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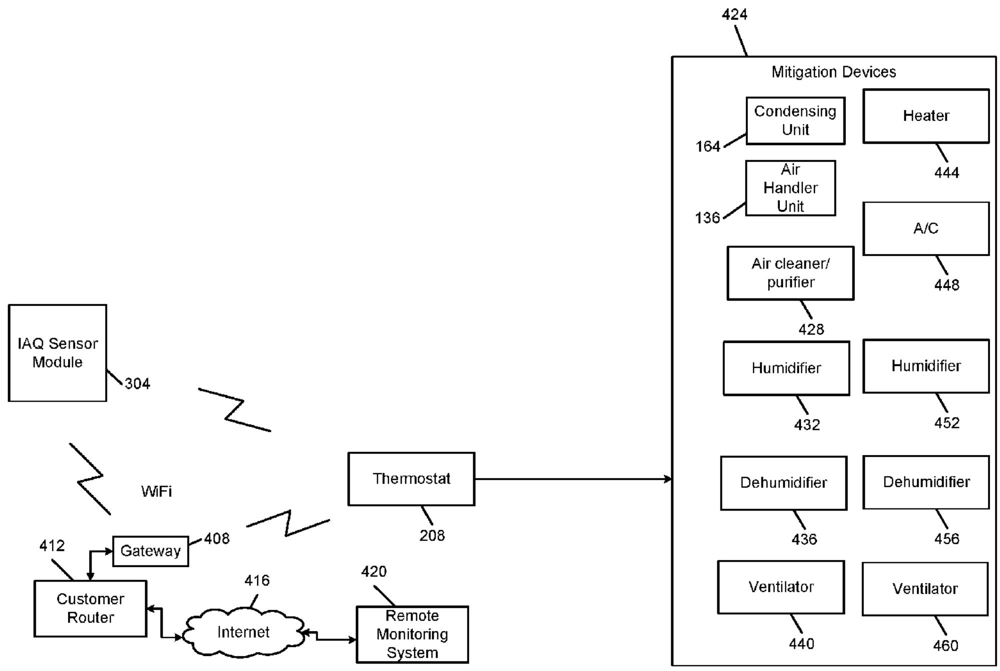

FIG. 4A

(57) **Abstract:** First and second IAQ sensors are located within a building and are configured to measure first and second IAQ parameters, respectively, the first and second IAQ parameter being the same one of: relative humidity; amount of particulate; amount of volatile organic compounds; and amount of carbon dioxide. A mitigation device is separate from an HVAC system and includes a control module configured to turn the mitigation device on and off based on the first IAQ parameter, the second IAQ parameter, and whether the HVAC system is on or off. A mitigation module is configured to selectively turn the HVAC system on and off based on the second IAQ parameter, the first IAQ parameter, and whether the HVAC system is on or off.

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COORDINATED CONTROL OF STANDALONE AND BUILDING INDOOR AIR QUALITY DEVICES AND SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/660,475, filed on April 20, 2018. The entire disclosure of the application referenced above is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to environmental control systems and more particularly to indoor air quality control systems and methods.

BACKGROUND

[0003] The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0004] A residential or light commercial HVAC (heating, ventilation, and/or air conditioning) system controls temperature and humidity of a building. Upper and lower temperature limits may be specified by an occupant or owner of the building, such as an employee working in the building or a homeowner.

[0005] A thermostat controls operation of the HVAC system based on a comparison of the temperature at a thermostat and the target values. The thermostat may control the HVAC system to heat the building when the temperature is less than the lower temperature limit. The thermostat may control the HVAC system to cool the building when the temperature is greater than the upper temperature limit. Heating the building and cooling the building generally decreases humidity, although the HVAC system may include a humidifier that adds humidity to warm air output by the HVAC system during heating of the building.

SUMMARY

[0006] In a feature, an indoor air quality (IAQ) system for a building is described. The IAQ system includes a heating, ventilation, and/or air conditioning (HVAC) system of the building. First and second IAQ sensors are located within the building and are configured to measure first and second IAQ parameters, respectively, the first and second IAQ parameter being the same one of: relative humidity (RH) of air; amount of particulate of at least a predetermined size present in air; amount of volatile organic compounds (VOCs) present in air; and amount of carbon dioxide present in air. A mitigation device is separate from the HVAC system and includes a control module configured to turn the mitigation device on and off based on the first IAQ parameter measured by the first IAQ sensor. A mitigation module is configured to selectively turn the HVAC system of the building on and off based on the second IAQ parameter measured by the second IAQ sensor. The control module is further configured to selectively turn the mitigation device on and off further based on at least one of: the second IAQ parameter; and whether the HVAC system of the building is on or off. The mitigation module is further configured to selectively turn the HVAC system of the building on and off further based on at least one of: the first IAQ parameter; and whether the mitigation device is on or off.

[0007] In further features, the mitigation module is configured to: turn the HVAC system of the building on when the second IAQ parameter is greater than a first predetermined value; and turn the HVAC system of the building off when the second IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

[0008] In further features, wherein the mitigation module is configured to turn the HVAC system of the building on when the first IAQ parameter is greater than a third predetermined value, wherein the third predetermined value is greater than the second predetermined value.

[0009] In further features, the control module is configured to turn the mitigation device on and off independently of the first IAQ parameter based on at least one of (i) the second IAQ parameter and (ii) whether the HVAC system of the building is on or off.

[0010] In further features, the mitigation module is configured to: turn the HVAC system of the building on in response to the mitigation device being turned on; maintain the HVAC system of the building on while the mitigation device is on; and turn the HVAC system of the building off in response to the mitigation device being turned off.

[0011] In further features, the mitigation module is configured to turn the HVAC system of the building on when at least one of: the second IAQ parameter is greater than a first predetermined value; and the mitigation device is turned on.

[0012] In further features, the control module is configured to: turn the mitigation device on when the first IAQ parameter is greater than a first predetermined value; and turn the mitigation device off when the first IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

[0013] In further features, the control module is configured to turn the mitigation device on when the second IAQ parameter is greater than a third predetermined value, where the third predetermined value is greater than the second predetermined value.

[0014] In further features, the mitigation module is configured to turn the HVAC system of the building on and off independently of the second IAQ parameter based on at least one of (i) the first IAQ parameter and (ii) whether the mitigation device is on or off.

[0015] In further features, the control module is configured to: turn the mitigation device on in response to the HVAC system of the building being turned on; maintain the mitigation device on while the HVAC system of the building is on; and turn the mitigation device off in response to the HVAC system of the building being turned off.

[0016] In further features, the control module is configured to turn the mitigation device on when at least one of: the first IAQ parameter is greater than a first predetermined value; and the HVAC system of the building is turned on.

[0017] In a feature, a method includes: by first and second indoor air quality (IAQ) sensors that are located within a building, measuring first and second IAQ parameters, respectively, the first and second IAQ parameter being the same one of: relative humidity (RH) of air; amount of particulate of at least a predetermined size present in air; amount of volatile organic compounds (VOCs) present in air; and amount of carbon dioxide present in air; turning a mitigation device on and off based on the first IAQ parameter measured by the first IAQ sensor, where the mitigation device is separate from a heating, ventilation, and/or air conditioning (HVAC) system of the building; selectively turning the HVAC system of the building on and off based on the second IAQ parameter measured by the second IAQ sensor; selectively turning the mitigation device on and off further based on at least one of: the second IAQ parameter; and whether the HVAC system of the building is on or off; and selectively turning the HVAC system of the building on and off further based on at least one of: the first IAQ parameter; and whether the mitigation device is on or off.

[0018] In further features, the method further includes: turning the HVAC system of the building on when the second IAQ parameter is greater than a first predetermined value; and turning the HVAC system of the building off when the second IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

[0019] In further features, the method further includes turning the HVAC system of the building on when the first IAQ parameter is greater than a third predetermined value, where the third predetermined value is greater than the second predetermined value.

[0020] In further features, the method further includes turning the mitigation device on and off independently of the first IAQ parameter based on at least one of (i) the second IAQ parameter and (ii) whether the HVAC system of the building is on or off.

[0021] In further features, the method further includes: turning the HVAC system of the building on in response to the mitigation device being turned on; maintaining the HVAC system of the building on while the mitigation device is on; and turning the HVAC system of the building off in response to the mitigation device being turned off.

[0022] In further features, the method further includes turning the HVAC system of the building on when at least one of: the second IAQ parameter is greater than a first predetermined value; and the mitigation device is turned on.

[0023] In further features, the method further includes: turning the mitigation device on when the first IAQ parameter is greater than a first predetermined value; and turning the mitigation device off when the first IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

[0024] In further features, the method further includes turning the mitigation device on when the second IAQ parameter is greater than a third predetermined value, where the third predetermined value is greater than the second predetermined value.

[0025] In further features, the method further includes turning the HVAC system of the building on and off independently of the second IAQ parameter based on at least one of (i) the first IAQ parameter and (ii) whether the mitigation device is on or off.

[0026] In further features, the method further includes: turning the mitigation device on in response to the HVAC system of the building being turned on; maintaining the mitigation device on while the HVAC system of the building is on; and turning the mitigation device off in response to the HVAC system of the building being turned off.

[0027] In further features, the method further includes turning the mitigation device on when at least one of: the first IAQ parameter is greater than a first predetermined value; and the HVAC system of the building is turned on.

[0028] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0030] FIG. 1 is a block diagram of an example heating, ventilation, and air conditioning (HVAC) system;

[0031] FIG. 2A is a functional block diagram of an air handler unit of an example HVAC system;

[0032] FIGs. 2B and 2C are functional block diagrams of example condenser units of example HVAC systems;

[0033] FIG. 3 is a functional block diagram of an example indoor air quality (IAQ) sensor module that can be used with an HVAC system and/or other mitigation devices;

[0034] FIGs. 4A-4C are a functional block diagram of an example IAQ control system;

[0035] FIG. 5A is a functional block diagram of an example remote monitoring system;

[0036] FIG. 5B is a functional block diagram of an example monitoring system;

[0037] FIGs. 6-9 are example user interfaces displayed by a user computing device during execution of an application based on data received from a remote monitoring system;

[0038] FIG. 10 includes a functional block diagram of an example implementation of an IAQ control module;

[0039] FIGs. 11-14 include example graphs of particulate versus time;

[0040] FIG. 15 includes a functional block diagram of an example building including an IAQ sensor module, an IAQ control module, and an IAQ system of the building;

[0041] FIG. 16 includes a functional block diagram of an building including a room and a mitigation device located within the room;

[0042] FIG. 17 includes a functional block diagram of the example building including the room, the mitigation device located within the room 1604, an IAQ sensor module, an IAQ control module, and an IAQ system of the building;

[0043] FIG. 18 includes a functional block diagram of the example building including the room, the mitigation device located within the room, a second room, a second mitigation device located within the second room, an IAQ sensor module, an IAQ control module, and an IAQ system of the building;

[0044] FIG. 19 includes a functional block diagram of the example building including the mitigation device and a second mitigation device;

[0045] FIG. 20 includes a flowchart depicting an example method of coordinating control of multiple mitigation devices; and

[0046] FIG. 21 includes a flowchart depicting an example method of coordinating control of multiple mitigation devices.

[0047] In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

[0048] According to the present disclosure, an indoor air quality (IAQ) sensor module can be used with one or more mitigation devices of a residential or light commercial HVAC (heating, ventilation, and/or air conditioning) system of a building and/or one or more other (e.g., standalone or room) mitigation devices. The IAQ sensor module includes one, more than one, or all of a temperature sensor, a relative humidity (RH) sensor, a particulate sensor, a volatile organic compound (VOC) sensor, and a carbon dioxide (CO_2) sensor. The IAQ sensor module may also include one or more other IAQ sensors, such as occupancy, barometric pressure, light, sound, etc. The temperature sensor senses a temperature of air at the location of the IAQ sensor. The RH sensor measures a RH of air at the location of the IAQ sensor. The particulate sensor measures an amount (e.g., concentration) of particulate greater than a predetermined size in the air at the location of the IAQ sensor. The VOC sensor measures an amount of VOCs in the air at the location of the IAQ sensor. The carbon dioxide sensor measures an amount of carbon dioxide in the air at the location of the IAQ sensor. Other IAQ sensors would measure an amount of a substance or condition in the air at the location of the IAQ sensor.

[0049] The IAQ sensor module is wirelessly connected to a thermostat of the HVAC system, such as via a Bluetooth or WiFi. The IAQ sensor module may additionally or alternatively be wirelessly connected to a control module. The IAQ sensor module communicates measurements from its sensors, and optionally, a time and date to the thermostat and/or the control module. The control module and/or the thermostat controls operation of the mitigation devices based on the measurements from the IAQ sensor module. For example, the control module and/or the thermostat controls operation of the mitigation devices based on maintaining a temperature measured by the IAQ sensor module within upper and lower temperature limits, based on maintaining a RH measured by the IAQ sensor within upper and lower RH limits, based on maintaining the amount of particulate in the air at the IAQ sensor module below a predetermined amount of particulate, based on maintaining the amount of VOCs in the air at the IAQ sensor module below a predetermined amount of VOCs, and/or based on maintaining the amount of carbon dioxide in the air at the IAQ sensor module below a predetermined amount of carbon dioxide.

[0050] The control module and/or the thermostat can provide information on the measurements of the IAQ sensor and other data (e.g., statuses of mitigation devices, local outdoor air conditions, etc.) to one or more user devices (e.g., of tenants, occupants, customers, contractors, etc.) associated with the building. For example, the building may be a single-family residence, and the customer may be the homeowner, a landlord, or a tenant. In other implementations, the building may be a light commercial building, and the customer may be the building owner, a tenant, or a property management company.

[0051] Mitigation devices include mitigation devices and mitigation device functionality of an HVAC system of a building. For example, the HVAC system of a building can humidity air, dehumidify air, heat air, cool air, reduce particulate in air, reduce VOCs in air, and reduce carbon dioxide in air within the building. Mitigation devices also include standalone mitigation devices, such as standalone heaters, standalone A/C units, standalone air cleaner/purifiers, standalone humidifiers, standalone dehumidifiers, and standalone ventilation devices.

[0052] According to the present disclosure, a control module coordinates operation of two or more mitigation devices configured to mitigate the same parameter. For example, as discussed above, the HVAC system of the building is configured to reduce particulate in air within the building via one or more filters of the HVAC system. A standalone air cleaner/purifier may also be configured to reduce particulate in air (e.g., a room of a predetermined size) within the building. Concurrent use of both mitigation devices, however, may more quickly and effectively mitigate the parameter's excursion above a predetermined value or outside of a predetermined range.

[0053] As used in this application, the term HVAC can encompass all environmental comfort systems in a building, including heating, cooling, humidifying, dehumidifying, and air exchanging and purifying, and covers devices such as furnaces, heat pumps, humidifiers, dehumidifiers, ventilators, and air conditioners. HVAC systems as described in this application do not necessarily include both heating and air conditioning, and may instead have only one or the other.

[0054] In split HVAC systems, an air handler unit is often located indoors, and a condensing unit is often located outdoors. In heat pump systems, the function of the air handler unit and the condensing unit are reversed depending on the mode of the heat pump. As a result, although the present disclosure uses the terms air handler unit and condensing unit, the terms indoor unit and outdoor unit could be used instead in the context of a heat pump. The terms indoor unit and outdoor unit emphasize that the physical locations of the components stay the same while their roles change depending on the mode of the heat pump. A reversing valve selectively reverses the flow of refrigerant from what is shown in FIG. 1 depending on whether the system is heating the building or cooling the building in a heat pump system. When the flow of refrigerant is reversed, the roles of the evaporator and condenser are reversed – i.e., refrigerant evaporation occurs in what is labeled the condenser while refrigerant condensation occurs in what is labeled as the evaporator.

[0055] The control module and/or the thermostat upload data to a remote location. The remote location may be accessible via any suitable network, including the Internet. The remote location includes one or more computers, which will be referred to as servers. The servers execute a monitoring system on behalf of a monitoring company. Additionally or alternatively, a user computing device may serve as the monitoring system. The monitoring system receives and processes the data from the controller and/or thermostat of customers who have such systems installed. The monitoring system can provide performance information, diagnostic alerts, and error messages to one or more users associated with the building and/or third parties, such as designated HVAC contractors.

[0056] A server of the monitoring system includes a processor and memory. The memory stores application code that processes data received from the controller and/or the thermostat. The processor executes this application code and stores received data either in the memory or in other forms of storage, including magnetic storage, optical storage, flash memory storage, etc. While the term server is used in this application, the application is not limited to a single server.

[0057] A collection of servers may together operate to receive and process data from multiple buildings. A load balancing algorithm may be used between the servers to distribute processing and storage. The present application is not limited to servers that are owned, maintained, and housed by a monitoring company. Although the present disclosure describes diagnostics and processing and alerting occurring in a remote monitoring system, some or all of these functions may be performed locally using installed equipment and/or customer resources, such as on a customer computer or computers.

[0058] Customers and/or HVAC contractors may be notified of current and predicted issues (e.g., dirty filter) affecting effectiveness or efficiency of the HVAC system and/or the mitigating devices, and may receive notifications related to routine maintenance. The methods of notification may take the form of push or pull updates to an application, which may be executed on a smart phone, tablet, another type of mobile device, or on a computer (e.g., laptop or desktop). Notifications may also be viewed using web applications or on local displays, such as on the thermostat and/or other displays located throughout the building. Notifications may also include text messages, emails, social networking messages, voicemails, phone calls, etc.

[0059] Based on measurements from the control module, the thermostat, and/or the IAQ sensor module, the monitoring company can determine whether various components are operating at their peak performance. The monitoring company can advise the customer and a contractor when performance is reduced. This performance reduction may be measured for the system as a whole, such as in terms of efficiency, and/or may be monitored for one or more individual components.

[0060] In addition, the monitoring system may detect and/or predict failures of one or more components of the system. When a failure is detected, the customer can be notified and potential remediation steps can be taken immediately. For example, components of the HVAC system may be shut down to prevent or minimize damage, such as water damage, to HVAC components. A contractor can also be notified that a service call may be required. Depending on the contractual relationship between the customer and the contractor, the contractor may schedule a service call to the building.

[0061] The monitoring system may provide specific information to a contractor, such as identifying information of the customer's components, including make and model numbers, as well as indications of the specific part numbers of components. Based on this information, the contractor can allocate the correct repair personnel that have experience with the specific components and/or the system. In addition, a service technician is able to bring replacement parts, avoiding return trips after diagnosis.

[0062] Depending on the severity of the failure, the customer and/or contractor may be advised of relevant factors in determining whether to repair or replace some or all of the components. For example only, these factors may include relative costs of repair versus replacement, and may include quantitative or qualitative information about advantages of replacement equipment. For example, expected increases in efficiency and/or comfort with new equipment may be provided. Based on historical usage data and/or electricity or other commodity prices, the comparison may also estimate annual savings resulting from the efficiency improvement.

