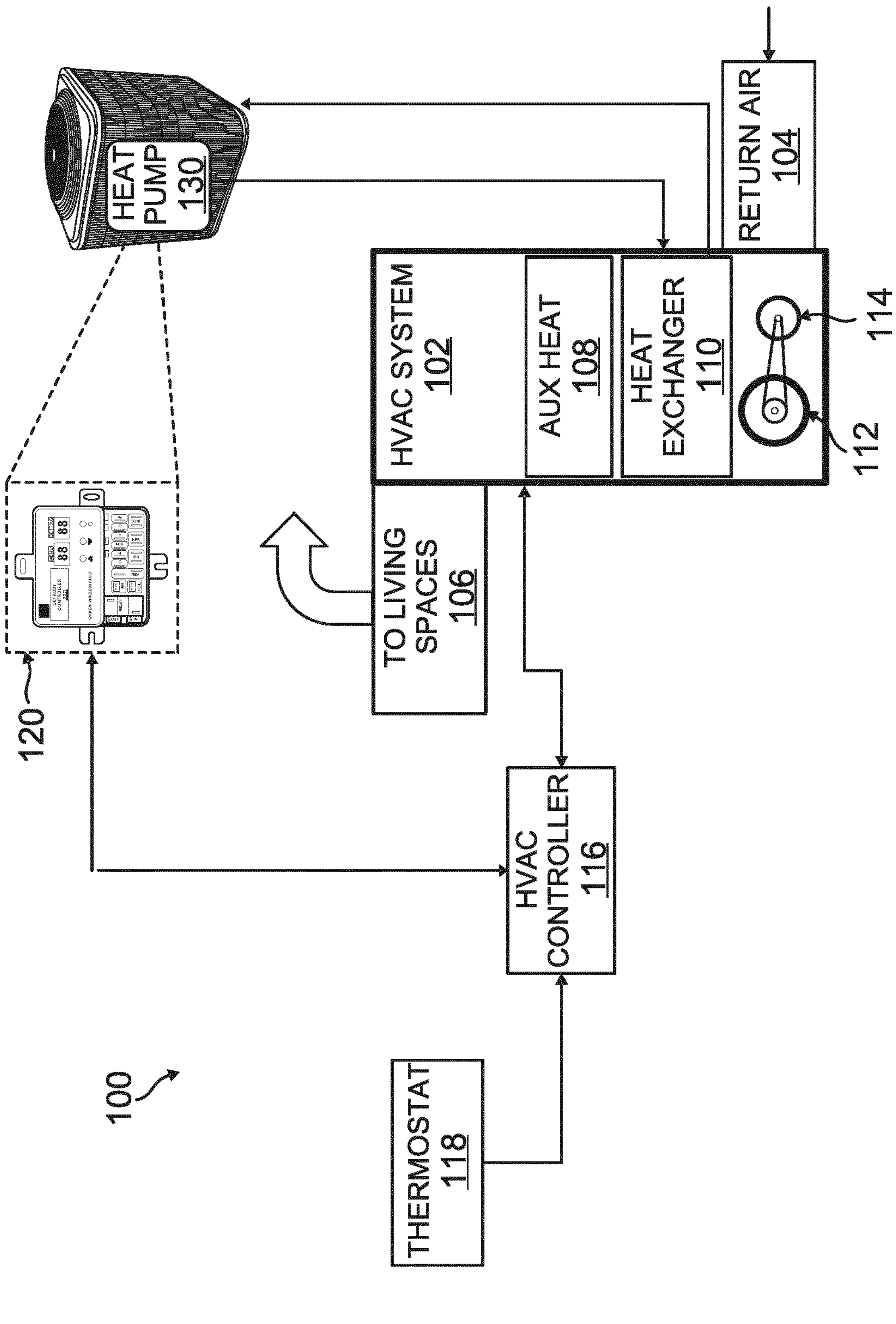

100
THERMOSTAT 118
HVAC CONTROLLER 116
120
TO LIVING SPACES 106
HVAC SYSTEM 102
AUX HEAT 108
HEAT EXCHANGER 110
112
114
HEAT PUMP 130
RETURN AIR 104

FIG. 1

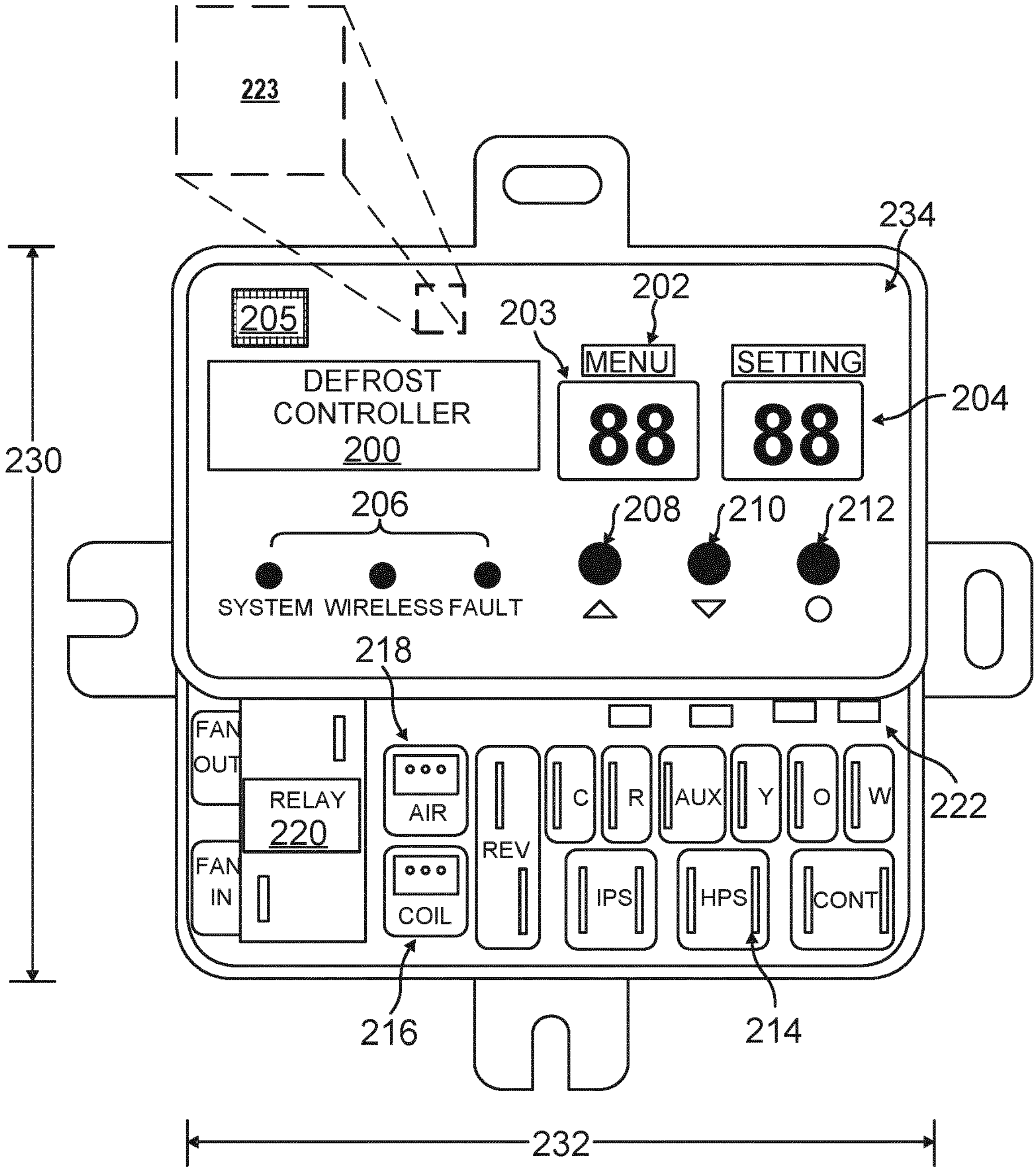

223
205
DEFROST
CONTROLLER
200
203
202
MENU
SETTING
234
88
88
204
230
206
208
210
212
SYSTEM
WIRELESS
FAULT
218
FAN OUT
RELAY 220
FAN IN
AIR
COIL
REV
C
R
AUX
Y
O
W
222
IPS
HPS
CONT
216
214
232