[0063] As mentioned above, the monitoring system may also predict impending failures. This allows for preventative maintenance and repair prior to an actual failure of components. Alerts regarding detected or impending failures reduce the time when the HVAC system is out of operation and allows for more flexible scheduling for both the customer and contractor. If the customer is out of town, these alerts may prevent damage from occurring when the customer is not present to detect the failure of a component. For example, failure of heating components of the HVAC system in winter may lead to pipes freezing and bursting.

[0064] Alerts regarding potential or impending failures may specify statistical timeframes before the failure is expected. For example only, if a sensor is intermittently providing bad data, the monitoring system may specify an expected amount of time before it is likely that the sensor effectively stops working due to the prevalence of bad data. Further, the monitoring system may explain, in quantitative or qualitative terms, how the current operation and/or the potential failure will affect operation of the HVAC system. This enables the customer to prioritize and budget for repairs.

[0065] For the monitoring service, the monitoring company may charge a periodic rate, such as a monthly rate. This charge may be billed directly to the customer and/or may be billed to the contractor. The contractor may pass along these charges to the customer and/or may make other arrangements, such as by requiring an up-front payment and/or applying surcharges to repairs and service visits.

[0066] The monitoring service allows the customer to remotely monitor real-time data within the building, outside of the building, and/or control components of the system, such as setting temperature and RH setpoints and other IAQ setpoints, enabling or disabling heating, cooling, ventilation, air purification, etc. In addition, the customer may be able to track usage data for components of the system and/or historical data.

[0067] In addition to being uploaded to the remote monitoring service (also referred to as the cloud), monitored data may be transmitted to a local device in the building. For example, a smartphone, laptop, or proprietary portable device may receive monitoring information to diagnose problems and receive real-time performance data. Alternatively, data may be uploaded to the cloud and then downloaded onto a local computing device, such as via the Internet from an interactive web site.

[0068] In FIG. 1, a block diagram of an example HVAC system is presented. In this particular example, a forced air system with a gas furnace is shown. Return air is pulled from the building through a filter 104 by a circulator blower 108. The circulator blower 108, also referred to as a fan, is controlled by a control module 112. The control module 112 receives signals from a thermostat 116. For example only, the thermostat 116 may include one or more temperature set points specified by the user.

[0069] The thermostat 116 may direct that the circulator blower 108 be turned on at all times or only when a heat request or cool request is present (automatic fan mode). In various implementations, the circulator blower 108 can operate at one or more discrete speeds or at any speed within a predetermined range. For example, the control module 112 may switch one or more switching relays (not shown) to control the circulator blower 108 and/or to select a speed of the circulator blower 108.

[0070] The thermostat 116 provides the heat and/or cool requests to the control module 112. When a heat request is made, the control module 112 causes a burner 120 to ignite. Heat from combustion is introduced to the return air provided by the circulator blower 108 in a heat exchanger 124. The heated air is supplied to the building and is referred to as supply air.

[0071] The burner 120 may include a pilot light, which is a small constant flame for igniting the primary flame in the burner 120. Alternatively, an intermittent pilot may be used in which a small flame is first lit prior to igniting the primary flame in the burner 120. A sparker may be used for an intermittent pilot implementation or for direct burner ignition. Another ignition option includes a hot surface igniter, which heats a surface to a high enough temperature that, when gas is introduced, the heated surface initiates combustion of the gas. Fuel for combustion, such as natural gas, may be provided by a gas valve 128.

[0072] The products of combustion are exhausted outside of the building, and an inducer blower 132 may be turned on prior to ignition of the burner 120. In a high efficiency furnace, the products of combustion may not be hot enough to have sufficient buoyancy to exhaust via conduction. Therefore, the inducer blower 132 creates a draft to exhaust the products of combustion. The inducer blower 132 may remain running while the burner 120 is operating. In addition, the inducer blower 132 may continue running for a set period of time after the burner 120 turns off.

[0073] A single enclosure, which will be referred to as an air handler unit 136, may include the filter 104, the circulator blower 108, the control module 112, the burner 120, the heat exchanger 124, the inducer blower 132, an expansion valve 140, an evaporator 144, and a condensate pan 146. In various implementations, the air handler unit 136 includes an electrical heating device (not shown) instead of or in addition to the burner 120. When used in addition to the burner 120, the electrical heating device may provide backup or secondary (extra) heat to the burner 120.

[0074] In FIG. 1, the HVAC system includes a split air conditioning system. Refrigerant is circulated through a compressor 148, a condenser 152, the expansion valve 140, and the evaporator 144. The evaporator 144 is placed in series with the supply air so that when cooling is desired, the evaporator 144 removes heat from the supply air, thereby cooling the supply air. During cooling, the evaporator 144 is cold (e.g., below the dew point of the air within the building), which causes water vapor to condense. This water vapor is collected in the condensate pan 146, which drains or is pumped out.

[0075] A control module 156 receives a cool request from the control module 112 and controls the compressor 148 accordingly. The control module 156 also controls a condenser fan 160, which increases heat exchange between the condenser 152 and outside air. In such a split system, the compressor 148, the condenser 152, the control module 156, and the condenser fan 160 are generally located outside of the building, often in a single condensing unit 164.

[0076] In various implementations, the control module 156 may include a run capacitor, a start capacitor, and a contactor or relay. In various implementations, the start capacitor may be omitted, such as when the condensing unit 164 includes a scroll compressor instead of a reciprocating compressor. The compressor 148 may be a variable-capacity compressor and may respond to a multiple-level cool request. For example, the cool request may indicate a mid-capacity call for cooling or a high-capacity call for cooling. The compressor 148 may vary its capacity according to the cool request.

[0077] The electrical lines provided to the condensing unit 164 may include a 240 volt mains power line (not shown) and a 24 volt switched control line. The 24 volt control line may correspond to the cool request shown in FIG. 1. The 24 volt control line controls operation of the contactor. When the control line indicates that the compressor should be on, the contactor contacts close, connecting the 240 volt power supply to the compressor 148. In addition, the contactor may connect the 240 volt power supply to the condenser fan 160. In various implementations, such as when the condensing unit 164 is located in the ground as part of a geothermal system, the condenser fan 160 may be omitted. When the 240 volt mains power supply arrives in two legs, as is common in the U.S., the contactor may have two sets of contacts, and can be referred to as a double-pole single-throw switch.

[0078] Typically, the thermostat 116 includes a temperature sensor and a relative humidity (RH) sensor. When in a heating (heat) mode, the thermostat 116 generates a heat request when the temperature measured by the temperature sensor is less than a lower temperature limit. When in a cooling (cool) mode, the thermostat 116 generates a cool request when the temperature measured by the temperature sensor is greater than an upper temperature limit. The upper and lower temperature limits may be set to a setpoint temperature + and – a predetermined amount (e.g., 1, 2, 3, 4, 5 degrees Fahrenheit), respectively. The setpoint temperature may be set to a predetermined temperature by default and may be adjusted by a user.

[0079] FIGs. 2A-2B are functional block diagrams of an example monitoring system associated with an HVAC system of a building. The air handler unit 136 of FIG. 1 is shown for reference. The thermostat 116 of FIG. 1 is a WiFi thermostat 208 having networking capability.

[0080] In many systems, the air handler unit 136 is located inside the building, while the condensing unit 164 is located outside the building. The present disclosure is not limited to that arrangement, however, and applies to other systems including, as examples only, systems where the components of the air handler unit 136 and the condensing unit 164 are located in close proximity to each other or even in a single enclosure. The single enclosure may be located inside or outside of the building. In various implementations, the air handler unit 136 may be located in a basement, garage, or attic. In ground source systems, where heat is exchanged with the earth, the air handler unit 136 and the condensing unit 164 may be located near the earth, such as in a basement, crawlspace, garage, or on the first floor, such as when the first floor is separated from the earth by only a concrete slab.

[0081] In FIG. 2A, a transformer 212 can be connected to an AC line in order to provide AC power to the control module 112 and the thermostat 208. For example, the transformer 212 may be a 10-to-1 transformer and therefore provide either a 12V or 24V AC supply depending on whether the air handler unit 136 is operating on nominal 120 volt or nominal 240 volt power.

[0082] The control module 112 controls operation in response to signals from the thermostat 208 received over control lines. The control lines may include a call for cool (cool request), a call for heat (heat request), and a call for fan (fan request). The control lines may include a line corresponding to a state of a reversing valve in heat pump systems.

[0083] The control lines may further carry calls for secondary heat and/or secondary cooling, which may be activated when the primary heating or primary cooling is insufficient. In dual fuel systems, such as systems operating from either electricity or natural gas, control signals related to the selection of the fuel may be monitored. Further, additional status and error signals may be monitored, such as a defrost status signal, which may be asserted when the compressor is shut off and a defrost heater operates to melt frost from an evaporator.

[0084] One or more of these control signals (on the control lines) is also transmitted to the condensing unit 164 (shown in FIGs. 2B and 2C). In various implementations, the condensing unit 164 may include an ambient temperature sensor that generates temperature data. When the condensing unit 164 is located outdoors, the ambient temperature represents an outside (or outdoor) ambient temperature. The temperature sensor supplying the ambient temperature may be located outside of an enclosure of the condensing unit 164. Alternatively, the temperature sensor may be located within the enclosure, but exposed to circulating air. In various implementations the temperature sensor may be shielded from direct sunlight and may be exposed to an air cavity that is not directly heated by sunlight. Alternatively or additionally, online (including Internet-based) weather data based on the geographical location of the building may be used to determine sun load, outside ambient air temperature, relative humidity, particulate, VOCs, carbon dioxide, etc.

[0085] In FIG. 2C, an example condensing unit 268 is shown for a heat pump implementation. The condensing unit 268 may be configured similarly to the condensing unit 164 of FIG. 2B. Although referred to as the condensing unit 268, the mode of the heat pump determines whether the condenser 152 of the condensing unit 268 is actually operating as a condenser or as an evaporator. A reversing valve 272 is controlled by a control module 276 and determines whether the compressor 148 discharges compressed refrigerant toward the condenser 152 (cooling mode) or away from the condenser 152 (heating mode). The control module 276 controls the reversing valve 272 and the compressor 148 based on the control signals. The control module 276 may receive power, for example, from the transformer 212 of the air handler unit 136 or via the incoming AC power line.

[0086] FIG. 3 includes a functional block diagram of an example indoor air quality (IAQ) sensor module 304 that can be used with an HVAC system and/or one or more other mitigation devices. The IAQ sensor module 304 includes one, more than one, or all of: a temperature sensor 308, a relative humidity (RH) sensor 312, a particulate sensor 316, a volatile organic compounds (VOC) sensor 320, and a carbon dioxide sensor 324. The IAQ sensor module 304 may also include a sampling module 328 and a transceiver module 332.

[0087] A power supply 336 may receive AC power from a standard wall outlet (or receptacle) 340 via a plug 344. For example, the standard wall outlet 340 may provide nominal 120 volt or nominal 240 volt AC power. The power supply 336 may include an AC to direct current (DC) converter that converts the AC power into DC power, such as 5 volt, 12 volt, or 24 volt DC power. The power supply 336 supplies power to the components of the IAQ sensor module 304 including the sensors, the sampling module 328, and the transceiver module 332. While the example of the power supply 336 being integrated within the IAQ sensor module 304 is provided, the power supply 336 may be integrated with the plug 344 in various implementations. Also, while the example of the power supply 336 providing one DC voltage to the components of the IAQ sensor module 304, the power supply 336 may provide two or more different DC voltages to different components of the IAQ sensor module 304.

[0088] Additionally or alternatively, the power supply 336 may include one or more batteries or one or more solar cells that supply power to the components of the IAQ sensor module 304. The one or more batteries may be replaceable or non-replaceable. In the example of the one or more batteries being non-replaceable, the one or more batteries may be re-chargeable, such as via a standard wall outlet. In this example, the IAQ sensor module 304 may include a charger that charges the one or more batteries using power supplied, for example, via a standard wall outlet.

[0089] The IAQ sensor module 304 is portable and can be moved into different rooms of a building. The IAQ sensor module 304 could also be placed outside the building, for example, to measure one or more conditions outside of the building, calibration, or for one or more other reasons. The temperature sensor 308 measures a temperature of air at the IAQ sensor module 304. The RH sensor 312 measures a relative humidity of air at the IAQ sensor module 304. The particulate sensor 316 measures an amount (e.g., a mass flow rate, such as micrograms (μg) per cubic meter) of particulate in air at the IAQ sensor module 304 having a diameter that is less than a predetermined size (e.g., 2.5 or 10 micrometers (μm)). The VOC sensor 320 measures an amount (e.g., parts per billion (ppb)) of VOC in air at the IAQ sensor module 304. The carbon dioxide sensor 324 measures an amount (e.g., ppm) of carbon dioxide in air at the IAQ sensor module 304. The included ones of the temperature sensor 308, the RH sensor 312, the particulate sensor 316, the VOC sensor 320, and the carbon dioxide sensor 324 will be referred to collectively as the IAQ sensors.

[0090] The sampling module 328 samples (analog) measurements of the IAQ sensors. The sampling module 328 may also digitize and/or store values of the measurements of the IAQ sensors. In various implementations, the IAQ sensors may be digital sensors and output digital values corresponding to the respective measured parameters. In such implementations, the sampling module 328 may perform storage or may be omitted.

[0091] The IAQ sensor module 304 may include one or more expansion ports to allow for connection of additional sensors and/or to allow connection to other devices. Examples of other devices include one or more other IAQ sensor modules, one or more other types of the IAQ sensors not included in the IAQ sensor module 304, a home security system, a proprietary handheld device for use by contractors, a mobile computing device, and other types of devices.

[0092] The transceiver module 332 transmits frames of data corresponding to predetermined periods of time. Each frame of data may include the measurements of the IAQ sensors over a predetermined period. One or more calculations may be performed for the data of each frame of data, such as averaging the measurements of one or more of the IAQ sensors. Each frame (including the calculations and/or the measurements) may be transmitted to a monitoring system, as discussed further below. The measurements of the IAQ sensors may be sampled at a predetermined rate, such as 10 samples per minute or another suitable rate. Each frame may correspond to a predetermined number of sets of samples (e.g., 10). The monitoring system may provide visual representations of the measurements over predetermined periods of time along with other data, as discussed further below.

[0093] The transceiver module 332 transmits each frame (including the calculations and/or the measurements) to an IAQ control module 404 and/or the thermostat 208. The transceiver module 332 transmits the frames wirelessly via one or more antennas, such as antenna 348, using a proprietary or standardized, wired or wireless protocol, such as Bluetooth, ZigBee (IEEE 802.15.4), 900 Megahertz, 2.4 Gigahertz, WiFi (IEEE 802.11). The IAQ sensor module 304 may communicate directly with the IAQ control module 404 and/or the thermostat 208 or with a separate computing device, such as a smartphone, tablet, or another type of computing device. In various implementations, a gateway 408 is implemented, which creates a wireless network for the IAQ sensor module 304, the IAQ control module 404, and the thermostat 208. The gateway 408 may also interface with a customer router 412 using a wired or wireless protocol, such as Ethernet (IEEE 802.3).

[0094] Referring now to FIGs. 4A-4C, functional block diagrams of example IAQ control systems are presented. The IAQ control module 404 may communicate with the customer router 412 using WiFi. Alternatively, the IAQ control module 404 may communicate with the customer router 412 via the gateway 408. The thermostat 208 may also communicate with the customer router 412 using WiFi or via the gateway 408. In various implementations, the IAQ control module 404 and the thermostat 208 may communicate directly or via the gateway 408.

[0095] The IAQ sensor module 304, the IAQ control module 404, and/or the thermostat 208 transmits data measured by the IAQ sensor module 304 and parameters of the IAQ control module 404 and/or the thermostat 208 over a wide area network 416, such as the Internet (referred to as the Internet 416). The IAQ sensor module 304, the IAQ control module 404, and/or the thermostat 208 may access the Internet 416 using the customer router 412 of the customer. The customer router 412 may already be present to provide Internet access to other devices (not shown) within the building, such as a customer computer and/or various other devices having Internet connectivity, such as a DVR (digital video recorder) or a video gaming system.

[0096] The IAQ sensor module 304, the IAQ control module 404, and/or the thermostat 208 transmit the data to a remote monitoring system 420 via the Internet 416 using the customer router 412. Further discussion of the remote monitoring system 420 is provided below.

[0097] The IAQ control module 404 and/or the thermostat 208 control operation (e.g., on, off, speed, etc.) of mitigation devices 424 based on the measurements from the IAQ sensor module 304, measurements from other IAQ sensors, and operation of ones of the mitigation devices 424. For example, the measurements of the IAQ sensor module 304 may be provided to the thermostat 208 and the thermostat 208 may control operation of the mitigation devices 424 in various implementations (e.g., FIG. 4A). The IAQ control module 404 can be omitted in such implementations. While the example of the thermostat 208 controlling the mitigation devices 424 will be discussed, alternatively the IAQ control module 404 may control operation of the mitigation devices 424 (e.g., FIG. 4B), or the thermostat 208 and the IAQ control module 404 may together control the mitigation devices 424 (e.g., FIG. 4C).

[0098] The IAQ control module 404 and/or the thermostat 208 control and communicate with the mitigation devices 424 wirelessly, by wire, using a combination of wireless and wired connections. In the case of wireless control and communication, the IAQ control module 404, the thermostat 208, and the mitigation devices 424 include respective transceivers.

[0099] The mitigation devices 424 include: (i) the condensing unit 164, (ii) the air handler unit 136, (iii) an air cleaner/purifier 428, (iv) a humidifier 432, (v) a dehumidifier 436, (vi) a ventilator 440; (vii) a standalone heater 444; (viii) a standalone A/C device 448; (ix) a standalone humidifier 452; (x) a standalone dehumidifier 456; and (xi) a room ventilator 460. The humidifier 432 is the humidifier of the air handler unit 136. The humidifier 452 is a standalone humidifier that can be powered, for example, via a standard wall outlet or a battery within the humidifier 452. The dehumidifier 436 represents dehumidification that can be performed using the air handler unit 136 or a combination of the air handler unit 136 and the condensing unit 164. The dehumidifier 456 is a standalone dehumidifier that can be powered, for example, via a standard wall outlet or a battery within the dehumidifier 456.

[0100] As discussed above, the air handler unit 136 can be used to provide heating. The heater 444 is a standalone heater that can be powered, for example, via a standard wall outlet or a battery within the heater 444. The air handler unit 136 and the condensing unit 164 can be used together to provide cooling. The A/C device 448 is a standalone A/C device that can be powered, for example, via a standard wall outlet or a battery within the A/C device 448.

[0101] The air handler unit 136 can function as an air cleaner/purifier to filter particulate and to reduce (or at least disperse) VOCs and carbon dioxide, as discussed above. The air cleaner/purifier 428 is a standalone air cleaner/purifier that can be powered, for example, via a standard wall outlet or a battery within the air cleaner/purifier 428. The air cleaner/purifier 428 draws in air and forces the air through a filter before expelling filtered air to the building. The filter may be rated (e.g., minimum efficiency reporting value, MERV) to remove a predetermined amount (e.g., 95%) of particulate of the size measured by the particulate sensor 316. For example, the filter may have a MERV rating of 12 or greater.