FIG. 2

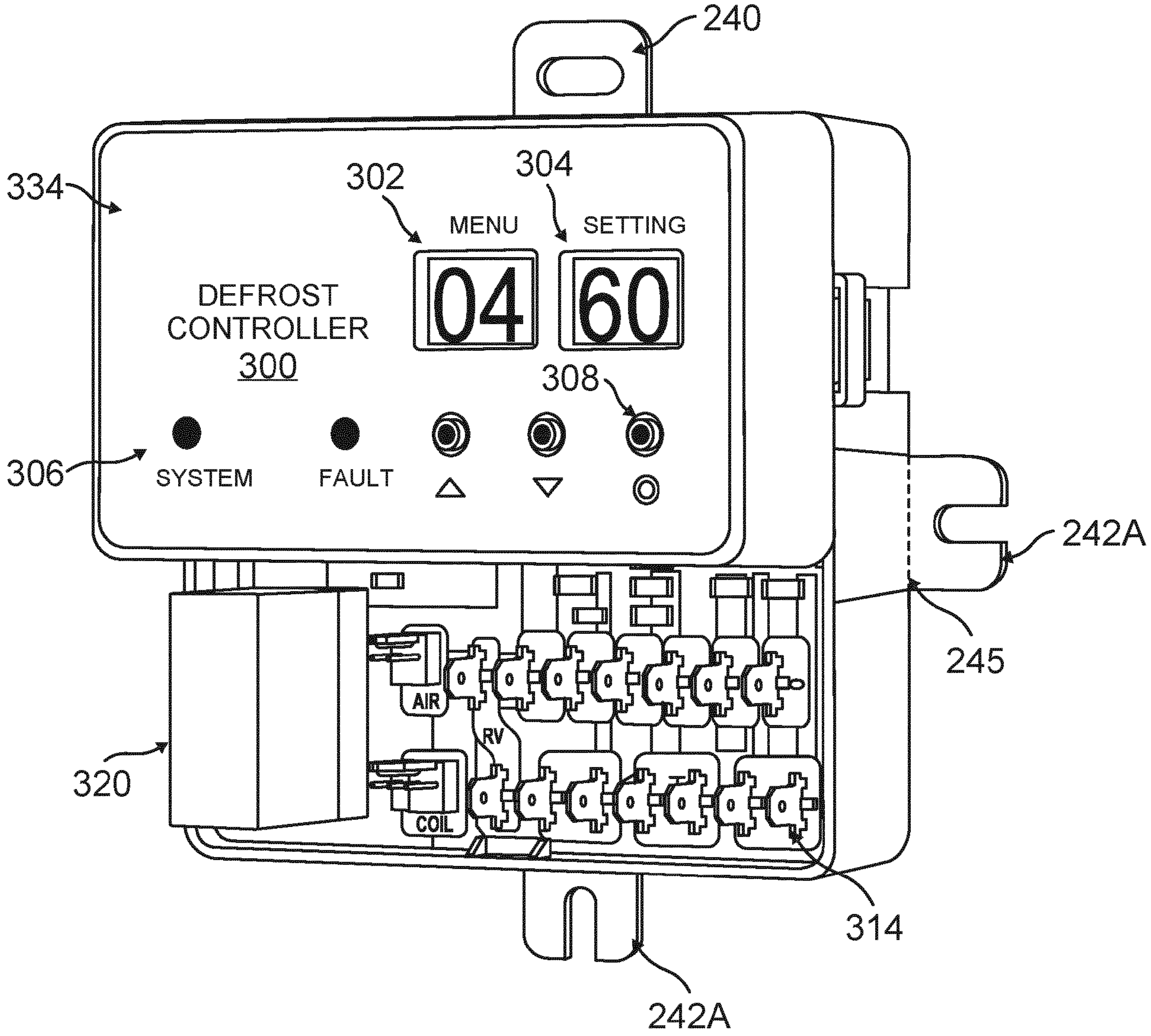

240
334
302
304
MENU
SETTING
DEFROST
CONTROLLER
300
04
60
308
306
SYSTEM
FAULT
242A
245
AIR
RV
320
COIL
314
242A

FIG. 3

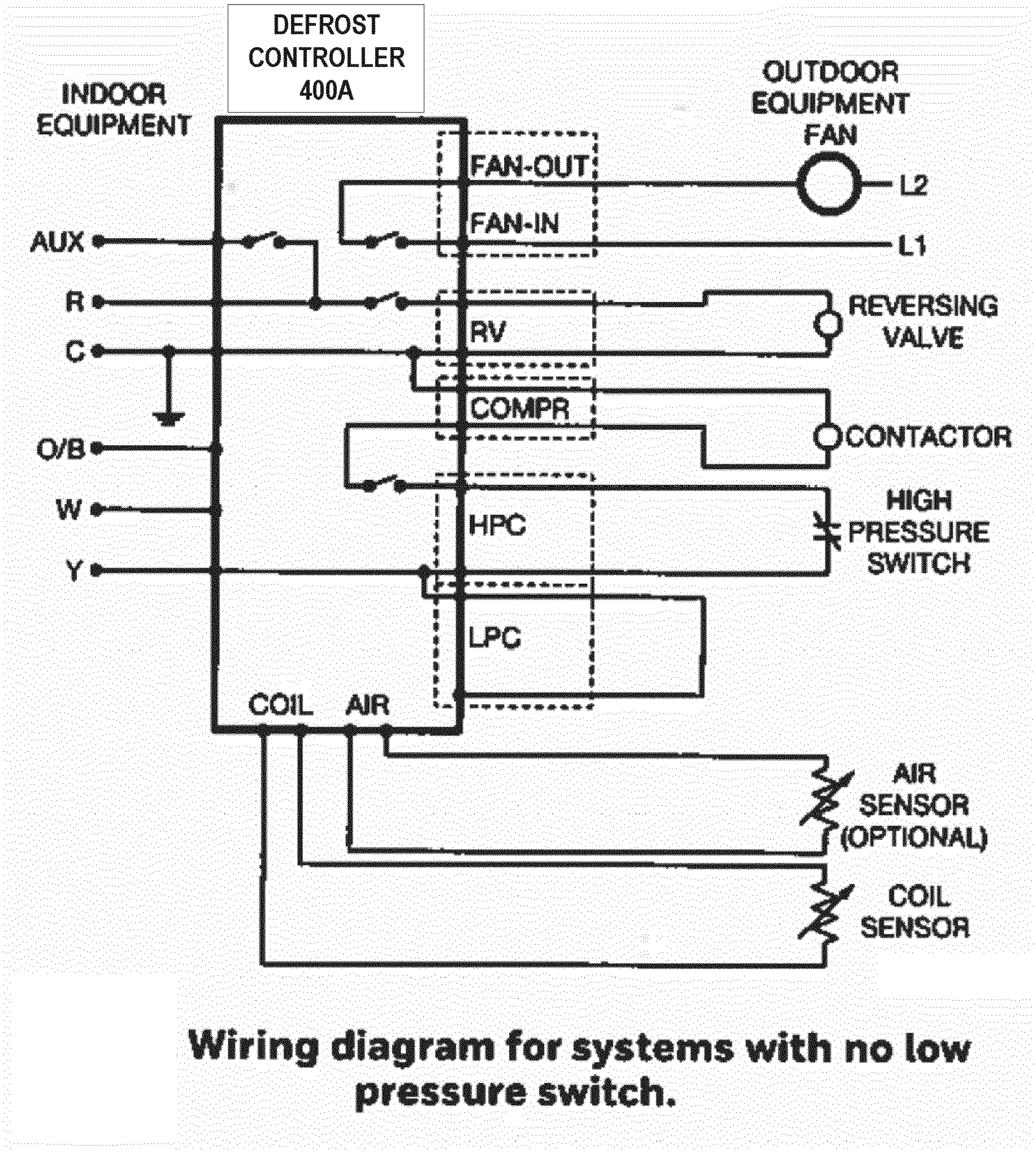
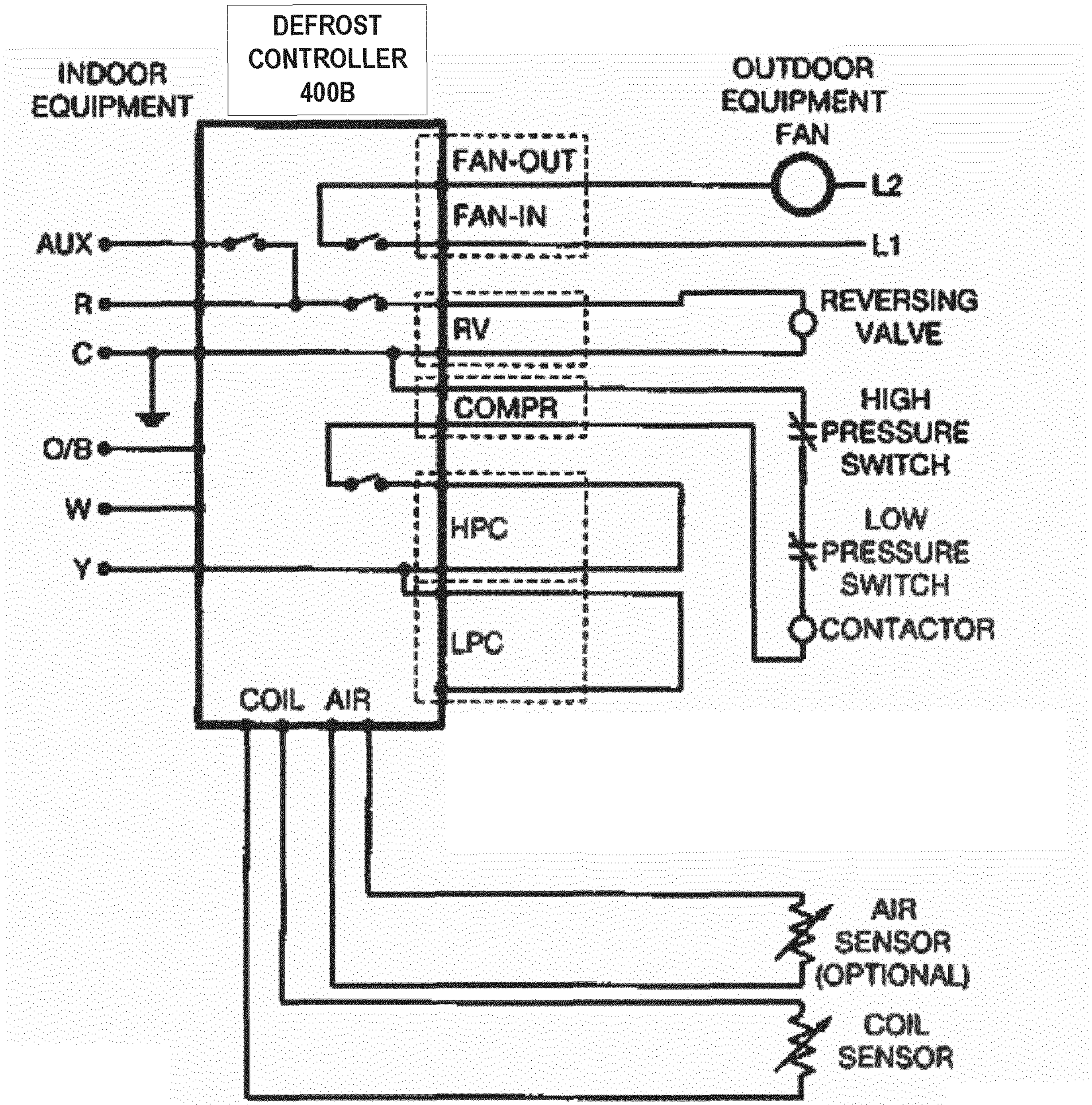

DEFROST
CONTROLLER
400A
INDOOR
EQUIPMENT
OUTDOOR
EQUIPMENT
FAN
FAN-OUT
FAN-IN
L2
L1
AUX
R
C
O/B
W
Y
RV
COMPR
HPC
LPC
REVERSING
VALVE
CONTACTOR
HIGH
PRESSURE
SWITCH
COIL
AIR
AIR
SENSOR
(OPTIONAL)
COIL
SENSOR
Wiring diagram for systems with no low pressure switch.

FIG. 4A



Wiring diagram for systems with pressure switches in series with the contactor and no connection to the defrost control.

FIG. 4B

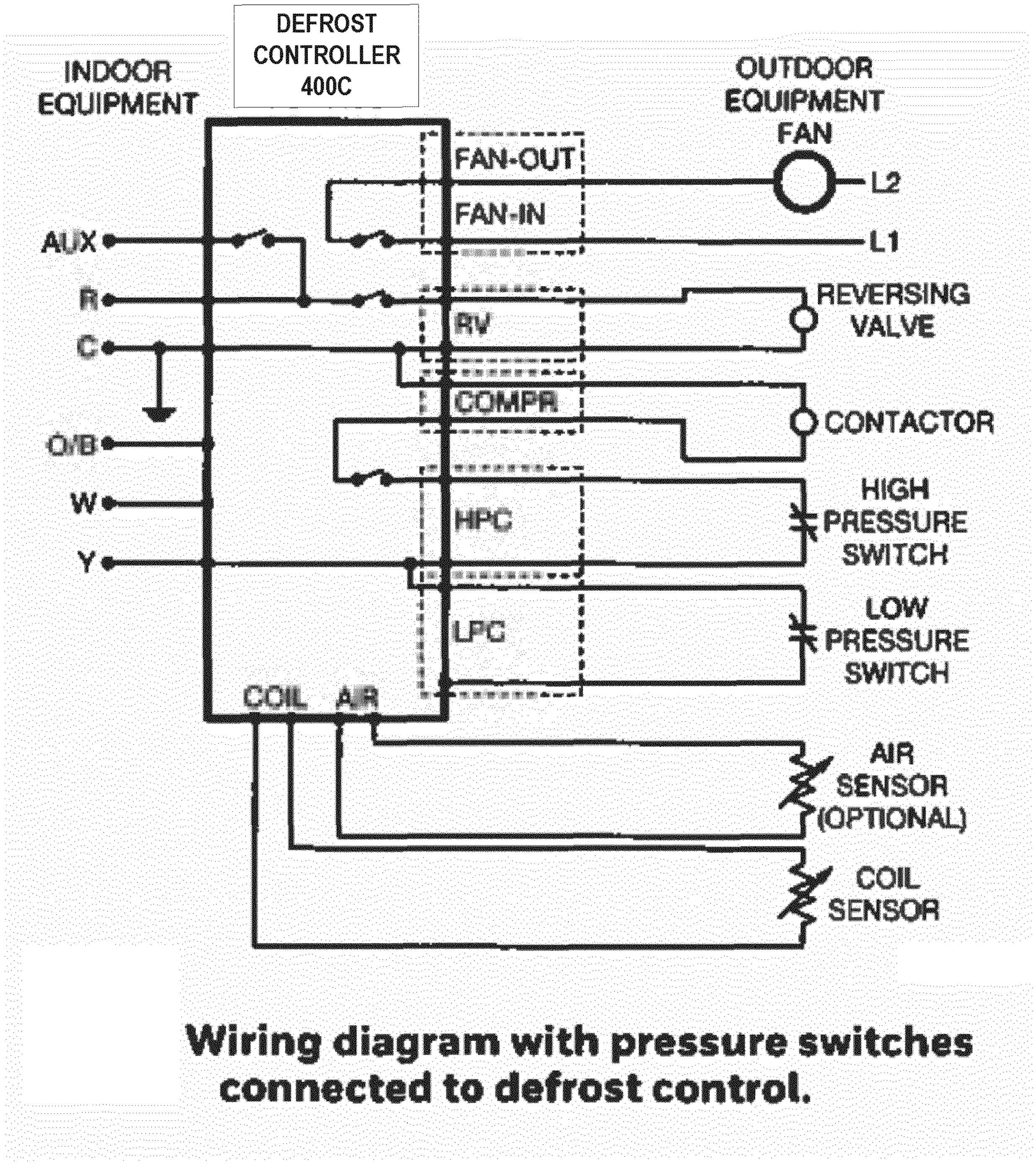

DEFROST
CONTROLLER
400C
INDOOR
EQUIPMENT
OUTDOOR
EQUIPMENT
FAN
FAN-OUT
FAN-IN
L2
L1
AUX
R
C
O/B
W
Y
RV
REVERSING
VALVE
COMPR
CONTACTOR
HPC
HIGH
PRESSURE
SWITCH
LPC
LOW
PRESSURE
SWITCH
COIL
AIR
AIR
SENSOR
(OPTIONAL)
COIL
SENSOR
Wiring diagram with pressure switches
connected to defrost control.