[0102] Operation of the air cleaner/purifier 428 may include whether the air cleaner/purifier 428 is on or off and, when on, a speed of the air cleaner/purifier 428. The air cleaner/purifier 428 may have a single speed or multiple discrete speeds. Operation of the air cleaner/purifier 428 may be controlled by a control module of the air cleaner/purifier 428 and/or by wire or wirelessly, for example, by the IAQ control module 404. Examples of wireless communication and control include, but are not limited to, Bluetooth connections and WiFi connections. For example only, The control module of the air cleaner/purifier 428 and the IAQ control module 404 may control whether the air cleaner/purifier 428 is on or off and, if on, the speed of the air cleaner/purifier 428.

[0103] As one example, the control module of the air cleaner/purifier 428 or the IAQ control module 404 may turn the air cleaner/purifier 428 on when an amount of particulate measured by a particulate sensor is greater than a first predetermined amount of particulate. The control module of the air cleaner/purifier 428 or the IAQ control module 404 may leave the air cleaner/purifier 428 on until the amount of particulate measured by the particulate sensor is less than a second predetermined amount of particulate that is less than the first predetermined amount of particulate. The control module of the air cleaner/purifier 428 or the IAQ control module 404 may turn the air cleaner/purifier 428 off when the amount of particulate measured by the particulate sensor is less than the second predetermined amount of particulate. In various implementations, the control module of the air cleaner/purifier 428 or the IAQ control module 404 may vary the speed of the air cleaner/purifier 428 based on the amount of particulate measured by the particulate sensor. For example, the control module of the air cleaner/purifier 428 or the IAQ control module 404 may increase the speed of the air cleaner/purifier 428 as the amount of particulate increases and vice versa.

[0104] The humidifier 432 humidifies air within the building. For example, the humidifier 432 may add moisture to the supply air before the supply air is output from vents to the building. The humidifier 432 may add moisture to air, for example, by supplying water to a medium (e.g., a pad) and forcing air (e.g., supply air) through the hydrated medium. Alternatively, the humidifier 432 may spray water in the form of mist into air (e.g., supply air).

[0105] Operation of the humidifier 432 may include whether the humidifier 432 is on or off. In various implementations, operation of the humidifier 432 may also include a humidification rate (e.g., an amount of water supplied to the pad or into the air as mist). The humidifier 432 may be configured to provide only a single humidification rate or multiple different humidification rates.

[0106] Operation of the humidifier 432 may be controlled via wire or wirelessly by the thermostat 208. For example only, the thermostat 208 may control (by wire) whether the humidifier 432 included with the air handler unit 136 is on or off. Examples of wireless communication include, but are not limited to, Bluetooth connections and WiFi connections. For example only, the thermostat 208 may turn the humidifier 432 on when the RH measured by an RH sensor is less than a first predetermined RH. The thermostat 208 may leave the humidifier 432 on until the RH measured by the RH sensor is greater than a second predetermined RH that is greater than the first predetermined RH. The thermostat 208 may turn the humidifier 432 off when the RH measured by the RH sensor is greater than the second predetermined RH.

[0107] The humidifier 452 humidifies air within the building, such as air within a room of the humidifier 452. The humidifier 452 may add moisture to air, for example, by supplying water to a medium (e.g., a pad) and forcing air through the hydrated medium. Alternatively, the humidifier 432 may spray water in the form of mist into air (e.g., supply air).

[0108] Operation of the humidifier 452 may include whether the humidifier 452 is on or off. In various implementations, operation of the humidifier 452 may also include a humidification rate (e.g., an amount of water supplied to the pad or into the air as mist). The humidifier 452 may be configured to provide only a single humidification rate or multiple different humidification rates.

[0109] Operation of the humidifier 452 may be controlled by a control module of the humidifier 452 and/or by wire or wirelessly, for example, by the IAQ control module 404. Examples of wireless communication and control include, but are not limited to, Bluetooth connections and WiFi connections. For example only, the control module of the humidifier 452 or the IAQ control module 404 may turn the humidifier 452 on when the RH measured by a RH sensor is less than a first predetermined RH. The control module of the humidifier 452 or the IAQ control module 404 may leave the humidifier 452 on until the RH measured by the RH sensor is greater than a second predetermined RH that is greater than the first predetermined RH. The control module of the humidifier 452 or the IAQ control module 404 may turn the humidifier 432 off when the RH measured by the RH sensor is greater than the second predetermined RH.

[0110] The dehumidifier 436 dehumidifies (i.e., removes humidity from) air within the building. The dehumidifier 436 may be included with the air handler unit 136. For example, the dehumidifier 436 may draw moisture from the supply air (or add dry air to the supply air) before the supply air is output from vents to the building. The dehumidifier 436 may not be implemented as a separate device and dehumidification may be provided via operation of the condensing unit 164, the burner 120, and/or the circulator blower 108. Operation of the dehumidifier 436 may include whether the dehumidifier 436 is on or off.

[0111] Operation of the dehumidifier 436 may be controlled via wire or wirelessly by the thermostat 208. For example only, the thermostat 208 may control (by wire) whether the dehumidifier 436 included with the air handler unit 136 is on or off. As another example, the thermostat 208 may wirelessly control whether the dehumidifier 436, implemented as a standalone device, is on or off. For example only, the thermostat 208 may turn the dehumidifier 436 on when the RH measured by the RH sensor 312 is greater than a third predetermined RH. The third predetermined RH may be the same as the second predetermined

RH or different than (e.g., greater than) the second predetermined RH. The thermostat 208 may leave the dehumidifier 436 on until the RH measured by the RH sensor 312 is less than a fourth predetermined RH that is less than the third predetermined RH. The thermostat 208 may turn the dehumidifier 436 off when the RH measured by the RH sensor 312 is less than the fourth predetermined RH. The fourth predetermined RH may be the same as the first predetermined RH or different than (e.g., greater than) the first predetermined RH.

[0112] The dehumidifier 456 humidifies air within the building, such as air within a room of the dehumidifier 456. The dehumidifier 456 may remove moisture from air, for example, by forcing air through a heat exchanger.

[0113] Operation of the dehumidifier 456 may include whether the dehumidifier 456 is on or off. In various implementations, operation of the dehumidifier 456 may also include a dehumidification rate. The dehumidifier 456 may be configured to provide only a single dehumidification rate or multiple different dehumidification rates.

[0114] Operation of the dehumidifier 456 may be controlled by a control module of the dehumidifier 456 and/or by wire or wirelessly, for example, by the IAQ control module 404. Examples of wireless communication and control include, but are not limited to, Bluetooth connections and WiFi connections. For example only, the control module of the dehumidifier 456 or the IAQ control module 404 may turn the dehumidifier 456 on when the RH measured by a RH sensor is greater than the third predetermined RH. The control module of the dehumidifier 456 or the IAQ control module 404 may leave the dehumidifier 456 on until the RH measured by the RH sensor is less than the fourth predetermined RH. The control module of the dehumidifier 456 or the IAQ control module 404 may turn the dehumidifier 456 off when the RH measured by the RH sensor is less than the fourth predetermined RH.

[0115] The ventilator 440 vents air from within the building out of the building. This also passively draws air from outside of the building into the building. The ventilator 440 may be included with the air handler unit 136 (e.g., the inducer blower 132). Operation of the ventilator 440 may include whether the ventilator 440 is on or off and, when on, a speed. The ventilator 440 may be configured to operate at a single speed or multiple different speeds.

[0116] Operation of the ventilator 440 may be controlled by a control module of the ventilator 440 or by wire or wirelessly, for example, by the IAQ control module 404. Examples of wireless communication include, but are not limited to, Bluetooth connections and WiFi connections. For example only, the control module of the ventilator 440 or the IAQ control module 404 may turn the ventilator 440 on when an amount of VOCs measured by a

VOC sensor is greater than a first predetermined amount of VOCs. The control module of the ventilator 440 or the IAQ control module 404 may leave the ventilator 440 on until the amount of VOCs measured by the VOC sensor is less than a second predetermined amount of VOCs that is less than the first predetermined amount of VOCs. The control module of the ventilator 440 or the IAQ control module 404 may turn the ventilator 440 off when the amount of VOCs measured by the VOC sensor is less than the second predetermined amount of VOCs.

[0117] Additionally or alternatively, the control module of the ventilator 440 or the IAQ control module 404 may turn the ventilator 440 on when an amount of carbon dioxide measured by a carbon dioxide sensor is greater than a first predetermined amount of carbon dioxide. The control module of the ventilator 440 or the IAQ control module 404 may leave the ventilator 440 on until the amount of carbon dioxide measured by the carbon dioxide sensor is less than a second predetermined amount of carbon dioxide that is less than the first predetermined amount of carbon dioxide. The control module of the ventilator 440 or the IAQ control module 404 may turn the ventilator 440 off when the amount of carbon dioxide measured by the carbon dioxide sensor is less than the second predetermined amount of carbon dioxide.

[0118] The room ventilator 460 also vents air from within the building out of the building. This also passively draws air from outside of the building into the building. The room ventilator 460 may be, for example, a range hood fan, a bathroom fan, or another type of ventilator. Operation of the room ventilator 460 may include whether the room ventilator 460 is on or off and, when on, a speed. The room ventilator 460 may be configured to operate at a single speed or multiple different speeds.

[0119] Operation of the room ventilator 460 may be controlled by a control module of the room ventilator 460 or by wire or wirelessly, for example, by the IAQ control module 404. Examples of wireless communication include, but are not limited to, Bluetooth connections and WiFi connections. For example only, the control module of the room ventilator 460 or the IAQ control module 404 may turn the room ventilator 460 on when an amount of VOCs measured by a VOC sensor is greater than a first predetermined amount of VOCs. The control module of the room ventilator 460 or the IAQ control module 404 may leave the room ventilator 460 on until the amount of VOCs measured by the VOC sensor is less than a second predetermined amount of VOCs that is less than the first predetermined amount of VOCs. The control module of the room ventilator 460 or the IAQ control module 404 may turn the room ventilator 460 off when the amount of VOCs measured by the VOC sensor is less than the second predetermined amount of VOCs.

[0120] Additionally or alternatively, the control module of the room ventilator 460 or the IAQ control module 404 may turn the room ventilator 460 on when an amount of carbon dioxide measured by a carbon dioxide sensor is greater than a first predetermined amount of carbon dioxide. The control module of the room ventilator 460 or the IAQ control module 404 may leave the room ventilator 460 on until the amount of carbon dioxide measured by the carbon dioxide sensor is less than a second predetermined amount of carbon dioxide that is less than the first predetermined amount of carbon dioxide. The control module of the room ventilator 460 or the IAQ control module 404 may turn the room ventilator 460 off when the amount of carbon dioxide measured by the carbon dioxide sensor is less than the second predetermined amount of carbon dioxide.

[0121] The heater 444 heats (i.e., warms, adds heat to) air within the building, such as air within a room of the heater 444. The heater 444 may heat the air, for example, via one or more electric heating devices. The heater 444 may include a fan or a blower that increases airflow through/past the one or more electric heating devices.

[0122] Operation of the heater 444 may include whether the heater 444 is on or off. In various implementations, operation of the heater 444 may also include a heating rate. The heater 444 may be configured to provide only a single heating rate or multiple different heating rates.

[0123] Operation of the heater 444 may be controlled by a control module of the heater 444 and wirelessly, for example, by the IAQ control module 404. For example only, the control module of the heater 444 or the IAQ control module 404 may turn the heater 444 on when a temperature measured by a temperature sensor is less than a first predetermined temperature. The control module of the heater 444 or the IAQ control module 404 may leave the heater 444 on until the temperature measured by the temperature sensor is greater than a second predetermined temperature. The control module of the heater 444 or the IAQ control module 404 may turn the heater 444 off when the temperature measured by the temperature sensor is greater than the second predetermined temperature.

[0124] The A/C device 448 cools (i.e., removes heat from) air within the building, such as air within a room of the A/C device 448. The A/C device 448 may cool the air, for example, via a heat exchanger. The A/C device 448 includes a fan or a blower that increases airflow through/past the heat exchanger. Operation of the A/C device 448 may include whether the A/C device 448 is on or off. In various implementations, operation of the A/C device 448 may also include a cooling rate. The A/C device 448 may be configured to provide only a single cooling rate or multiple different cooling rates.

[0125] Operation of the A/C device 448 may be controlled by a control module of the A/C device 448 and wirelessly, for example, by the IAQ control module 404. For example only, the control module of the A/C device 448 or the IAQ control module 404 may turn the A/C device 448 on when a temperature measured by a temperature sensor is less than a third predetermined temperature (that may be less than or the same as the second predetermined temperature). The control module of the A/C device 448 or the IAQ control module 404 may leave the A/C device 448 on until the temperature measured by the temperature sensor is less than a fourth predetermined temperature that is less than the third predetermined temperature. The control module of the A/C device 448 or the IAQ control module 404 may turn the A/C device 448 off when the temperature measured by the temperature sensor is less than the fourth predetermined temperature.

[0126] The mitigation devices described above are only described as example. One or more of the example mitigation devices may be omitted. One or more other types of mitigation devices may be included. Additionally, while the example of only one of each type of mitigation device is provided, two or more of a given type of mitigation device may be included and controlled.

[0127] Changes in temperature and/or humidity also cause changes in particulate, VOCs, and/or carbon dioxide. For example, a change in temperature may cause a change in VOCs, RH, particulate, and/or carbon dioxide. As another example, a change in RH may cause a change in particulate, VOCs, and/or carbon dioxide. For example, particulate may increase as RH increases and vice versa.

[0128] The thermostat 208 and the IAQ control module 404 therefore control operation of the mitigation devices 424 based on all of the parameters measured by the IAQ sensor module 304 in an attempt to: adjust the temperature within a predetermined temperature range, adjust the RH within a predetermined RH range, adjust the amount of particulate (if measured) to less than a predetermined amount of particulate, adjust the amount of VOCs (if measured) to less than a predetermined amount of VOCs, and to adjust the amount of carbon dioxide (if measured) to less than a predetermined amount of carbon dioxide.

[0129] FIG. 5A includes a functional block diagram of an example monitoring system. In FIG. 5A, the IAQ control module 404 and/or the thermostat 208 are shown transmitting, using the customer router 412, data to the remote monitoring system 420 via the Internet 416. In other implementations, the IAQ control module 404 and/or the thermostat 208 may transmit the data to an external wireless receiver. The external wireless receiver may be a proprietary receiver for a neighborhood in which the building is located, or may be an infrastructure receiver, such as a metropolitan area network (such as WiMAX), a WiFi access point, or a mobile phone base station.

[0130] The remote monitoring system 420 includes a monitoring server 508 that receives data from the IAQ control module 404 and/or the thermostat 208 and maintains and verifies network continuity with the IAQ control module 404 and/or the thermostat 208. The monitoring server 508 executes various algorithms to store setpoints for the building and to store measurements from the thermostat 208 and/or the IAQ sensor module 304 taken over time.

[0131] The monitoring server 508 may notify a review server 512 when one or more predetermined conditions are satisfied. This programmatic assessment may be referred to as an advisory. Some or all advisories may be triaged by a technician to reduce false positives and potentially supplement or modify data corresponding to the advisory. For example, a technician device 516 operated by a technician may be used to review the advisory and to monitor data (in various implementations, in real-time) from the IAQ control module 404 and/or the thermostat 208 via the monitoring server 508.

[0132] A technician using the technician device 516 may review the advisory. If the technician determines that a problem or fault is either already present or impending, the technician instructs the review server 512 to send an alert to a customer device 524 that is associated with the building. The technician may determine that, although a problem or fault is present, the cause is more likely to be something different than specified by the automated advisory. The technician can therefore issue a different alert or modify the advisory before issuing an alert based on the advisory. The technician may also annotate the alert sent to the customer device 524 with additional information that may be helpful in identifying the urgency of addressing the alert and presenting data that may be useful for diagnosis or troubleshooting.

[0133] In various implementations, minor problems may not be reported to the customer device 524 so as not to alarm the customer or inundate the customer with alerts. The review server 512 (or a technician) may determine whether a problem is minor based on a threshold. For example, an efficiency decrease greater than a predetermined threshold may be reported to the customer device 524, while an efficiency decrease less than the predetermined threshold may not be reported to the customer device 524.

[0134] In various implementations, the technician device 516 may be remote from the remote monitoring system 420 but connected via a wide area network. For example only, the technician device 516 may include a computing device such as a laptop, desktop, smartphone, or tablet.

[0135] Using the customer device 524 executing an application, the customer can access a customer portal 528, which provides historical and real-time data from the IAQ control module 404 and/or the thermostat 208. The customer portal 528 may also provide setpoints and predetermined ranges for each of the measurements, local outdoor air quality data, statuses of the mitigation devices 424 (e.g., on or off), and other data to the customer device 524. Via the customer device 524, the customer may change the setpoints and predetermined ranges. The monitoring server 508 transmits changed setpoints and predetermined ranges to the thermostat 208 and/or the IAQ control module 404 for use in controlling operation of the mitigation devices 424.

[0136] The remote monitoring system 420 includes a local data server 520 that obtains local data at (outside) the building. The local data server 520 may obtain the local data from one or more local data sources 532 via a wide area network, such as the internet 416, using a geographical location of the building. The geographical location may be, for example, an address, zip code, coordinates, or other geographical identifier of the building. The remote monitoring system 420 may obtain the geographical location of the building, for example, via the customer device 524 before providing data to the customer device 524. The local data includes, for example, air temperature within a predetermined geographical area including the geographical location of the building, RH within the predetermined geographical area, amount of VOCs in the air within the predetermined geographical area, amount of particulate of the predetermined size measured by the particulate sensor 316 within the predetermined geographical area, and amount of carbon dioxide within the predetermined geographical area.

[0137] FIG. 5B includes a functional block diagram of an example monitoring system where the customer device 524 serves as a monitoring system and provides the functionality of the remote monitoring system 420. The thermostat 208 and/or the IAQ control module 404 transmit data to the customer device 524 wirelessly, such as via a Bluetooth connection, WiFi, or another wireless connection. The customer device 524 may obtain the local data from the local data sources 532 via a wide area network, such as the internet 416. Alternatively, the IAQ control module 404 or the thermostat 208 may serve as a monitoring system and provide the functionality of the remote monitoring system 420.

[0138] FIG. 6 includes an example user interface displayed by the customer device 524 during execution of the application based on data from the customer portal 528. It should be understood that the following functions are performed by the customer device 524 during execution of the application.

[0139] As shown in FIG. 6, the customer device 524 may display real-time values of the temperature, RH, amount of VOCs, amount of particulate, and amount of carbon dioxide (CO2) measured by the IAQ sensor module 304. In FIG. 6, these are illustrated in the row labeled “indoor” as they represent parameters within the building. The real-time values may be received by the customer device 524 from the monitoring server 508 via the customer portal 528.

[0140] The customer device 524 may also display real-time values of the temperature, RH, amount of VOCs, amount of particulate, and amount of carbon dioxide (CO2) measured outside of the building but within the predetermined geographical area including the geographical area of the building. In FIG. 6, these are illustrated in the row labeled “outdoor” as they represent parameters outside of the building. The real-time values may be received by the customer device 524 from the monitoring server 508 via the customer portal 528.

[0141] The customer device 524 may also display present setpoints for beginning heating (Heat) of the building, cooling (Cool) of the building, humidification (Humidify), dehumidification (Dehumidify), VOC removal (VOCs), particulate removal (Particulate), and carbon dioxide removal (Carbon Dioxide). In FIG. 6, these setpoints are illustrated in the row labeled “setpoints” as they represent setpoints for beginning associated mitigation actions within the building. The present setpoints may be received by the customer device 524 from the monitoring server 508 via the customer portal 528.

[0142] A predetermined range for a measurement may be set based on the setpoint for a measurement. For example, a predetermined range for heating may be set to the temperature setpoint for heating plus and minus a predetermined amount. A predetermined range for cooling may be set to the temperature setpoint for cooling plus and minus a predetermined amount. The predetermined amount may be user adjustable in various implementations.

[0143] The customer device 524 also allows a user to adjust one or more of the present setpoints via the customer device 524. For example, the customer device 524 may provide positive and negative adjustment inputs in association with one, more than one, or all of the setpoints to allow for adjustment of the present setpoints. FIG. 6 includes the example of + serving as the positive adjustment input and – serving as the negative adjustment input. Adjustment inputs labeled and provided differently, however, may be used.

[0144] In response to receipt of input indicative of user interaction (e.g., touching, clicking, etc.) with an adjustment input associated with a setpoint, the customer device 524 may transmit a command to the monitoring server 508 to adjust (i.e., increment or decrement) the setpoint by a predetermined amount. For example, in response to receipt of input indicative of user interaction (e.g., touching, clicking, etc.) with the positive adjustment input associated with the heating temperature setpoint, the customer device 524 may transmit a command to the monitoring server 508 to increment the heating temperature setpoint by a first predetermined amount. In response to receipt of input indicative of user interaction (e.g., touching, clicking, etc.) with the negative adjustment input associated with the heating temperature setpoint, the customer device 524 may transmit a command to the monitoring server 508 to decrement the heating temperature setpoint by the first predetermined amount. As another example, in response to receipt of input indicative of user interaction (e.g., touching, clicking, etc.) with the positive adjustment input associated with the humidification RH setpoint, the customer device 524 may transmit a command to the monitoring server 508 to increment the humidification RH setpoint by a second predetermined amount. In response to receipt of input indicative of user interaction (e.g., touching, clicking, etc.) with the negative adjustment input associated with the humidification RH setpoint, the customer device 524 may transmit a command to the monitoring server 508 to decrement the humidification RH setpoint by the second predetermined amount.

[0145] The monitoring server 508 relays (transmits) received commands for adjusting setpoints to the thermostat 208 and/or the IAQ control module 404 via the internet 416. Alternatively, the customer device 524 may transmit commands for adjusting setpoints to the thermostat 208 and/or the IAQ control module 404 directly or via the internet 416. The thermostat 208 and/or the IAQ control module 404 adjust the associated setpoints in response to the commands received from the monitoring server 508.

[0146] As discussed above, one or more than one IAQ sensor module 304 may be concurrently used within the building, such as in different rooms of the building. FIG. 7 includes an example user interface displayed by the customer device 524 during execution of the application when the building includes multiple IAQ sensor modules. In the example of FIG. 7, the measurements from each IAQ sensor module are shown in a separate column. In various implementations, a user, via the customer device 524, may re-name the columns, such as to names that are descriptive of the location of the IAQ sensor modules, respectively.

[0147] As also discussed above, one or more of the IAQ sensors may be omitted from an IAQ sensor module. The temperature, relative humidity, and VOCs of zero in the example of FIG. 7 are examples only and may not be indicative of actual conditions within a building.

[0148] FIG. 8 includes an example user interface displayed by the customer device 524 during execution of the application based on additional data indicative of present statuses of control modes and present (operation) statuses of various devices and modes of devices of the building. The present statuses may be, for example, on or off. The present status of a control mode, device, or mode of a device may be on (currently in use) or off (not currently in use). One type of indicator may be used to indicate a present status of on, while another type of indicator may be used to indicate a present status of off. The customer device 524 may display the additional data concurrently with the data from one or more IAQ modules, the local data, and/or the setpoint data.

[0149] The customer device 524 selectively displays measurements of one or more IAQ sensor modules, local data, control modes, and/or statuses from a predetermined period of time. The predetermined period of time may be, for example, the present day, a predetermined number of days (including or not including the present day), a predetermined number of hours before a present time, a predetermined number of minutes before the present time, or another suitable period. By default, a predetermined period may be selected (e.g., the present day), but a user may select a different predetermined period and the customer device 524 may display the data for the selected predetermined period.

[0150] FIG. 9 includes an example user interface displayed by the customer device 524 during execution of the application for the present day (from 12:01 pm of the present day to the present time (approximately 10 pm in this example)). The customer device 524 displays data selected by a user of the customer device 524. By default, all data may be selected, but a user may select less than all of the data to be displayed, and the customer device 524 may display only the selected data.

[0151] For example, in FIG. 9, only outdoor temperature (from the local data), outdoor RH (from the local data), indoor temperature (from the IAQ sensor module 304), indoor RH (from the IAQ sensor module 304), and particulate (from the IAQ sensor module 304) are graphed over time. Indicators of the statuses of the cooling mode, the heating mode, and use of the circulator blower 108 are also concurrently shown over time. Indoor Carbon dioxide (from the IAQ sensor module 304, if measured) and indoor VOCs (from the IAQ sensor module 304, if measures) are not graphed over time in this example.

[0152] The customer device 524 selectively displays a user interface for user selection of a priority for mitigating deviations in IAQ parameters. For example, the customer device 524 may display a user interface that allows user assignment of an order of prioritization for: (i) temperature control: (ii) RH control; (iii) particulate control; (vi) VOC control; and (v) carbon dioxide control. Temperature control may refer to maintaining, as much as possible, the temperature within the building within a predetermined temperature range. RH control may refer to maintaining, as much as possible, the RH within the building within a predetermined temperature range. Particulate control may refer to maintaining, as much as possible, the amount of particulate within the building less than a predetermined amount of particulate. VOC control may refer to maintaining, as much as possible, the amount of VOCs within the building less than a predetermined amount of VOCs. Carbon dioxide control may refer to maintaining, as much as possible, the amount of carbon dioxide within the building less than a predetermined amount of carbon dioxide. The order of prioritization for (i)-(v) may be initially preset, but may be user selected, as stated above.

[0153] The thermostat 208 and/or the IAQ control module 404 may control the mitigation devices 424 based on the prioritization (order). For example, when particulate control is the first priority, the thermostat 208 may control the mitigation devices 424 to decrease particulate as quickly as possible as opposed to, for example, controlling the mitigation devices 424 to more quickly adjust temperature or RH or to more quickly decrease the amount of VOCs and/or the amount of carbon dioxide.

[0154] The user interfaces provided by the customer device 524 provide visual information to the user regarding real-time measurements, historical measurements over a period of time, trends, and efficacy of IAQ mitigation and control. The user interfaces also enable the user to adjust setpoints to be used to control the mitigation devices 424 to control comfort and IAQ within the building. The user interfaces also enable the user to adjust prioritization in which IAQ conditions are mitigated. All of the above improves IAQ within the building and user experience regarding IAQ within the building.

[0155] FIG. 10 includes a block diagram of an example implementation of a mitigation system using the example of the IAQ control module 404. While the example of the IAQ control module 404 is provided for purposes of discussion, the modules of the IAQ control module 404 may alternatively be implemented within the thermostat 208 or within a combination of the thermostat 208 and the IAQ control module 404.

[0156] A mitigation module 1004 coordinates control of operation of sets of mitigation devices that mitigate the same IAQ parameter. For example, the mitigation module 1004 coordinates operation of the air cleaner/purifier 428 with operation of the circulator blower 108 of the air handler unit 136 for reducing particulate and/or VOCs. Additionally or alternatively, the mitigation module 1004 coordinates operation of the heating function of the air handler unit 136 with the heater 444 for heating. Additionally or alternatively, the mitigation module 1004 coordinates operation of the cooling function of the condensing unit 164 and the air handler unit 136 with the A/C device 448 for cooling. Additionally or alternatively, the mitigation module 1004 coordinates operation of the humidifier 432 with the humidifier 452 for humidification. Additionally or alternatively, the mitigation module 1004 coordinates operation of the dehumidifier 436 with the dehumidifier 456 for dehumidification. Additionally or alternatively, the mitigation module 1004 coordinates operation of the ventilator 440 with the room ventilator 460 for reducing carbon dioxide and/or VOCs.

[0157] The mitigation module 1004 controls operation of the mitigation devices based on measured IAQ parameters and primary/secondary settings for IAQ sensors or mitigation devices. The primary/secondary settings may be set to predetermined settings by default. A settings module 1008 may update the primary/secondary settings based on user input, such as to the customer device 524 and/or the thermostat 208.

[0158] In various implementations, the settings module 1008 may set the primary/secondary settings based on a present day (or date) and/or a present time. For example, the settings module 1008 may set the primary/secondary settings to a first set of primary/secondary settings between predetermined times (e.g., from 9 pm to the following 7 am daily) and to a second set of primary/secondary settings otherwise (e.g., from 7:01 am to the following 8:59 pm daily). In this manner, the settings module 1008 may set a first sensor module located in a first room (e.g., a bedroom) as the primary sensor (and a single room device set as the primary mitigation device) and a second sensor module located in a second room (e.g., a living room) to be a secondary sensor (and the whole-home device set as the secondary mitigation device) during night time hours (e.g., from 9 pm to the following 7 am daily), as the first set of primary/secondary settings, to ensure user comfort during sleeping hours. During the day (e.g., from 7:01 am to the following 8:59 pm daily), the settings module 1008 may designate the second sensor module located in the second (e.g., living) room to be the primary sensor (and the whole-home device being the primary mitigation device) and the first sensor module located in the first room (e.g., bedroom) to be the secondary sensor (and the single room device being the secondary mitigation device) to ensure a user's comfort while occupants are awake and moving about the building. The first set, the second set, the times, and the days may be set, for example, based on user input, such as to the customer device 524 and/or the thermostat 208.

[0159] The primary/secondary settings may specify which one of a set of two or more mitigation devices for mitigating the same IAQ parameter is a primary mitigation device of that set of two or more mitigation devices. The remaining mitigation devices of that set are considered secondary mitigation devices. For example, the air cleaner/purifier 428 may be a primary mitigation device for reducing particulate and the air handler unit 136 may be a secondary device for reducing particulate.

[0160] The mitigation module 1004 turns on a primary device when its associated IAQ parameter is greater than a predetermined value or outside of a predetermined range for that IAQ parameter. The mitigation module 1004 may also turn on a secondary mitigation device when the primary mitigation device is on.

[0161] In the example of the air cleaner/purifier 428 being a primary mitigation device and the air handler unit 136 being a secondary mitigation device for reducing particulate, the mitigation module 1004 may turn on the air cleaner/purifier 428 (the primary mitigation device) when the amount of particulate at the air cleaner/purifier 428 is greater than a predetermined amount of particulate. The mitigation module 1004 may also turn on the air handler unit 136 (the secondary mitigation device) when the air cleaner/purifier 428 is turned on.

[0162] The mitigation module 1004, however, may not automatically turn on a primary mitigation device in response to the secondary mitigation device being turned on due to its associated IAQ parameter being greater than a predetermined value or outside of a predetermined range. In the example of the air cleaner/purifier 428 being a primary mitigation device and the air handler unit 136 being a secondary mitigation device for reducing particulate, the mitigation module 1004 may turn on the air handler unit 136 (the secondary mitigation device) when an amount of particulate (e.g., measured by the IAQ sensor module 304) is greater than the predetermined amount of particulate. The mitigation module 1004, however, may leave the air cleaner/purifier 428 (the primary mitigation device) off despite the air handler unit 136 being turned on. That is, unless an amount of particulate measured by the particulate sensor at the air cleaner/purifier 428 is also greater than the predetermined amount of particulate.

[0163] Under some circumstances, turning on of both the primary mitigation device and the secondary mitigation device may cause another IAQ parameter to become greater than its predetermined value or outside of its predetermined range. To avoid this, the mitigation module 1004 may leave a secondary mitigation device off and maintain a primary mitigation device running for a longer period. Alternatively, the mitigation module 1004 may turn on both the primary and secondary mitigation devices and mitigate the other IAQ parameter if the other IAQ parameter in fact becomes greater than its predetermined value or outside of its predetermined range.

[0164] In various implementations, the primary/secondary settings may alternatively specify which one of a set of two or more sensors of one IAQ parameter is a primary sensor of that set of two or more sensors. The remaining sensors of that set are considered secondary sensors. For example, a particulate sensor of the air cleaner/purifier 428 may be a primary sensor for reducing particulate and the particulate sensor 316 of the IAQ sensor module 304 may be a secondary sensor for reducing particulate.

[0165] The mitigation module 1004 turns on a first mitigation device associated with the primary sensor when the IAQ parameter measured by the primary sensor is greater than a predetermined value or outside of a predetermined range for that IAQ parameter. The mitigation module 1004 also turns on a second mitigation device when the IAQ parameter measured by the primary sensor is greater than the predetermined value or outside of the predetermined range for that IAQ parameter. In various implementations, the mitigation module 1004 may wait to turn on the second mitigation device until the IAQ parameter measured by the primary sensor is greater than a second predetermined value that is greater than the predetermined value or outside of a second predetermined range for that IAQ parameter.

[0166] In the example of the particulate sensor of the air cleaner/purifier 428 being the primary sensor and the particulate sensor 316 of the IAQ sensor module 304 being the secondary sensor, the mitigation module 1004 may turn on the air cleaner/purifier 428 (that is associated with the primary sensor) when the amount of particulate measured by the particulate sensor at the air cleaner/purifier 428 is greater than a predetermined amount of particulate. The mitigation module 1004 may also turn on the air handler unit 136 (that is associated with the secondary sensor) when the amount of particulate measured by the particulate sensor at the air cleaner/purifier 428 is greater than the predetermined amount of particulate.

[0167] The mitigation module 1004, however, does not turn on the first mitigation device associated with the primary sensor when IAQ parameter measured by the secondary sensor associated with the second mitigation device is greater than the predetermined value or outside of the predetermined range for that IAQ parameter. In the example of the particulate sensor of the air cleaner/purifier 428 being the primary sensor and the particulate sensor 316 of the IAQ sensor module 304 being the secondary sensor, the mitigation module 1004 may turn on the air handler unit 136 (that is associated with the secondary sensor) when the amount of particulate measured by the particulate sensor 316 of the IAQ sensor module 304 (the secondary sensor) is greater than the predetermined amount of particulate. The mitigation module 1004, however, may leave the air cleaner/purifier 428 (that is associated with the primary sensor) off when the amount of particulate measured by the particulate sensor 316 of the IAQ sensor module 304 (the secondary sensor) is greater than the predetermined amount of particulate. That is, unless the amount of particulate measured by the particulate sensor at the air cleaner/purifier 428 is also greater than the predetermined amount of particulate.

[0168] FIGs. 11-14 include example graphs of particulate versus time. In FIG. 11, trace 1104 tracks the amount of particulate measured using a particulate sensor located within a room of a building while the air handler unit 136 was on and an air cleaner/purifier located within the room was off to decrease the amount of particulate measured by the particulate sensor. Trace 1108 tracks the amount of particulate measured using the particulate sensor located within the room of the building while the air handler unit 136 was on and the air cleaner/purifier located within the room was on to decrease the amount of particulate measured by the particulate sensor. As illustrated by trace 1108, the amount of particulate within the room decreased more quickly when both the air handler unit 136 and the air cleaner/purifier were on to decrease the amount of particulate measured by the particulate sensor. The mitigation module 1004 turned both the air handler unit 136 and the air cleaner/purifier on due to either the primary mitigation device being turned on or the amount of particulate measured by the primary particulate sensor being greater than the predetermined amount of particulate.

[0169] In FIG. 12, trace 1204 tracks the amount of particulate measured using a particulate sensor located within a room of a building while the air handler unit 136 was off and an air cleaner/purifier located within the room was off. Trace 1208 tracks the amount of particulate measured using the particulate sensor located within the room of the building while the air handler unit 136 was off and the air cleaner/purifier located within the room was on to decrease the amount of particulate measured by the particulate sensor. As illustrated by comparing trace 1204 with trace 1208 of FIG. 12, the amount of particulate within the room decreased more quickly when the air cleaner/purifier was on to decrease the amount of particulate measured by the particulate sensor.

[0170] In FIG. 13, trace 1304 tracks the amount of particulate measured using a particulate sensor located within a room of a building while the air handler unit 136 was off and an air cleaner/purifier located within the room was off. Trace 1308 tracks the amount of particulate measured using the particulate sensor located within the room of the building while the air handler unit 136 was on to decrease the amount of particulate measured by the particulate sensor and the air cleaner/purifier located within the room was off. As illustrated by comparing trace 1304 with trace 1308 of FIG. 13, the amount of particulate within the room decreased more quickly when the air handler unit 136 was on to decrease the amount of particulate measured by the particulate sensor.

[0171] In FIG. 14, trace 1404 tracks the amount of particulate measured using a particulate sensor located within a room of a building while the air handler unit 136 was off and an air cleaner/purifier located within the room was on. Trace 1408 tracks the amount of particulate measured using the particulate sensor located within the room of the building while the air handler unit 136 was on and the air cleaner/purifier located within the room was on to decrease the amount of particulate measured by the particulate sensor. As illustrated by trace 1408, the amount of particulate within the room decreased more quickly when both the air handler unit 136 and the air cleaner/purifier was on to decrease the amount of particulate measured by the particulate sensor.

[0172] The trend exhibited is also applicable to other types of mitigation devices used to mitigate other IAQ parameters. For example, the amount of VOCs within a room may decrease more quickly when the ventilator 440 and a ventilator of the room (e.g., 460) are both on to decrease the amount of VOCs. The amount of carbon dioxide within a room may decrease more quickly when the ventilator 440 and a ventilator of the room (e.g., 460) are both on to decrease the amount of carbon dioxide. The RH within a room may decrease more quickly when the dehumidifier 436 and a dehumidifier within the room are both on to decrease the RH. The RH within a room may increase more quickly when the humidifier 432 and a humidifier within the room are both on to increase the RH. The temperature within a room may increase more quickly when the heating function of the air handler unit 136 and a heater within the room are both on to increase the temperature. The temperature within a room may decrease more quickly when the cooling function of the air handler unit 136 and the condensing unit 164 and an A/C unit within the room are both on to decrease the temperature.