FIG. 4C

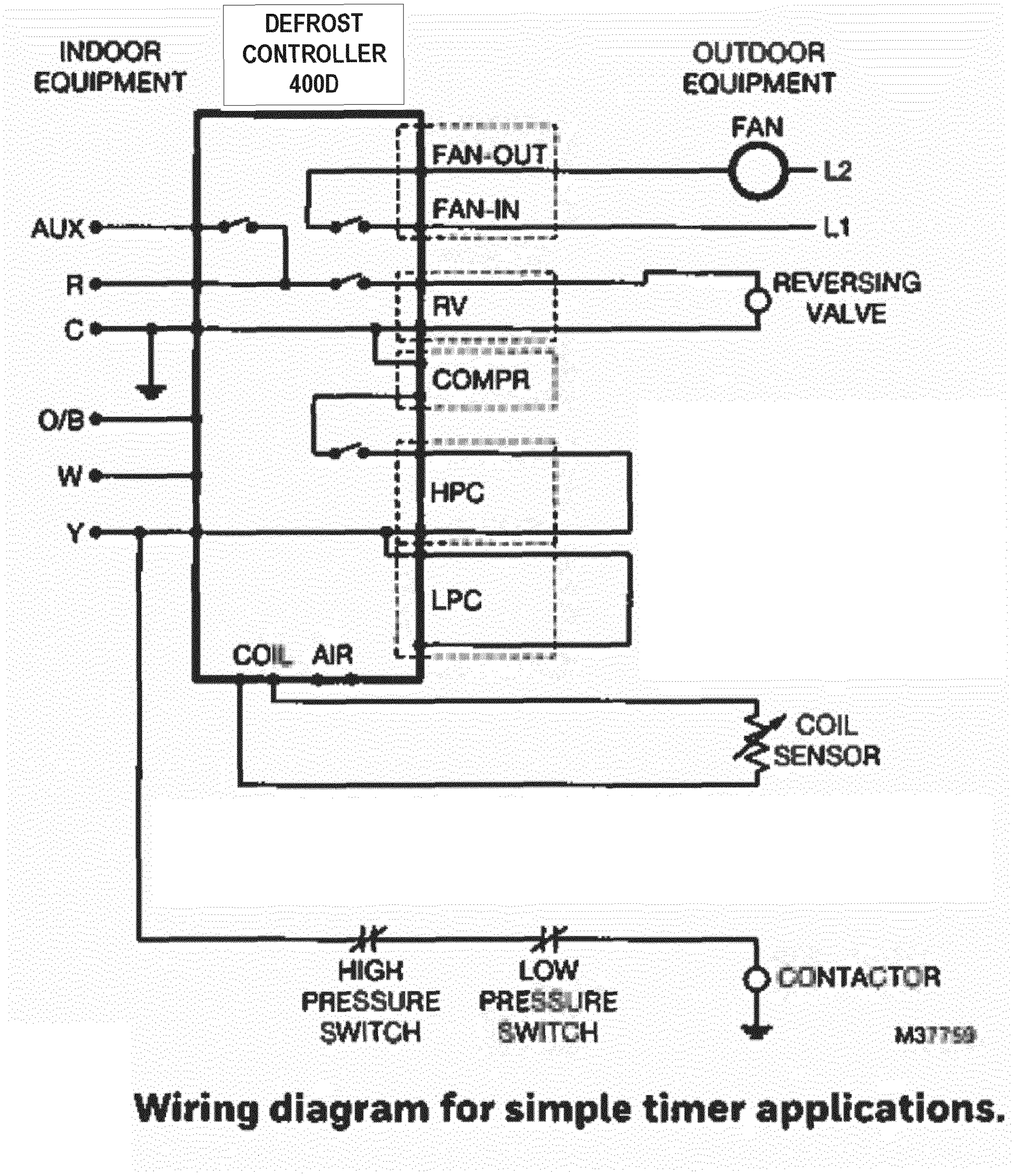

DEFROST
CONTROLLER
400D
INDOOR
EQUIPMENT
OUTDOOR
EQUIPMENT
FAN
FAN-OUT
FAN-IN
L2
L1
AUX
R
C
O/B
W
Y
RV
REVERSING
VALVE
COMPR
HPC
LPC
COIL
AIR
COIL
SENSOR
HIGH
PRESSURE
SWITCH
LOW
PRESSURE
SWITCH
CONTACTOR
M37759
Wiring diagram for simple timer applications.

FIG. 4D

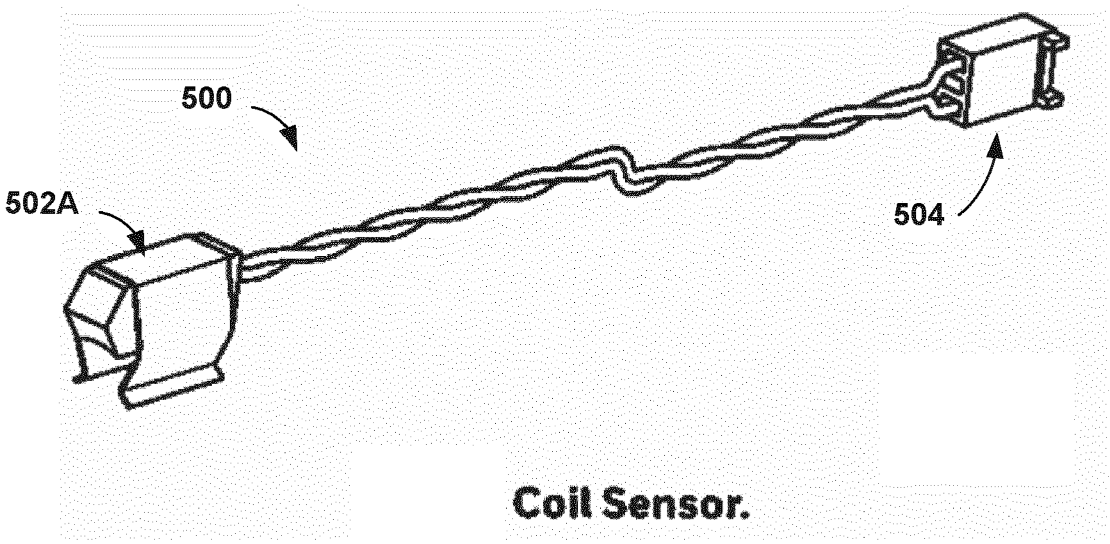

500
502A
504
Coil Sensor.