[0173] FIG. 15 includes a functional block diagram of an example building including the IAQ sensor module 304, the IAQ control module 404, and an IAQ system 1504 for the building. The IAQ system 1504 may include the air handler unit 136 and the condensing unit

164 of the building. The IAQ system 1504 may also include one or more other air handler units and one or more other condensing units in buildings that include multiple air handler units and/or multiple condensing units. The IAQ control module 404 and/or the thermostat 208 control operation of the IAQ system 1504, for example, based on the IAQ parameters from the IAQ sensor module 304 and or the measurements from the thermostat 208.

[0174] FIG. 16 includes a functional block diagram of the example building including a room 1604 and a (standalone) mitigation device 1608 located within the room 1604. The mitigation device 1608 may be one of the standalone (or room) mitigation devices described above (e.g., 444, 448, 452, 456, 460). The mitigation device 1608 includes a sensor 1612 and a control module 1616. The IAQ sensor 1612 is connected to the control module 1616 by wire or wirelessly. The IAQ sensor 1612 may be fixed to the mitigation device 1608. In various implementations, the IAQ sensor 1612 may be separable from the mitigation device 1608 and moveable by a distance corresponding to a length of wire connected to the IAQ sensor 1612 or a distance for wireless connections. The IAQ sensor 1612 senses an IAQ parameter that the mitigation device 1608 is configured to vary.

[0175] The control module 1616 may control operation of the mitigation device 1608 based on the IAQ parameter measured by the IAQ sensor 1612. For example, the mitigation device 1608 may be an air cleaner/purifier and the IAQ sensor 1612 may measure an amount of particulate in the air at the mitigation device 1608. The control module 1616 may turn the air cleaner/purifier on when the amount of particulate measured by the IAQ sensor 1612 is greater than a predetermined amount of particulate.

[0176] In various implementations, a second IAQ sensor 1620 may be included and senses the IAQ parameter that the mitigation device 1608 is configured to vary. The second IAQ sensor 1620 may be an IAQ sensor module like the IAQ sensor module 304 described above. In the example of the mitigation device 1608 being an air cleaner/purifier, the second IAQ sensor 1620 may measure an amount of particulate in the air. The control module 1616 may turn the air cleaner/purifier on when at least one of: (a) the amount of particulate measured by the IAQ sensor 1612 is greater than a predetermined amount of particulate; and (b) the amount of particulate measured by the second IAQ sensor 1620 is greater than the predetermined amount of particulate.

[0177] FIG. 17 includes a functional block diagram of the example building including the room 1604 and the (standalone) mitigation device 1608 located within the room 1604. As discussed above, the mitigation module 1004 may coordinate operation of one or more mitigation devices of the building IAQ system 1504 and the mitigation device 1608 based on the primary/secondary settings. When the mitigation device 1608 is a secondary mitigation device, the control module 1616 may also turn on the mitigation device 1608 when the same type of mitigation device of the building IAQ system 1504 is turned on.

[0178] FIG. 18 includes a functional block diagram of the example building including the room 1604, the (standalone) mitigation device 1608 located within the room 1604, a second room 1804, and a second (standalone) mitigation device 1808 located within the second room 1804. FIG. 18 illustrates that the concept of FIG. 17 is not limited to one room.

[0179] FIG. 19 includes a functional block diagram of the example building including the (standalone) mitigation device 1608 and the second (standalone) mitigation device 1808. FIG. 19 illustrates that the control of operation of multiple standalone mitigation devices can be coordinated.

[0180] FIG. 20 includes a flowchart depicting an example method of coordinating control of multiple mitigation devices. In the example of FIG. 20, the example of the mitigation device 1608 (e.g. the air cleaner/purifier 428) being the primary mitigation device and the corresponding type of mitigation device (e.g., the air handler unit 136) being the secondary mitigation device will be discussed for purposes of discussion only.

[0181] Control may begin with 2004 where the mitigation module 1004 receives the IAQ parameter (e.g., amount of particulate) associated with the secondary device (e.g., from the IAQ sensor module 304). At 2008, the mitigation module 1004 determines whether the primary mitigation device (e.g., the air cleaner/purifier 428) is on. As discussed above, the control module 1616 may turn on the mitigation device 1608 when the IAQ parameter (e.g., the amount of particulate) measured by the IAQ sensor 1612 (or 1620) is greater than a predetermined value. If 2008 is true (i.e., the primary mitigation device is on), the mitigation module 1004 turns the secondary mitigation device (e.g., the air handler unit 136) on at 2012, and control returns to 2004. If 2008 is false (i.e., the primary mitigation device is off), control transfers to 2016.

[0182] At 2016, the mitigation module 1004 determines whether the IAQ parameter (e.g., amount of particulate) associated with the secondary mitigation device (e.g., from the IAQ sensor module 304) is greater than a predetermined value or outside of a predetermined range. If 2016 is true, the mitigation module 1004 may turn on the secondary mitigation device (e.g., the air handler unit 136) at 2020, and control may return to 2004. This, however, does not cause the primary mitigation device to be turned on. If 2016 is false, the mitigation module

1004 may leave the secondary mitigation device (e.g., the air handler unit 136) off at 2024, and control may return to 2004.

[0183] FIG. 21 includes a flowchart depicting an example method of coordinating control of multiple mitigation devices. In the example of FIG. 21, the example of the IAQ sensor 1612 (e.g., a particulate sensor) being the primary sensor and a sensor of the IAQ sensor module 304 (e.g., the particulate sensor 316) will be discussed for purposes of discussion only.

[0184] Control may begin with 2104 where the mitigation module 1004 receives the IAQ parameter measured by the IAQ sensor 1612 (the primary sensor) and the same IAQ parameter measured by the IAQ sensor module 304 (the secondary sensor). At 2108, the mitigation module 1004 determines whether the IAQ parameter measured by the IAQ sensor 1612 (the primary sensor) is greater than a predetermined value (e.g., a predetermined amount of particulate) or outside of a predetermined range. If 2108 is true, the mitigation module 1004 turns a mitigation device of the building IAQ system 1504 (e.g., the air handler unit 136) on at 2112, and control returns to 2104. Based on the IAQ parameter measured by the IAQ sensor 1612 (the primary sensor) being greater than the predetermined value (e.g., the predetermined amount of particulate) or outside of the predetermined range, the control module 1616 also turns on the mitigation device 1608 at 2112. If 2108 is false, control transfers to 2116.

[0185] At 2116, the mitigation module 1004 determines whether the IAQ parameter measured by the IAQ sensor module 304 (the secondary sensor) is greater than the predetermined value (e.g., the predetermined amount of particulate) or outside of the predetermined range. If 2116 is true, the mitigation module 1004 may turn on the mitigation device of the building IAQ system 1504 (e.g., the air handler unit 136) at 2120, and control may return to 2104. This, however, does not cause the control module 1616 to also turn on the mitigation device 1608. If 2116 is false, the mitigation module 1004 may leave the mitigation device of the building IAQ system 1504 (e.g., the air handler unit 136) off at 2124, and control may return to 2104. Based on the IAQ parameter measured by the IAQ sensor 1612 (the primary sensor) being less than the predetermined value (e.g., the predetermined amount of particulate) or within the predetermined range, the control module 1616 may also maintain or turn the mitigation device off 1608 at 2124.

[0186] The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the embodiments is described above as having certain features, any one or more of those features described with respect to any embodiment of the disclosure can be implemented in and/or combined with features of any of the other embodiments, even if that combination is not explicitly described. In other words, the described embodiments are not mutually exclusive, and permutations of one or more embodiments with one another remain within the scope of this disclosure.

[0187] Spatial and functional relationships between elements (for example, between modules, circuit elements, semiconductor layers, etc.) are described using various terms, including “connected,” “engaged,” “coupled,” “adjacent,” “next to,” “on top of,” “above,” “below,” and “disposed.” Unless explicitly described as being “direct,” when a relationship between first and second elements is described in the above disclosure, that relationship can be a direct relationship where no other intervening elements are present between the first and second elements, but can also be an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”

[0188] In the figures, the direction of an arrow, as indicated by the arrowhead, generally demonstrates the flow of information (such as data or instructions) that is of interest to the illustration. For example, when element A and element B exchange a variety of information but information transmitted from element A to element B is relevant to the illustration, the arrow may point from element A to element B. This unidirectional arrow does not imply that no other information is transmitted from element B to element A. Further, for information sent from element A to element B, element B may send requests for, or receipt acknowledgements of, the information to element A.

[0189] In this application, including the definitions below, the term “module” or the term “controller” may be replaced with the term “circuit.” The term “module” may refer to, be part of, or include: an Application Specific Integrated Circuit (ASIC); a digital, analog, or mixed analog/digital discrete circuit; a digital, analog, or mixed analog/digital integrated circuit; a combinational logic circuit; a field programmable gate array (FPGA); a processor circuit (shared, dedicated, or group) that executes code; a memory circuit (shared, dedicated, or group) that stores code executed by the processor circuit; other suitable hardware components that provide the described functionality; or a combination of some or all of the above, such as in a system-on-chip.

[0190] The module may include one or more interface circuits. In some examples, the interface circuits may include wired or wireless interfaces that are connected to a local area network (LAN), the Internet, a wide area network (WAN), or combinations thereof. The functionality of any given module of the present disclosure may be distributed among multiple modules that are connected via interface circuits. For example, multiple modules may allow load balancing. In a further example, a server (also known as remote, or cloud) module may accomplish some functionality on behalf of a client module.

[0191] The term code, as used above, may include software, firmware, and/or microcode, and may refer to programs, routines, functions, classes, data structures, and/or objects. The term shared processor circuit encompasses a single processor circuit that executes some or all code from multiple modules. The term group processor circuit encompasses a processor circuit that, in combination with additional processor circuits, executes some or all code from one or more modules. References to multiple processor circuits encompass multiple processor circuits on discrete dies, multiple processor circuits on a single die, multiple cores of a single processor circuit, multiple threads of a single processor circuit, or a combination of the above. The term shared memory circuit encompasses a single memory circuit that stores some or all code from multiple modules. The term group memory circuit encompasses a memory circuit that, in combination with additional memories, stores some or all code from one or more modules.

[0192] The term memory circuit is a subset of the term computer-readable medium. The term computer-readable medium, as used herein, does not encompass transitory electrical or electromagnetic signals propagating through a medium (such as on a carrier wave); the term computer-readable medium may therefore be considered tangible and non-transitory. Non-limiting examples of a non-transitory, tangible computer-readable medium are nonvolatile memory circuits (such as a flash memory circuit, an erasable programmable read-only memory circuit, or a mask read-only memory circuit), volatile memory circuits (such as a static random access memory circuit or a dynamic random access memory circuit), magnetic storage media (such as an analog or digital magnetic tape or a hard disk drive), and optical storage media (such as a CD, a DVD, or a Blu-ray Disc).

[0193] The apparatuses and methods described in this application may be partially or fully implemented by a special purpose computer created by configuring a general purpose computer to execute one or more particular functions embodied in computer programs. The functional blocks, flowchart components, and other elements described above serve as software specifications, which can be translated into the computer programs by the routine work of a skilled technician or programmer.

[0194] The computer programs include processor-executable instructions that are stored on at least one non-transitory, tangible computer-readable medium. The computer programs may also include or rely on stored data. The computer programs may encompass a basic input/output system (BIOS) that interacts with hardware of the special purpose computer, device drivers that interact with particular devices of the special purpose computer, one or more operating systems, user applications, background services, background applications, etc.

[0195] The computer programs may include: (i) descriptive text to be parsed, such as HTML (hypertext markup language), XML (extensible markup language), or JSON (JavaScript Object Notation) (ii) assembly code, (iii) object code generated from source code by a compiler, (iv) source code for execution by an interpreter, (v) source code for compilation and execution by a just-in-time compiler, etc. As examples only, source code may be written using syntax from languages including C, C++, C#, Objective-C, Swift, Haskell, Go, SQL, R, Lisp, Java®, Fortran, Perl, Pascal, Curl, OCaml, Javascript®, HTML5 (Hypertext Markup Language 5th revision), Ada, ASP (Active Server Pages), PHP (PHP: Hypertext Preprocessor), Scala, Eiffel, Smalltalk, Erlang, Ruby, Flash®, Visual Basic®, Lua, MATLAB, SIMULINK, and Python®.

CLAIMS

What is claimed is:

1. An indoor air quality (IAQ) system for a building, comprising:

a heating, ventilation, and/or air conditioning (HVAC) system of the building;

a first and second IAQ sensors that are located within the building and that are configured to measure first and second IAQ parameters, respectively, the first and second IAQ parameter being the same one of:

relative humidity (RH) of air;

amount of particulate of at least a predetermined size present in air;

amount of volatile organic compounds (VOCs) present in air; and

amount of carbon dioxide present in air;

a mitigation device that is separate from the HVAC system and that comprises a control module configured to turn the mitigation device on and off based on the first IAQ parameter measured by the first IAQ sensor; and

a mitigation module configured to selectively turn the HVAC system of the building on and off based on the second IAQ parameter measured by the second IAQ sensor,

wherein the control module is further configured to selectively turn the mitigation device on and off further based on at least one of:

the second IAQ parameter; and

whether the HVAC system of the building is on or off; and

wherein the mitigation module is further configured to selectively turn the HVAC system of the building on and off further based on at least one of:

the first IAQ parameter; and

whether the mitigation device is on or off.

2. The IAQ system of claim 1 wherein the mitigation module is configured to:

turn the HVAC system of the building on when the second IAQ parameter is greater than a first predetermined value; and

turn the HVAC system of the building off when the second IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

3. The IAQ system of claim 2 wherein the mitigation module is configured to turn the HVAC system of the building on when the first IAQ parameter is greater than a third predetermined value,

wherein the third predetermined value is greater than the second predetermined value.

4. The IAQ system of claim 1 wherein the control module is configured to turn the mitigation device on and off independently of the first IAQ parameter based on at least one of (i) the second IAQ parameter and (ii) whether the HVAC system of the building is on or off.

5. The IAQ system of claim 1 wherein the mitigation module is configured to:

turn the HVAC system of the building on in response to the mitigation device being turned on;

maintain the HVAC system of the building on while the mitigation device is on; and

turn the HVAC system of the building off in response to the mitigation device being turned off.

6. The IAQ system of claim 1 wherein the mitigation module is configured to turn the HVAC system of the building on when at least one of:

the second IAQ parameter is greater than a first predetermined value; and

the mitigation device is turned on.

7. The IAQ system of claim 1 wherein the control module is configured to:

turn the mitigation device on when the first IAQ parameter is greater than a first predetermined value; and

turn the mitigation device off when the first IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

8. The IAQ system of claim 7 wherein the control module is configured to turn the mitigation device on when the second IAQ parameter is greater than a third predetermined value,

wherein the third predetermined value is greater than the second predetermined value.

9. The IAQ system of claim 1 wherein the mitigation module is configured to turn the HVAC system of the building on and off independently of the second IAQ parameter based on at least one of (i) the first IAQ parameter and (ii) whether the mitigation device is on or off.

10. The IAQ system of claim 1 wherein the control module is configured to:

turn the mitigation device on in response to the HVAC system of the building being turned on;

maintain the mitigation device on while the HVAC system of the building is on; and

turn the mitigation device off in response to the HVAC system of the building being turned off.

11. The IAQ system of claim 1 wherein the control module is configured to turn the mitigation device on when at least one of:

the first IAQ parameter is greater than a first predetermined value; and

the HVAC system of the building is turned on.

12. A method, comprising:

by first and second indoor air quality (IAQ) sensors that are located within a building, measuring first and second IAQ parameters, respectively, the first and second IAQ parameter being the same one of:

relative humidity (RH) of air;

amount of particulate of at least a predetermined size present in air;

amount of volatile organic compounds (VOCs) present in air; and

amount of carbon dioxide present in air;

turning a mitigation device on and off based on the first IAQ parameter measured by the first IAQ sensor,

wherein the mitigation device is separate from a heating, ventilation, and/or air conditioning (HVAC) system of the building;

selectively turning the HVAC system of the building on and off based on the second IAQ parameter measured by the second IAQ sensor;

selectively turning the mitigation device on and off further based on at least one of:

the second IAQ parameter; and

whether the HVAC system of the building is on or off; and

selectively turning the HVAC system of the building on and off further based on at least one of:

the first IAQ parameter; and

whether the mitigation device is on or off.

13. The method of claim 12 further comprising:

turning the HVAC system of the building on when the second IAQ parameter is greater than a first predetermined value; and

turning the HVAC system of the building off when the second IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

14. The method of claim 13 further comprising turning the HVAC system of the building on when the first IAQ parameter is greater than a third predetermined value,

wherein the third predetermined value is greater than the second predetermined value.

15. The method of claim 12 further comprising turning the mitigation device on and off independently of the first IAQ parameter based on at least one of (i) the second IAQ parameter and (ii) whether the HVAC system of the building is on or off.

16. The method of claim 12 further comprising:

turning the HVAC system of the building on in response to the mitigation device being turned on;

maintaining the HVAC system of the building on while the mitigation device is on; and

turning the HVAC system of the building off in response to the mitigation device being turned off.

17. The method of claim 12 further comprising turning the HVAC system of the building on when at least one of:

the second IAQ parameter is greater than a first predetermined value; and

the mitigation device is turned on.

18. The method of claim 12 further comprising:

turning the mitigation device on when the first IAQ parameter is greater than a first predetermined value; and

turning the mitigation device off when the first IAQ parameter is less than a second predetermined value that is less than the first predetermined value.

19. The method of claim 18 further comprising turning the mitigation device on when the second IAQ parameter is greater than a third predetermined value,

wherein the third predetermined value is greater than the second predetermined value.

20. The method of claim 12 further comprising turning the HVAC system of the building on and off independently of the second IAQ parameter based on at least one of (i) the first IAQ parameter and (ii) whether the mitigation device is on or off.

21. The method of claim 12 further comprising:

turning the mitigation device on in response to the HVAC system of the building being turned on;

maintaining the mitigation device on while the HVAC system of the building is on; and

turning the mitigation device off in response to the HVAC system of the building being turned off.

22. The method of claim 12 further comprising turning the mitigation device on when at least one of:

the first IAQ parameter is greater than a first predetermined value; and

the HVAC system of the building is turned on.