FIG. 5A

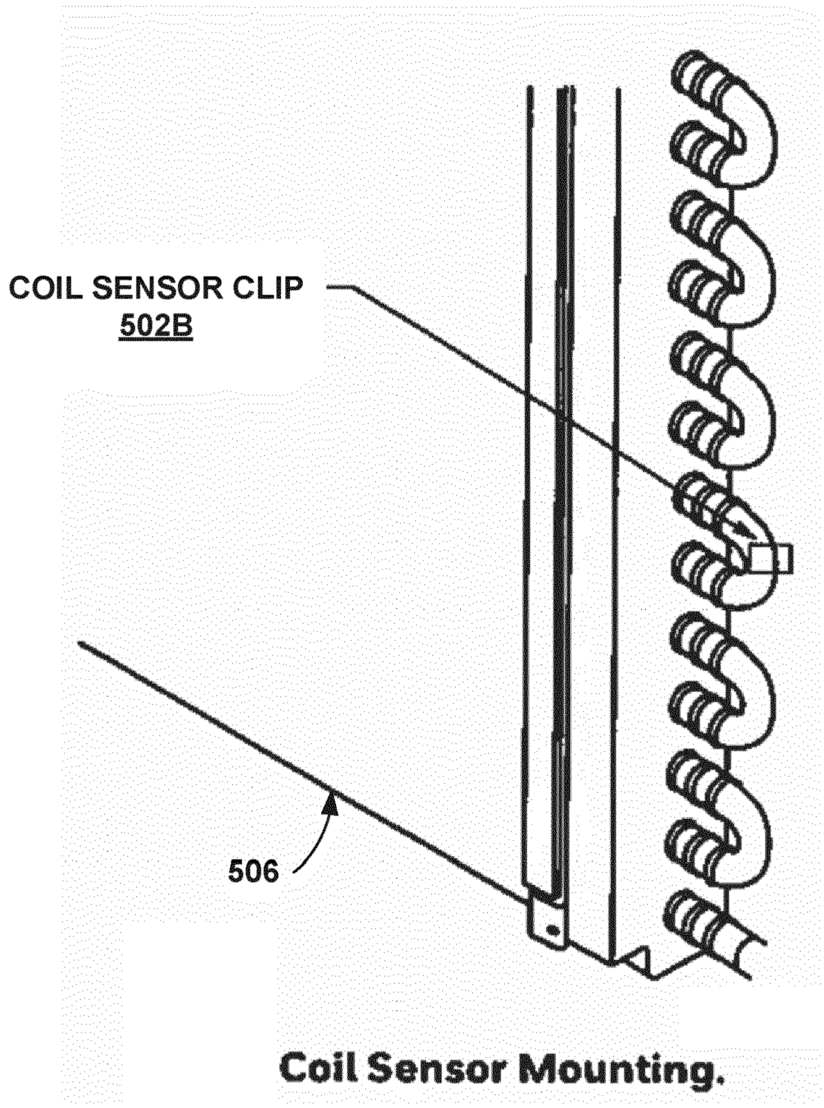

COIL SENSOR CLIP
502B
506
Coil Sensor Mounting.