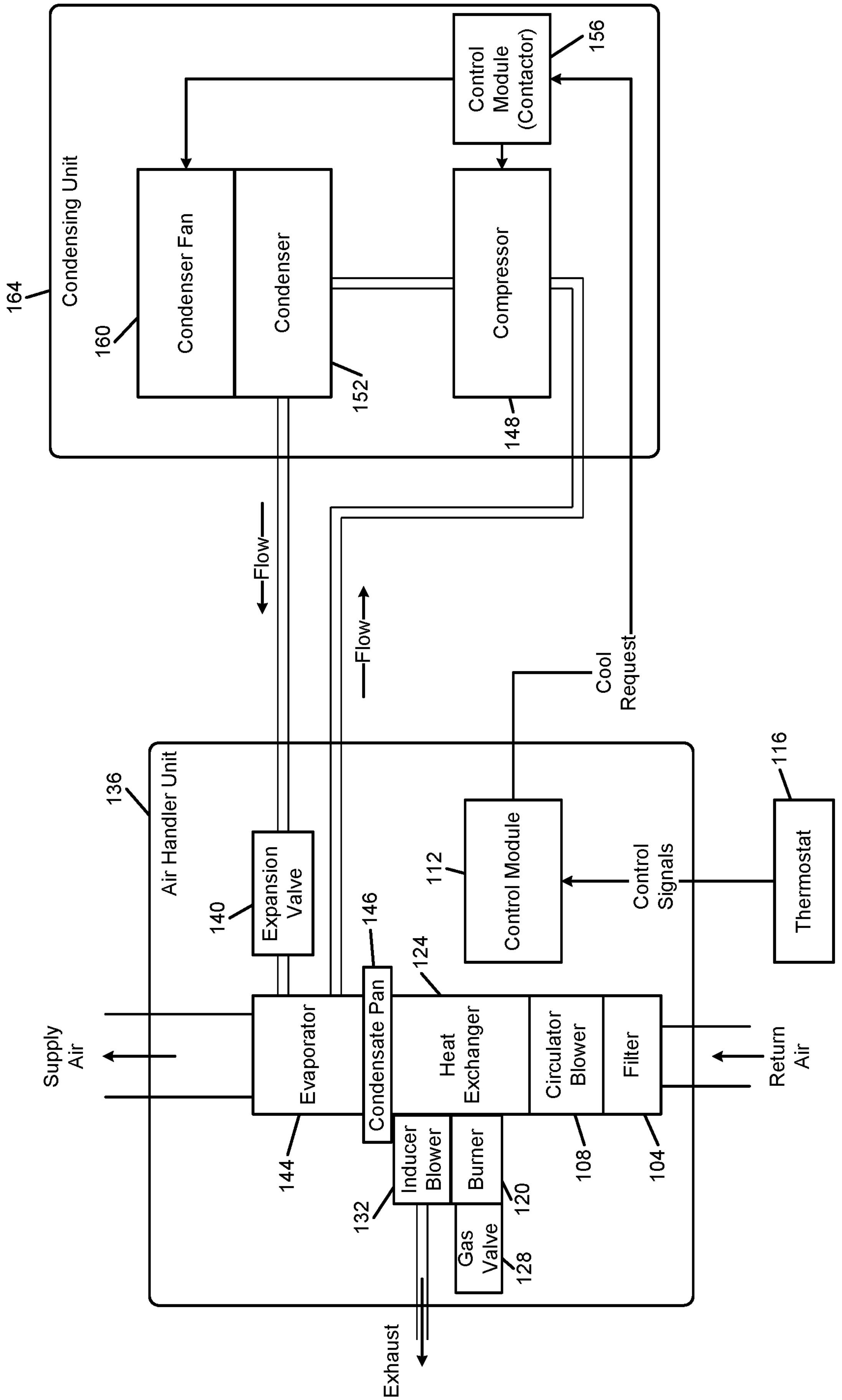

164
Condensing Unit
160
Condenser Fan
Condenser
152
Compressor
148
Control Module (Contactor)
156
Flow
Flow
Cool Request
136
Air Handler Unit
140
Expansion Valve
146
112
Control Module
Control Signals
116
Thermostat
124
Supply Air
Evaporator
Condensate Pan
Heat Exchanger
Circulator Blower
Filter
Return Air
144
Inducer Blower
Burner
108
104
132
120
Gas Valve
128
Exhaust

FIG. 1

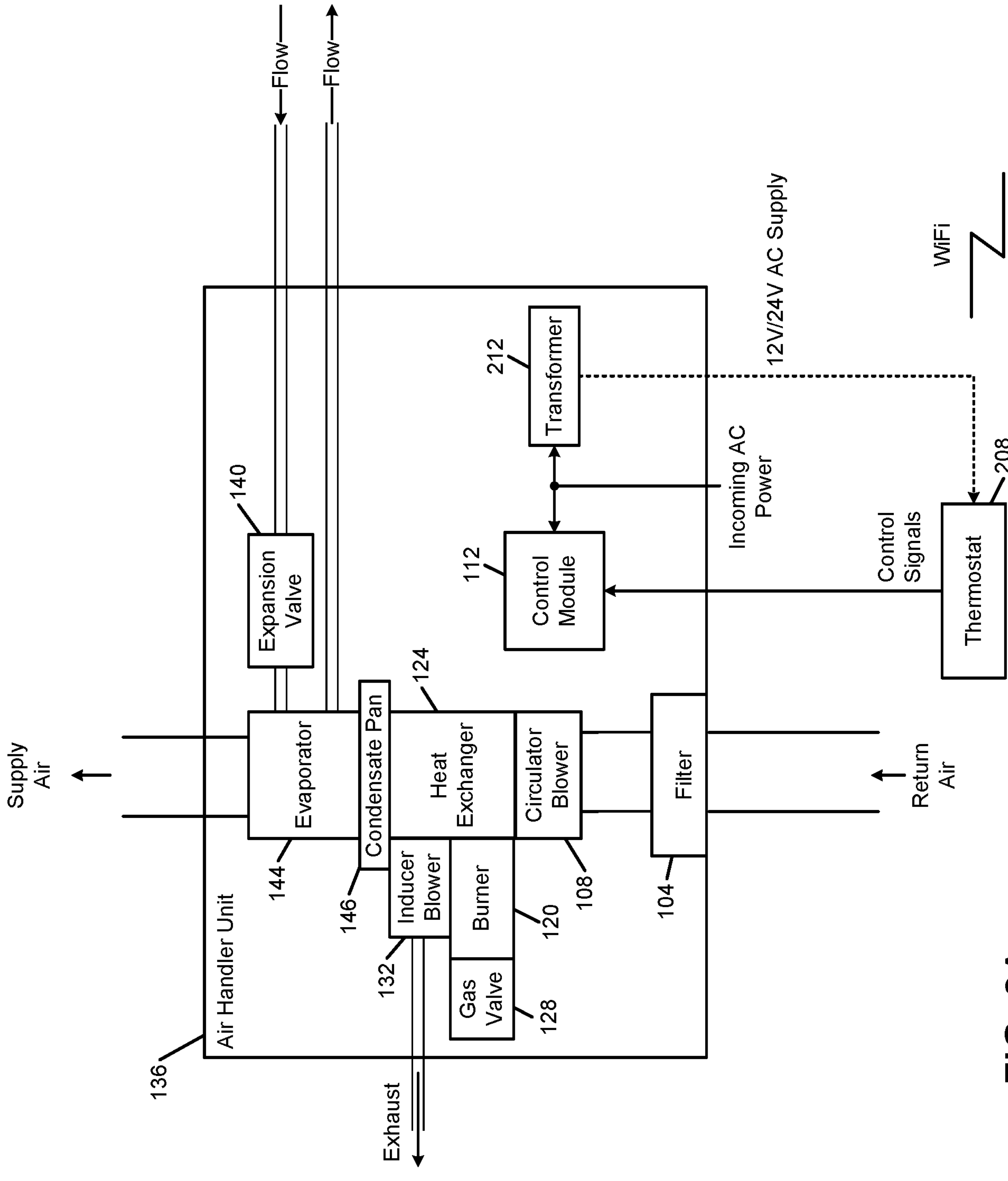

Flow
Flow
12V/24V AC Supply
WiFi
Expansion Valve
140
212
Transformer
Incoming AC Power
112
Control Module
Control Signals
208
Thermostat
Supply Air
Evaporator
Condensate Pan
124
Heat Exchanger
Circulator Blower
Filter
Return Air
144
146
Inducer Blower
Burner
120
108
104
Air Handler Unit
132
Gas Valve
128
136
Exhaust

FIG. 2A

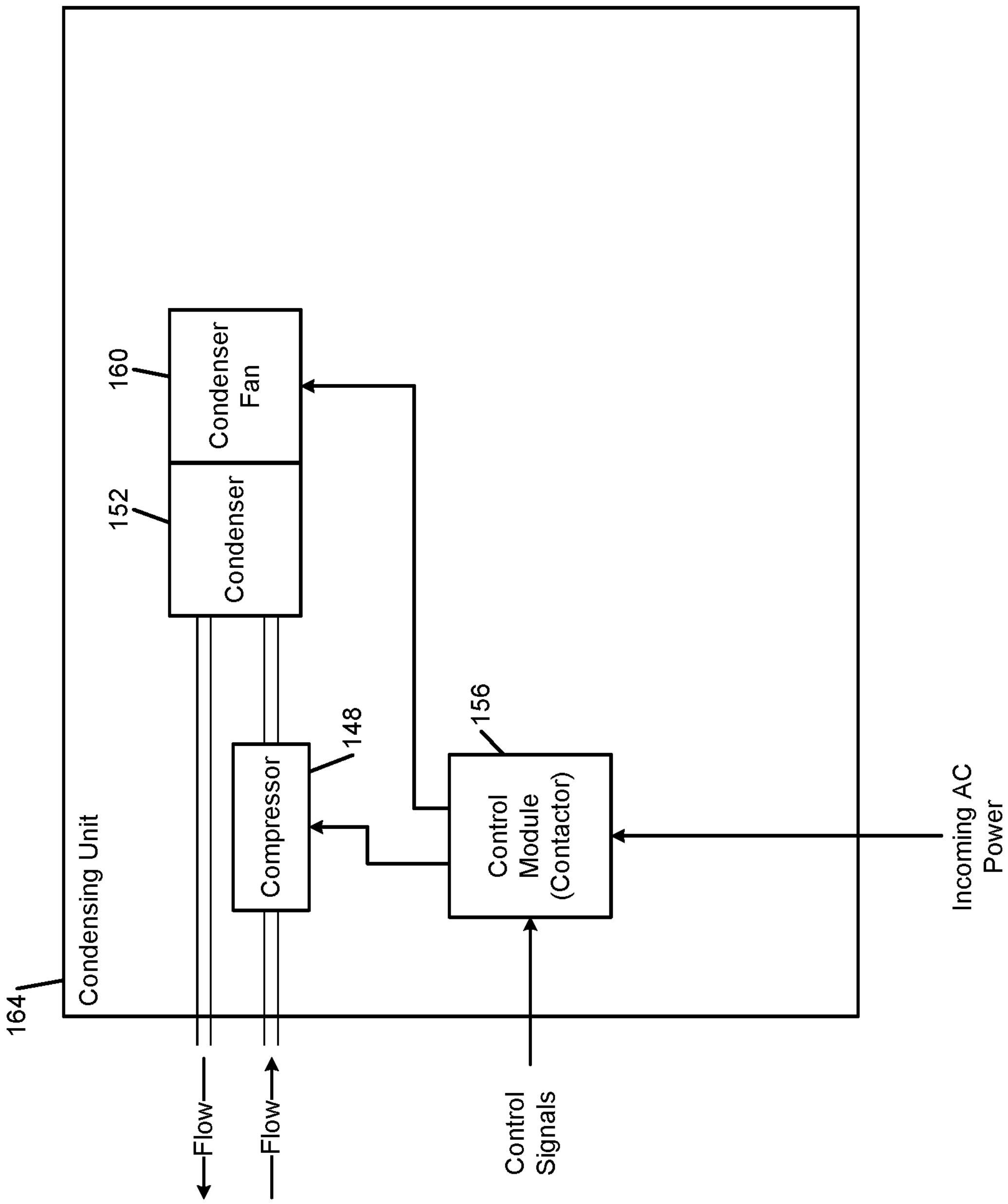

164
Condensing Unit
Condenser
152
Condenser Fan
160
Compressor
148
Control Module (Contactor)
156
Flow
Flow
Control Signals
Incoming AC Power

FIG. 2B

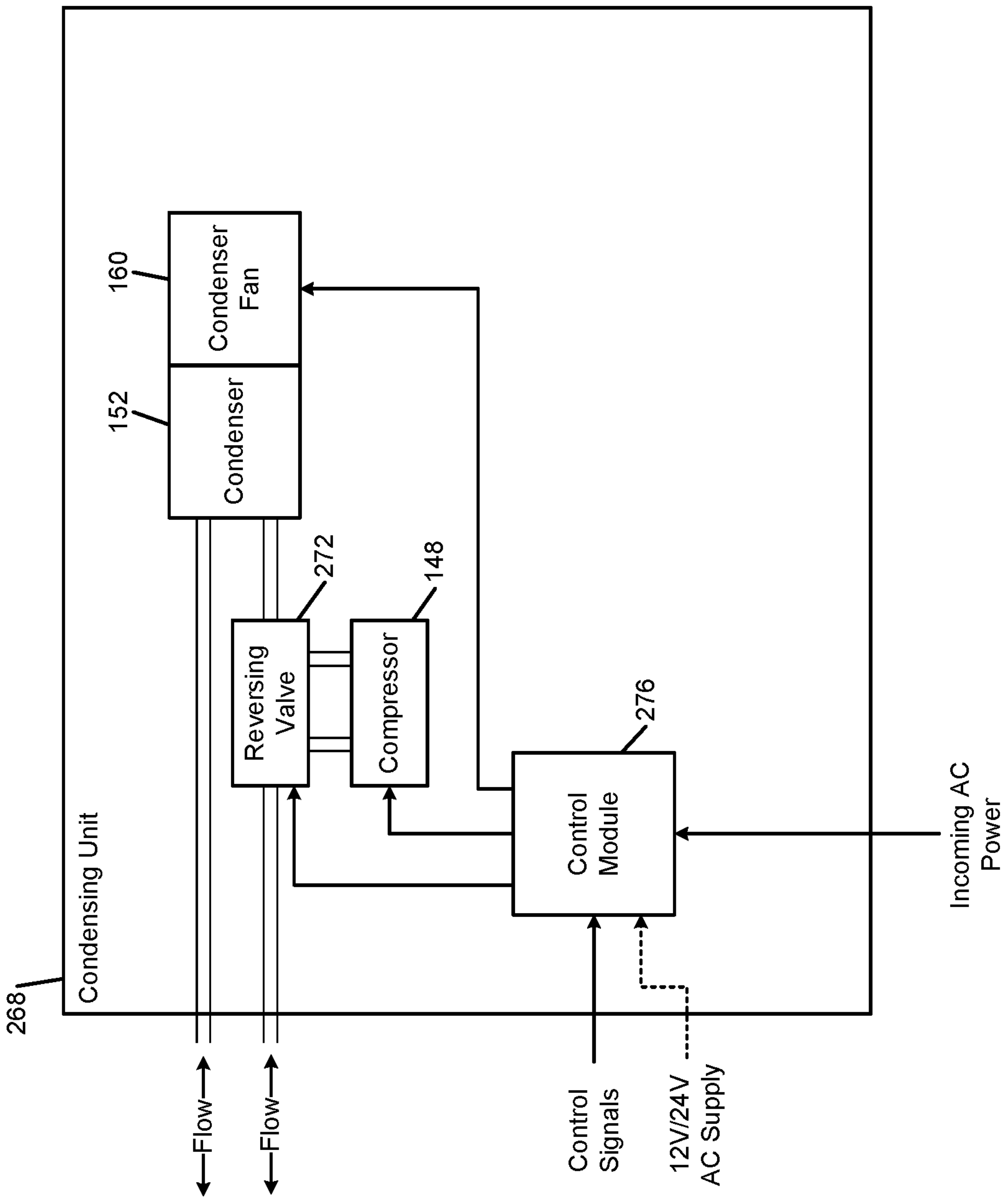

Condensing Unit
268
Condenser
152
Condenser Fan
160
Reversing Valve
272
Compressor
148
Control Module
276
Incoming AC Power
Control Signals
12V/24V AC Supply
Flow
Flow

FIG. 2C

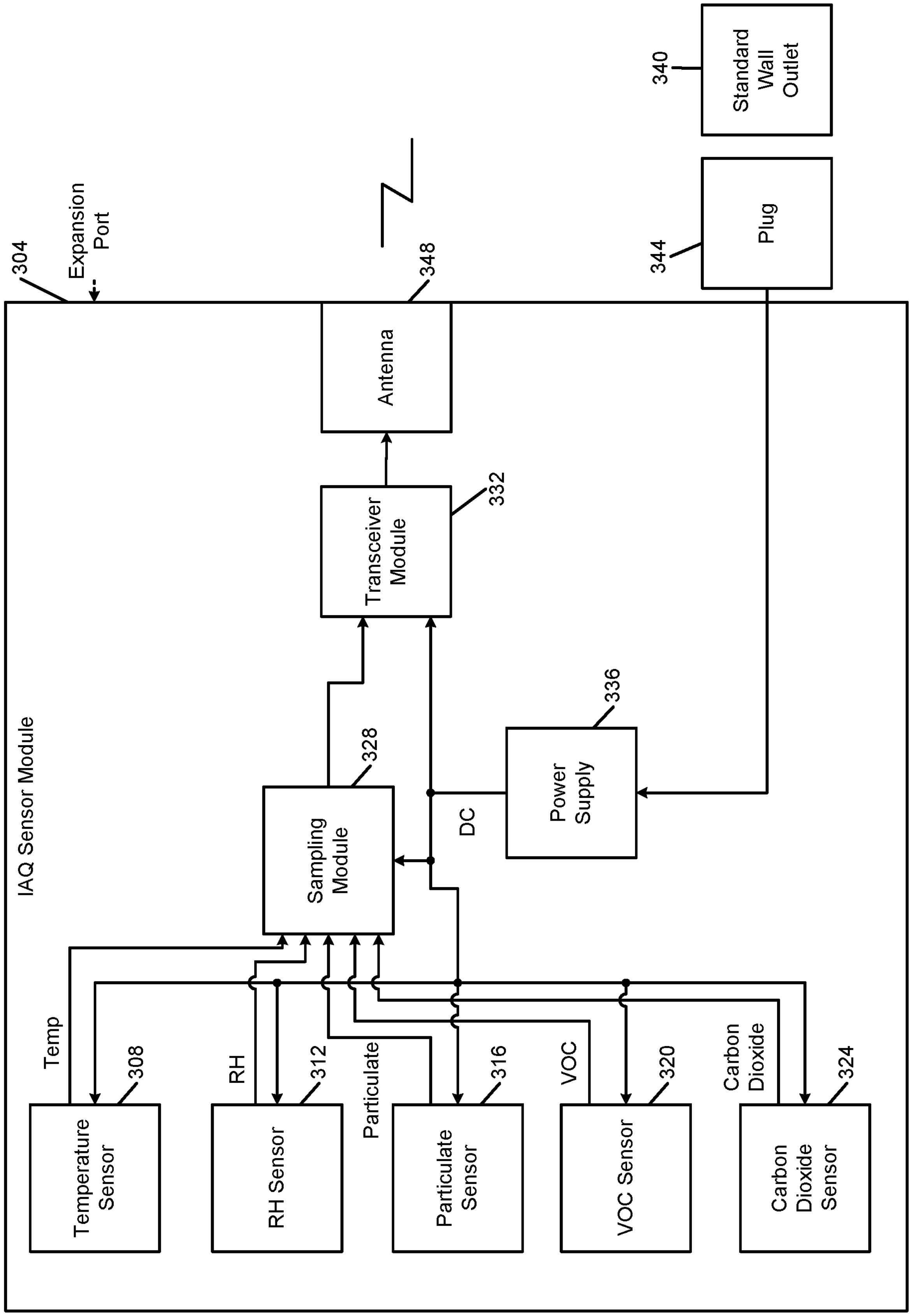

IAQ Sensor Module
304
Expansion Port
348
Antenna
332
Transceiver Module
328
Sampling Module
336
Power Supply
DC
344
Plug
340
Standard Wall Outlet
Temp
308
Temperature Sensor
RH
312
RH Sensor
Particulate
316
Particulate Sensor
VOC
320
VOC Sensor
Carbon Dioxide
324
Carbon Dioxide Sensor

FIG. 3

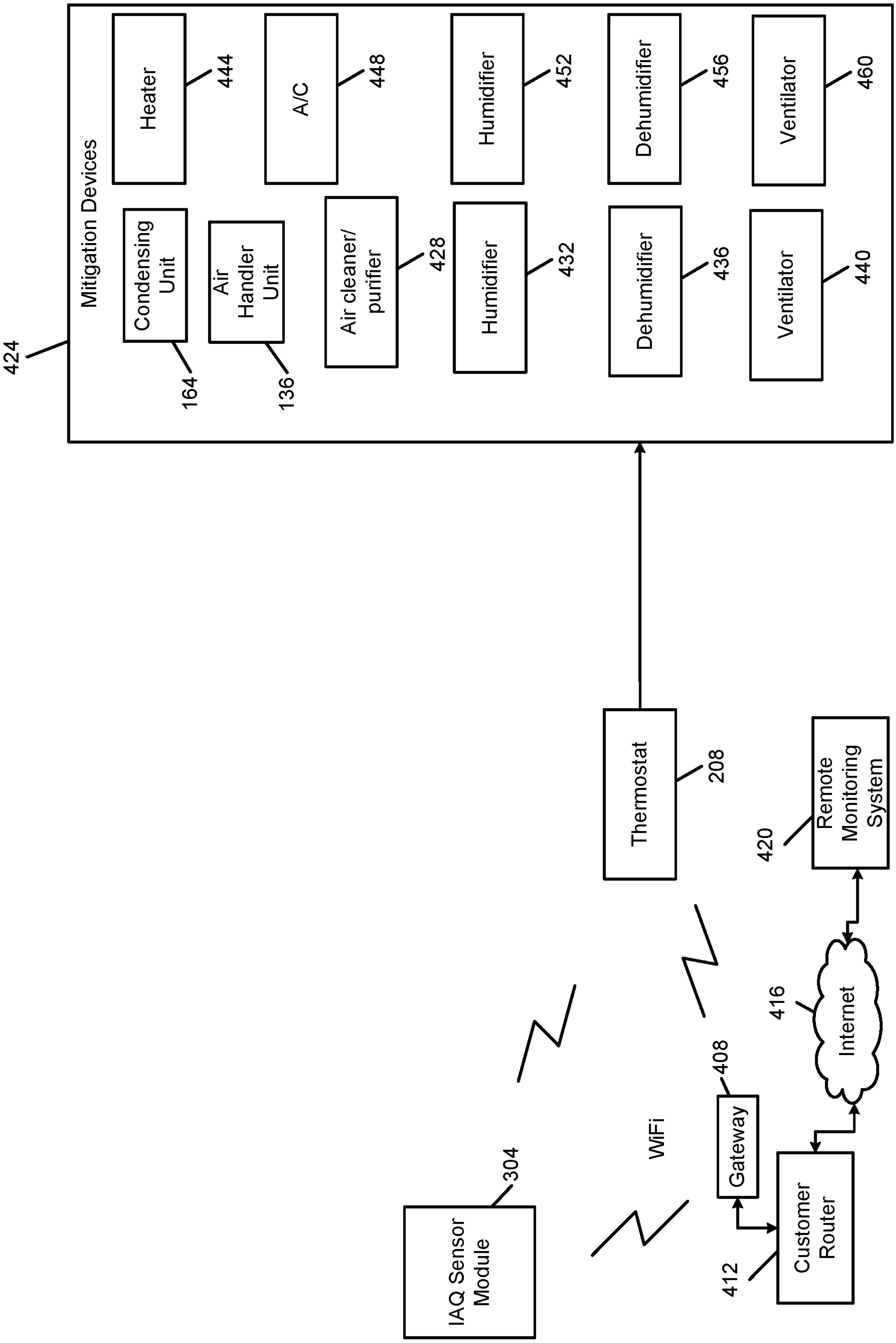

424
Mitigation Devices
Condensing Unit
164
Air Handler Unit
136
Air cleaner/ purifier
428
Humidifier
432
Dehumidifier
436
Ventilator
440
Heater
444
A/C
448
Humidifier
452
Dehumidifier
456
Ventilator
460
Thermostat
208
Remote Monitoring System
420
Internet
416
Gateway
408
WiFi
Customer Router
412
IAQ Sensor Module
304

FIG. 4A

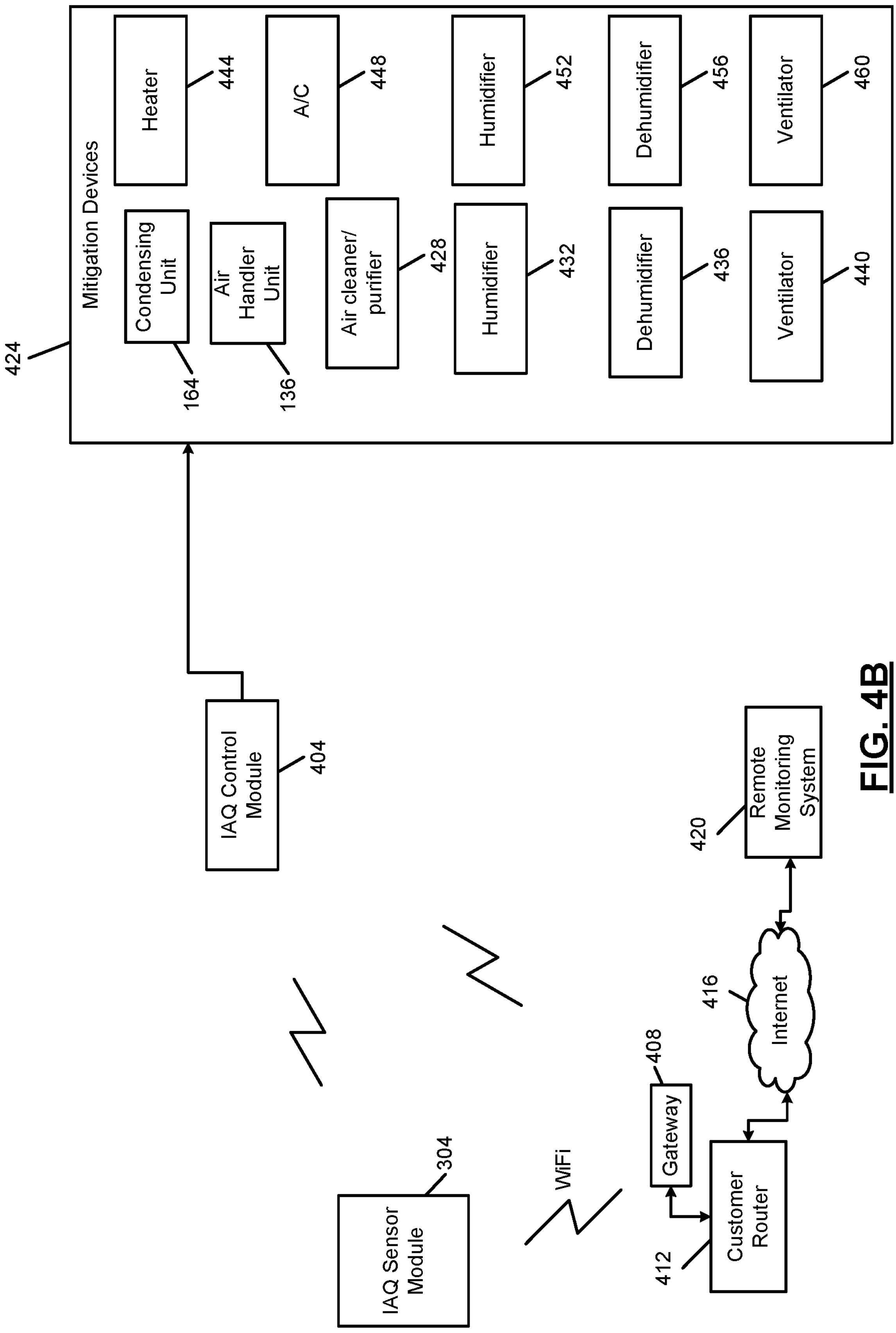

Mitigation Devices
424
Condensing Unit
164
Air Handler Unit
136
Air cleaner/ purifier
428
Humidifier
432
Dehumidifier
436
Ventilator
440
Heater
444
A/C
448
Humidifier
452
Dehumidifier
456
Ventilator
460
IAQ Control Module
404
IAQ Sensor Module
304
WiFi
Gateway
408
Customer Router
412
Internet
416
Remote Monitoring System
420

FIG. 4B

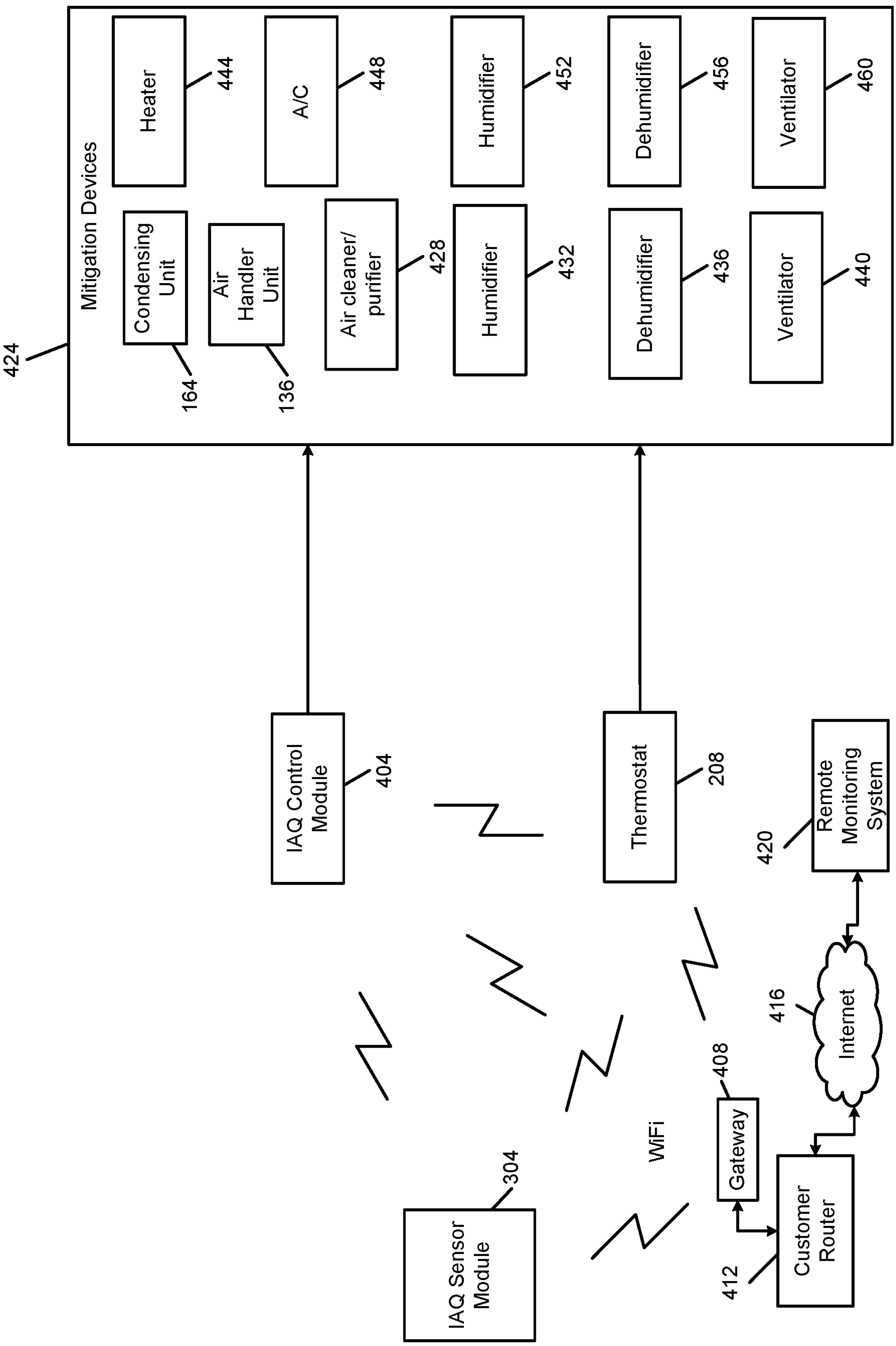

424
Mitigation Devices
Condensing Unit
164
Air Handler Unit
136
Air cleaner/ purifier
428
Humidifier
432
Dehumidifier
436
Ventilator
440
Heater
444
A/C
448
Humidifier
452
Dehumidifier
456
Ventilator
460
IAQ Control Module
404
Thermostat
208
Remote Monitoring System
420
Internet
416
Gateway
408
Customer Router
412
WiFi
IAQ Sensor Module
304

FIG. 4C

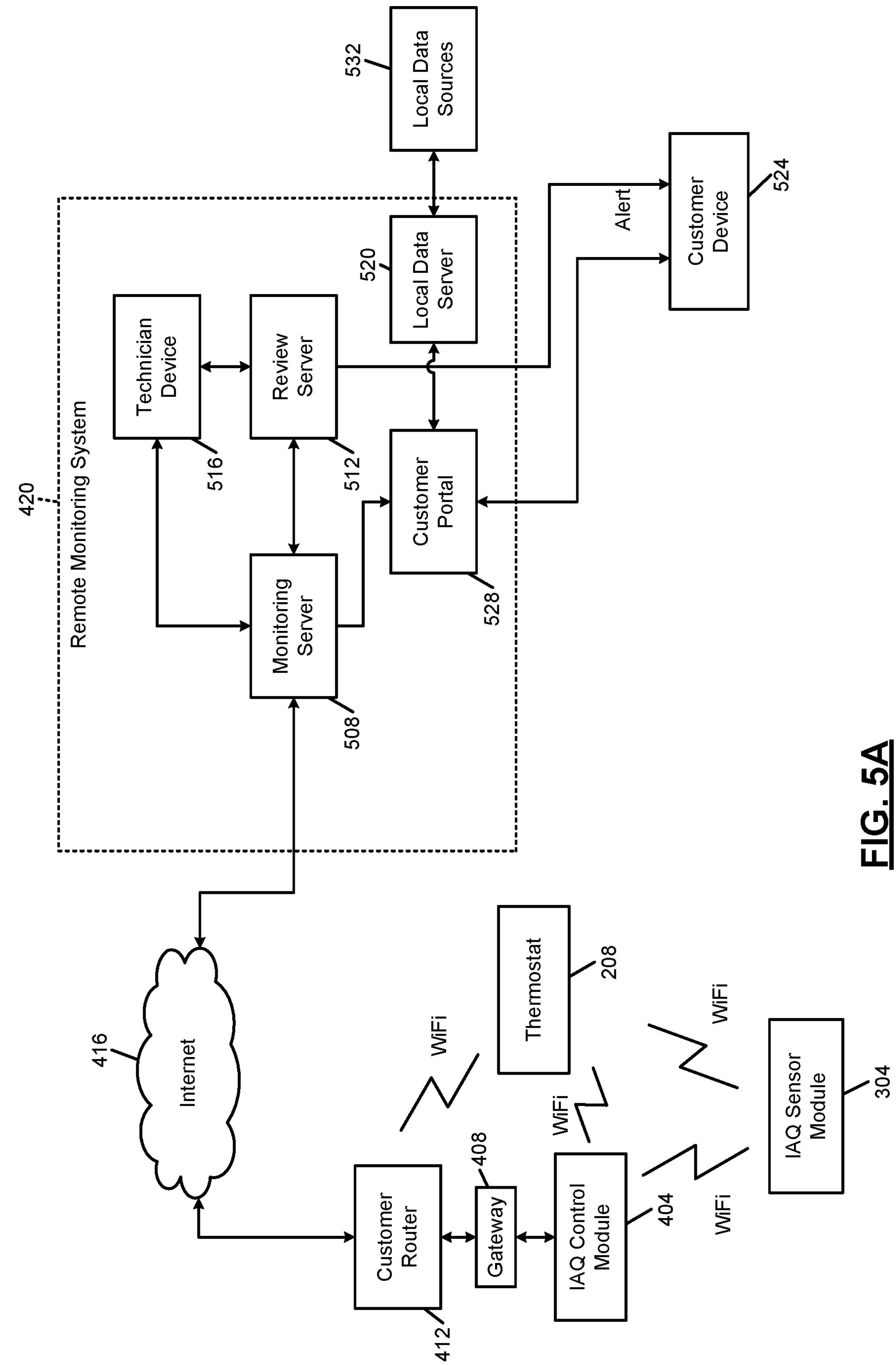

420
Remote Monitoring System
Technician Device
516
Review Server
512
Monitoring Server
508
Local Data Server
520
Customer Portal
528
Local Data Sources
532
Customer Device
524
Alert
Internet
416
Customer Router
412
Gateway
408
IAQ Control Module
404
Thermostat
208
IAQ Sensor Module
304
WiFi
WiFi
WiFi
WiFi