FIG. 5B

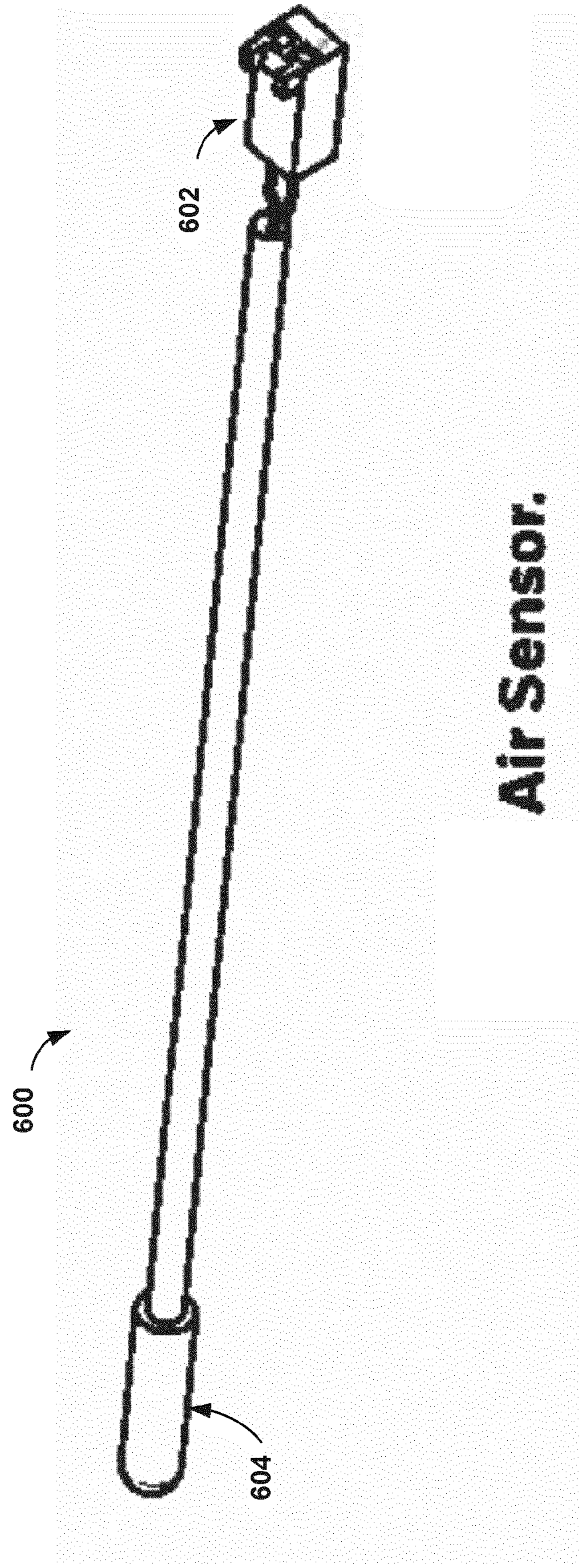


FIG. 6

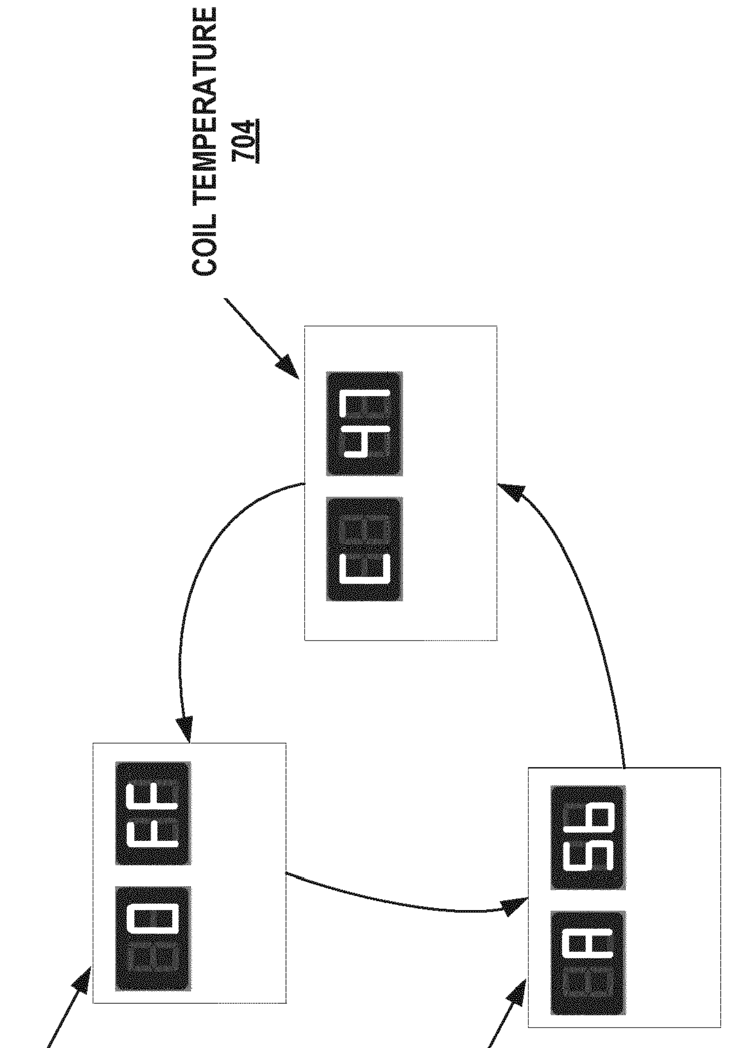


FIG. 7

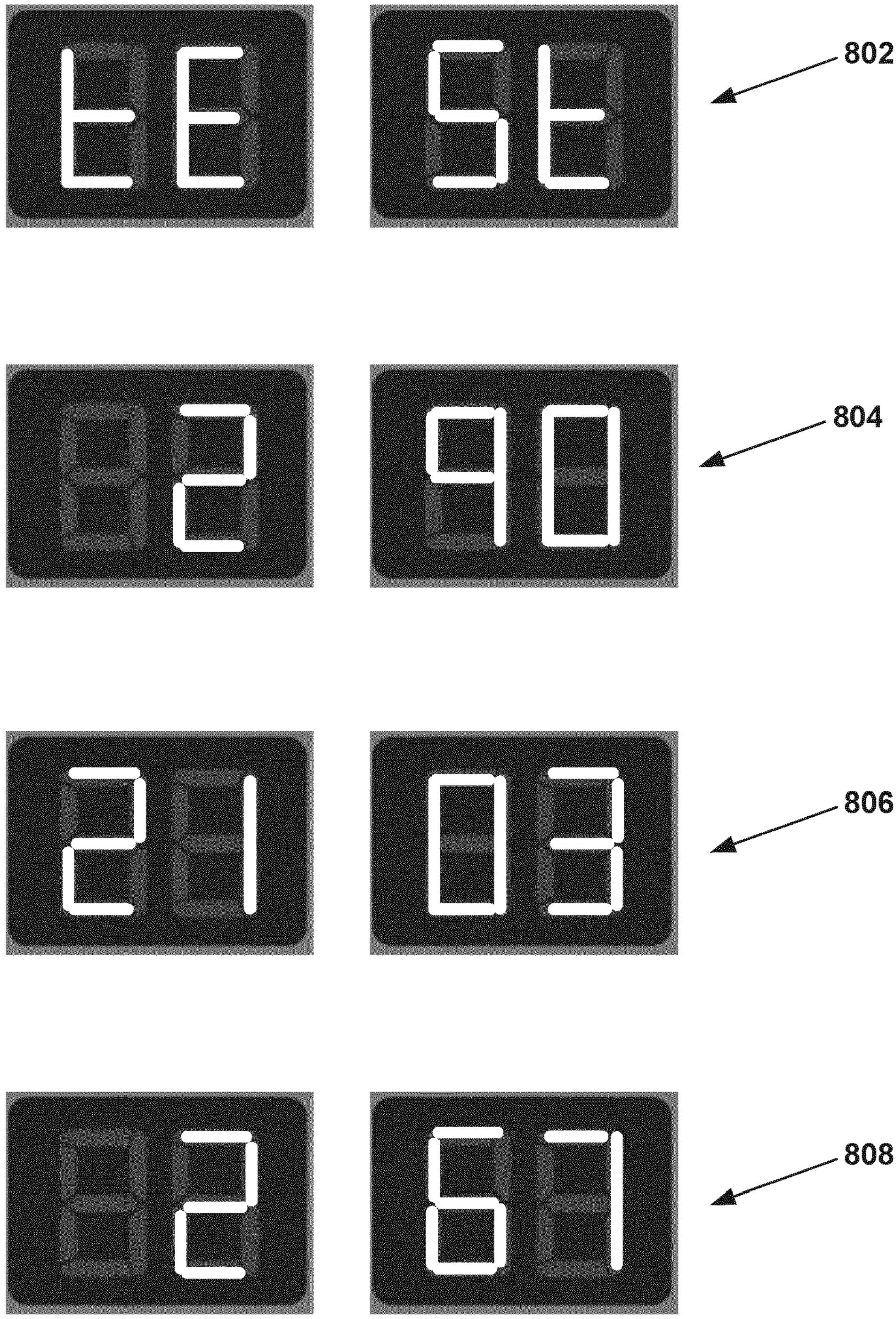


FIG. 8

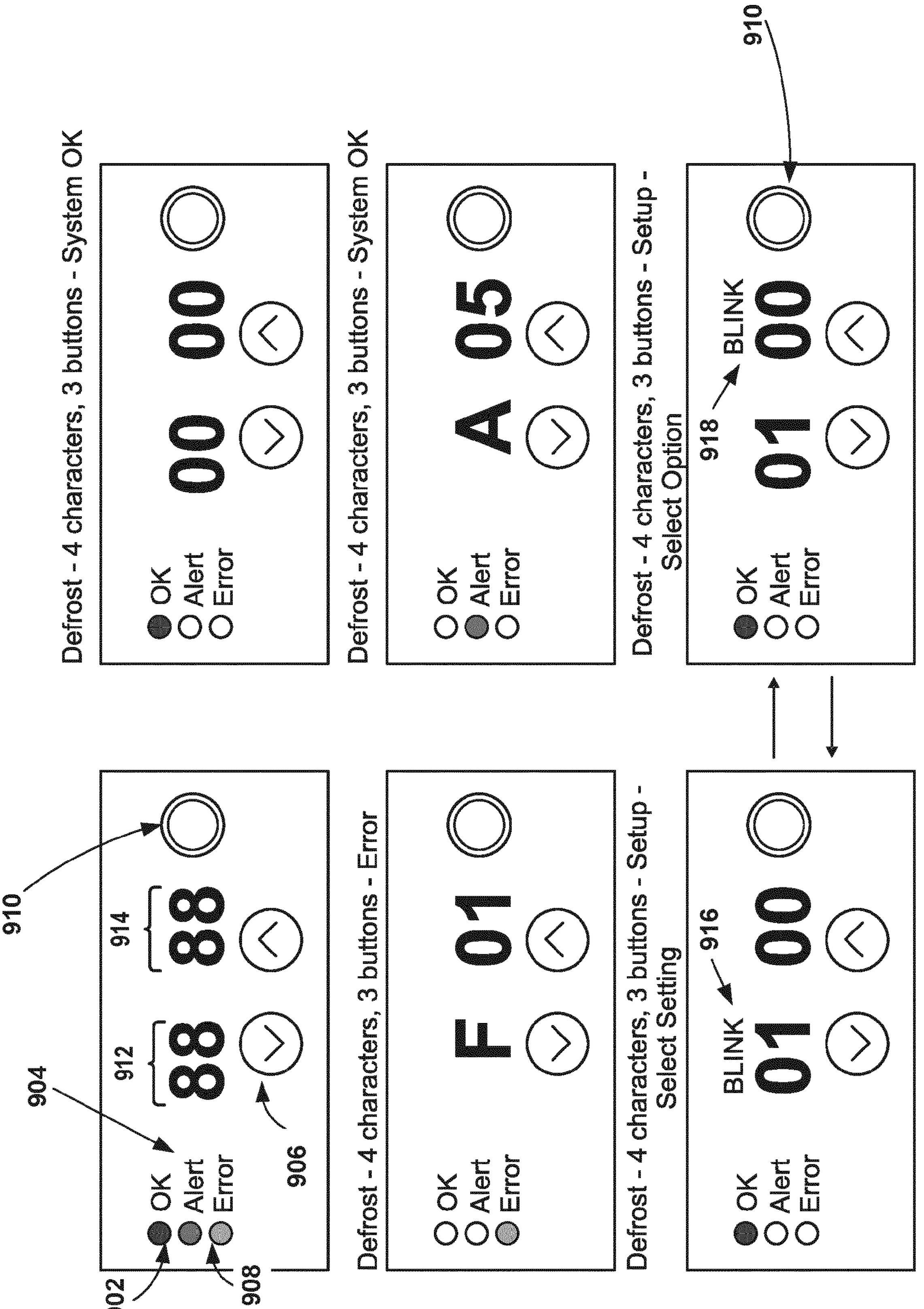

Defrost - 4 characters, 3 buttons - System OK
OK
Alert
Error
00 00
Defrost - 4 characters, 3 buttons - System OK
OK
Alert
Error
A 05
Defrost - 4 characters, 3 buttons - Setup - Select Option
OK
Alert
Error
918
BLINK
01 00
910
902
904
908
906
912
914
88 88
910
OK
Alert
Error
Defrost - 4 characters, 3 buttons - Error
OK
Alert
Error
F 01
Defrost - 4 characters, 3 buttons - Setup - Select Setting
OK
Alert
Error
BLINK
916
01 00

FIG. 9

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EUROPEAN SEARCH REPORT

Application Number
EP 19 21 7749

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	US 2015/184921 A1 (VIE DAVID L [US] ET AL) 2 July 2015 (2015-07-02) * paragraphs [0033] - [0035], [0040], [0041], [0048], [0053], [0057]; figures 1,2 *	1-7, 11-15 8-10	INV. F24F11/42 F24F11/52 F24F11/61 F24F11/62 F25B47/02 F25D21/00
Y	JP S60 142138 A (HONEYWELL INC) 27 July 1985 (1985-07-27) * claim 1; figure 1 *	8-10	
Y A	US 2015/211779 A1 (BRANDT GEORGE WILLIAM [US] ET AL) 30 July 2015 (2015-07-30) * paragraph [0038] *	8-10 1-7, 11-15	
A	US 2006/232907 A1 (HUBER TERRY L [US] ET AL) 19 October 2006 (2006-10-19) * paragraph [0023]; figure 1 *	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F24F F25B F25D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	7 May 2020	Degen, Marcello

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 19 21 7749

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07-05-2020

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		WO 2006113548 A2	26-10-2006

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