FIG. 5A

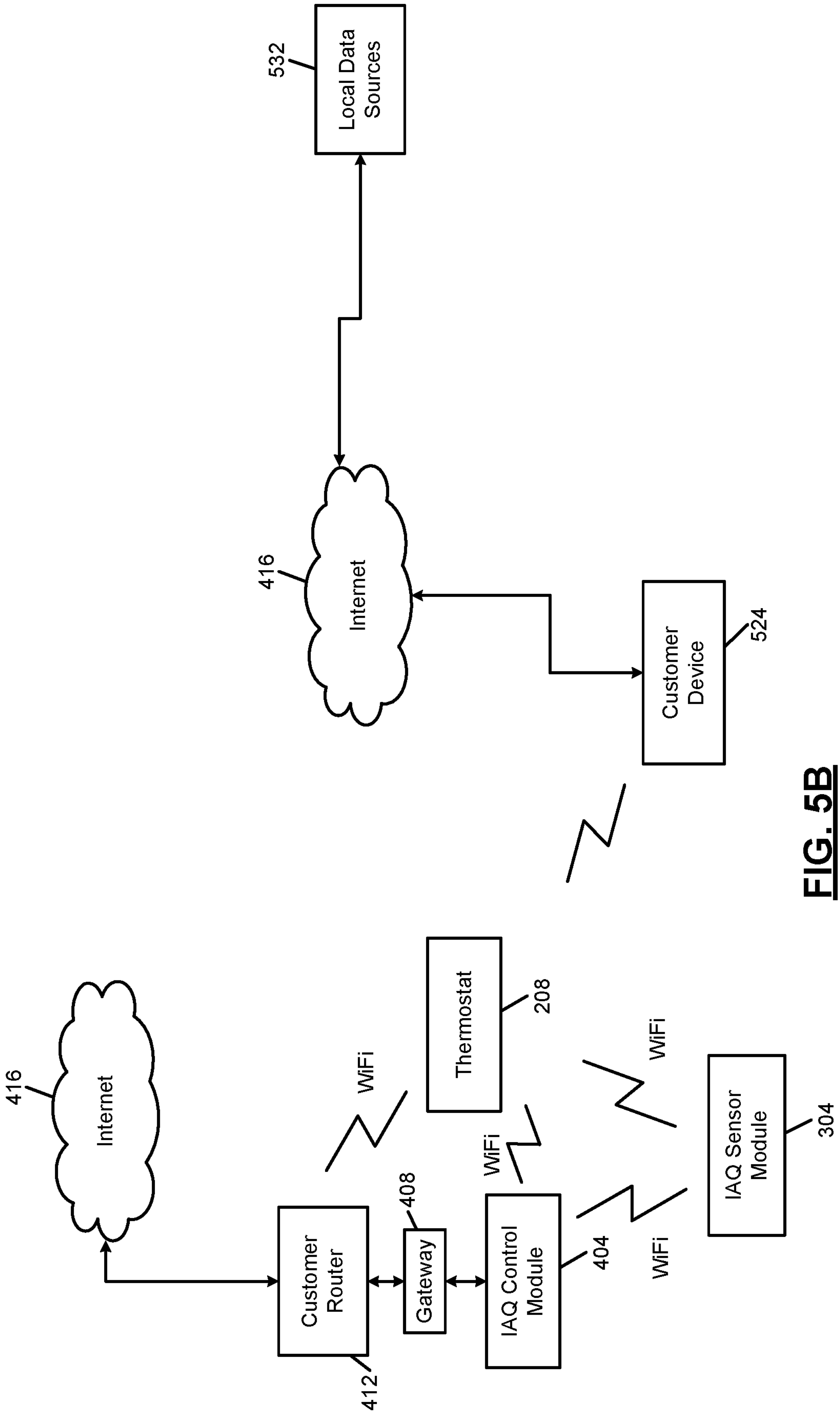

Local Data Sources
532
Internet
416
Customer Device
524
Internet
416
Thermostat
208
WiFi
WiFi
WiFi
WiFi
IAQ Sensor Module
304
Customer Router
412
Gateway
408
IAQ Control Module
404

FIG. 5B

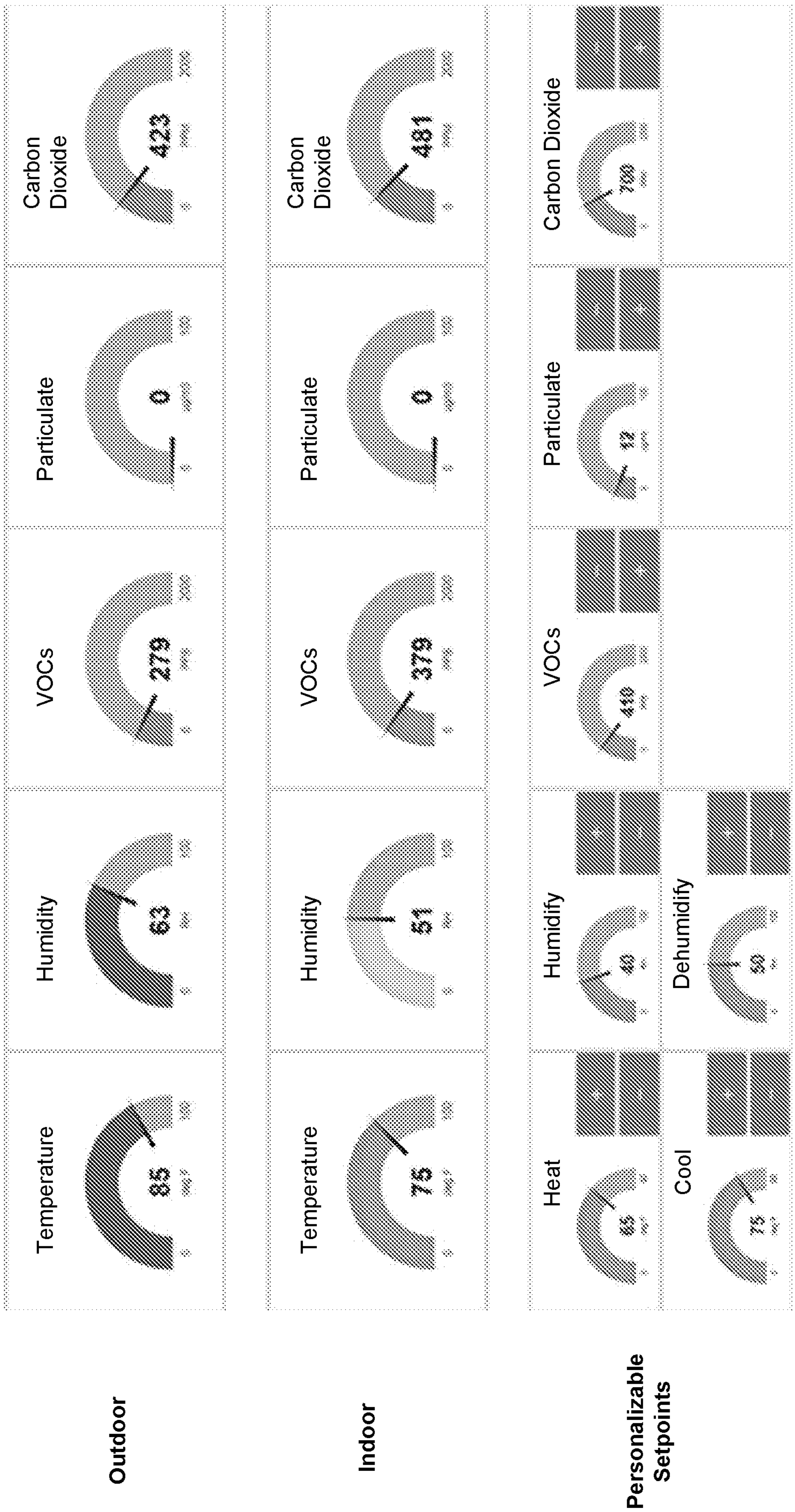

Outdoor
Indoor
Personalizable Setpoints
Temperature
85
Humidity
63
VOCs
279
Particulate
0
Carbon Dioxide
423
Temperature
75
Humidity
51
VOCs
379
Particulate
0
Carbon Dioxide
481
Heat
65
Cool
75
Humidify
40
Dehumidify
50
VOCs
410
Particulate
12
Carbon Dioxide
700

FIG. 6

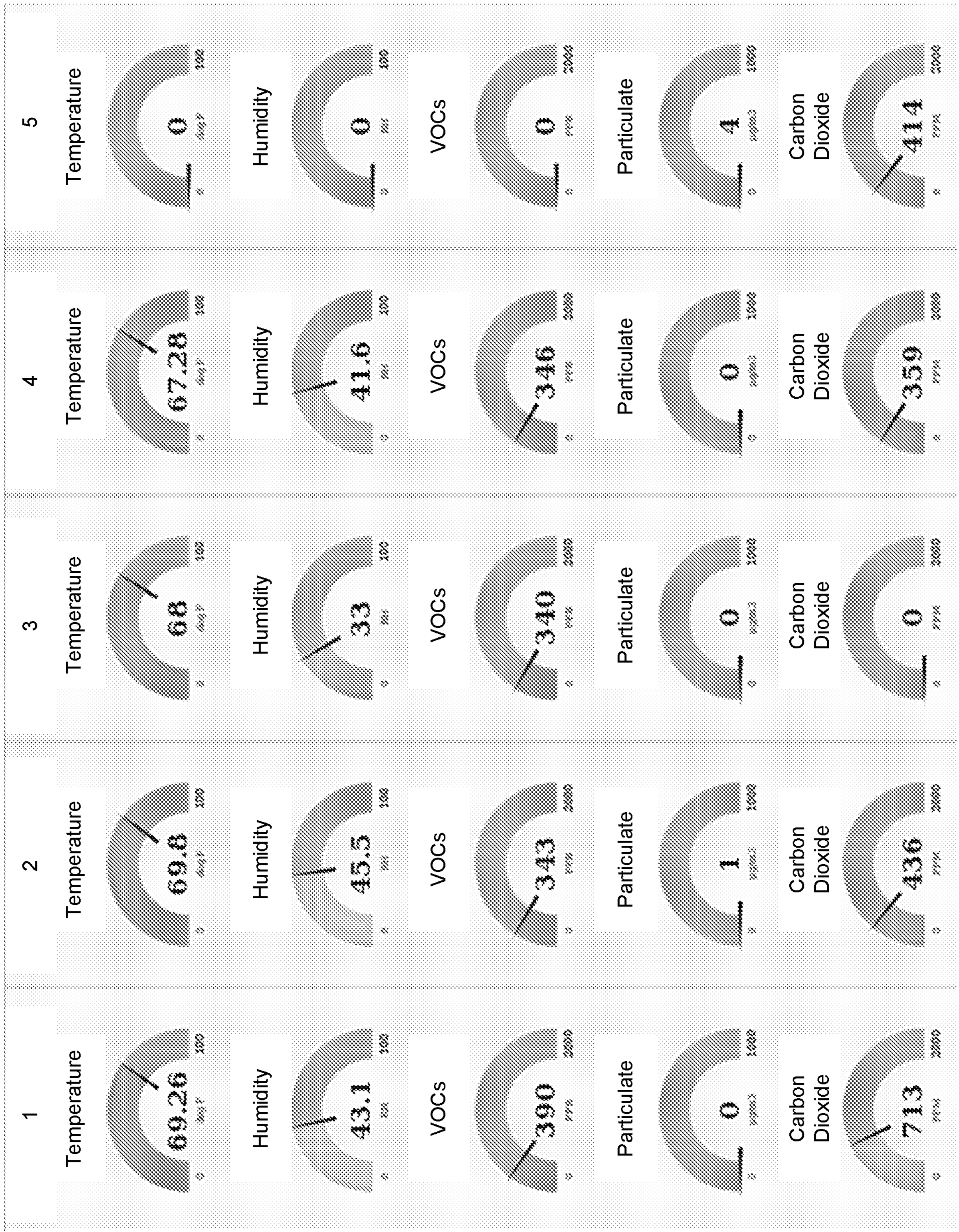

1
Temperature
69.26
Humidity
43.1
VOCs
390
Particulate
0
Carbon Dioxide
713
2
Temperature
69.8
Humidity
45.5
VOCs
343
Particulate
1
Carbon Dioxide
436
3
Temperature
68
Humidity
33
VOCs
340
Particulate
0
Carbon Dioxide
0
4
Temperature
67.28
Humidity
41.6
VOCs
346
Particulate
0
Carbon Dioxide
359
5
Temperature
0
Humidity
0
VOCs
0
Particulate
4
Carbon Dioxide
414

FIG. 7

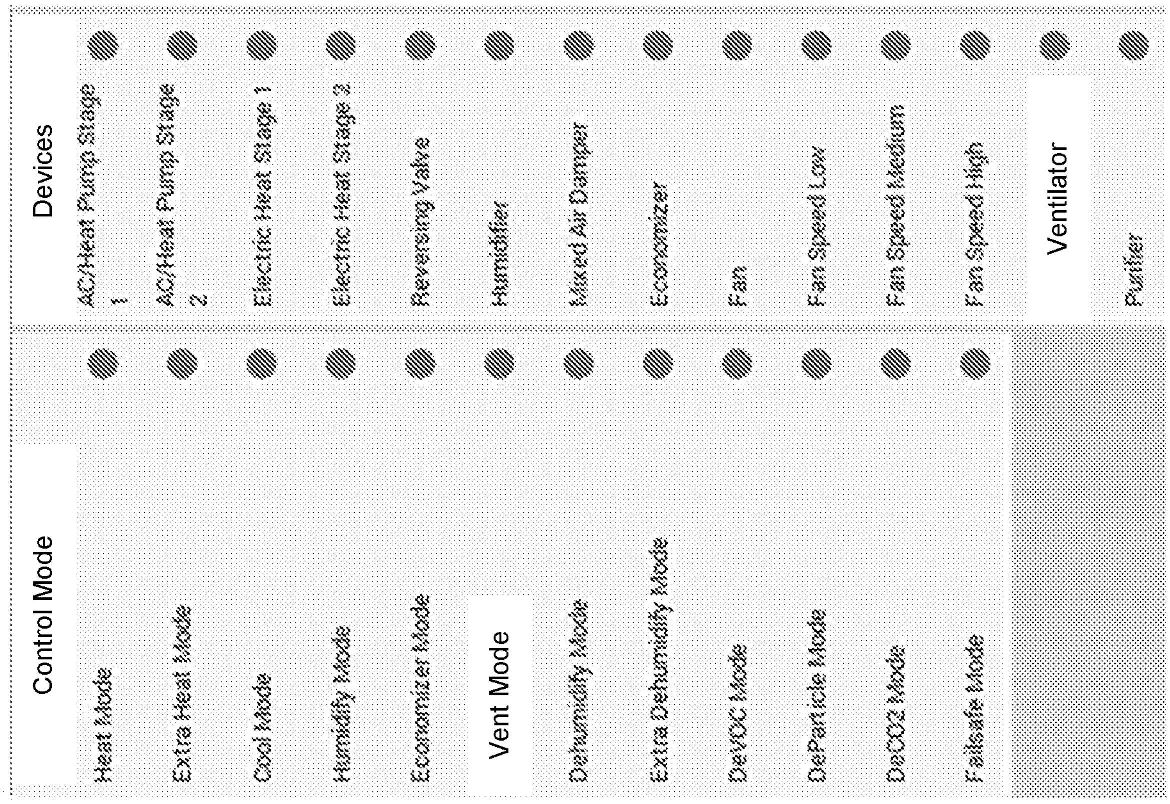

Control Mode
Heat Mode
Extra Heat Mode
Cool Mode
Humidify Mode
Economizer Mode
Vent Mode
Dehumidify Mode
Extra Dehumidify Mode
DeVOC Mode
DeParticle Mode
DeCO2 Mode
Failsafe Mode
Devices
AC/Heat Pump Stage 1
AC/Heat Pump Stage 2
Electric Heat Stage 1
Electric Heat Stage 2
Reversing Valve
Humidifier
Mixed Air Damper
Economizer
Fan
Fan Speed Low
Fan Speed Medium
Fan Speed High
Ventilator
Purifier

FIG. 8

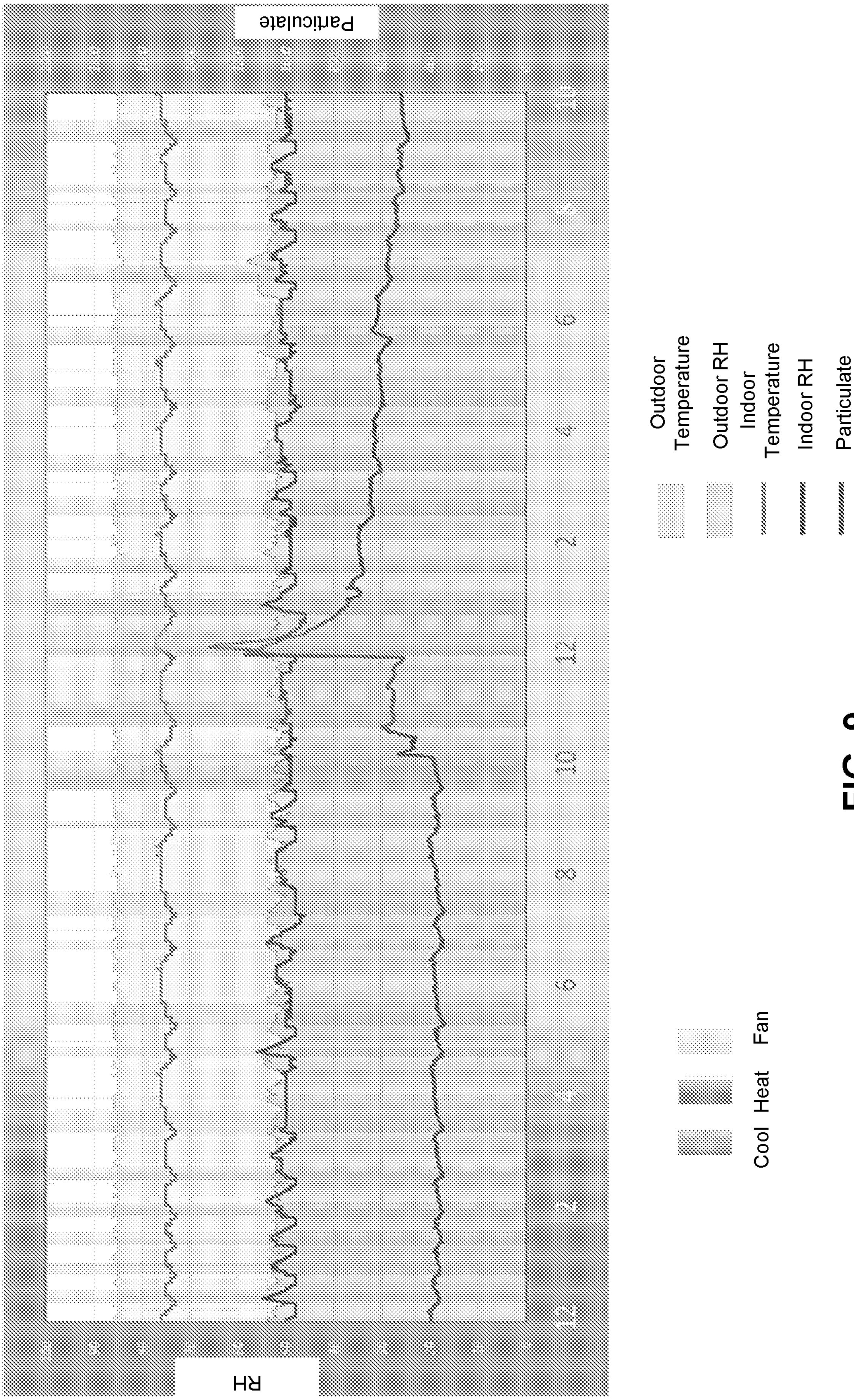

Particulate
RH
12
2
4
6
8
10
12
2
4
6
8
10
Outdoor Temperature
Outdoor RH
Indoor Temperature
Indoor RH
Particulate
Cool
Heat
Fan

FIG. 9

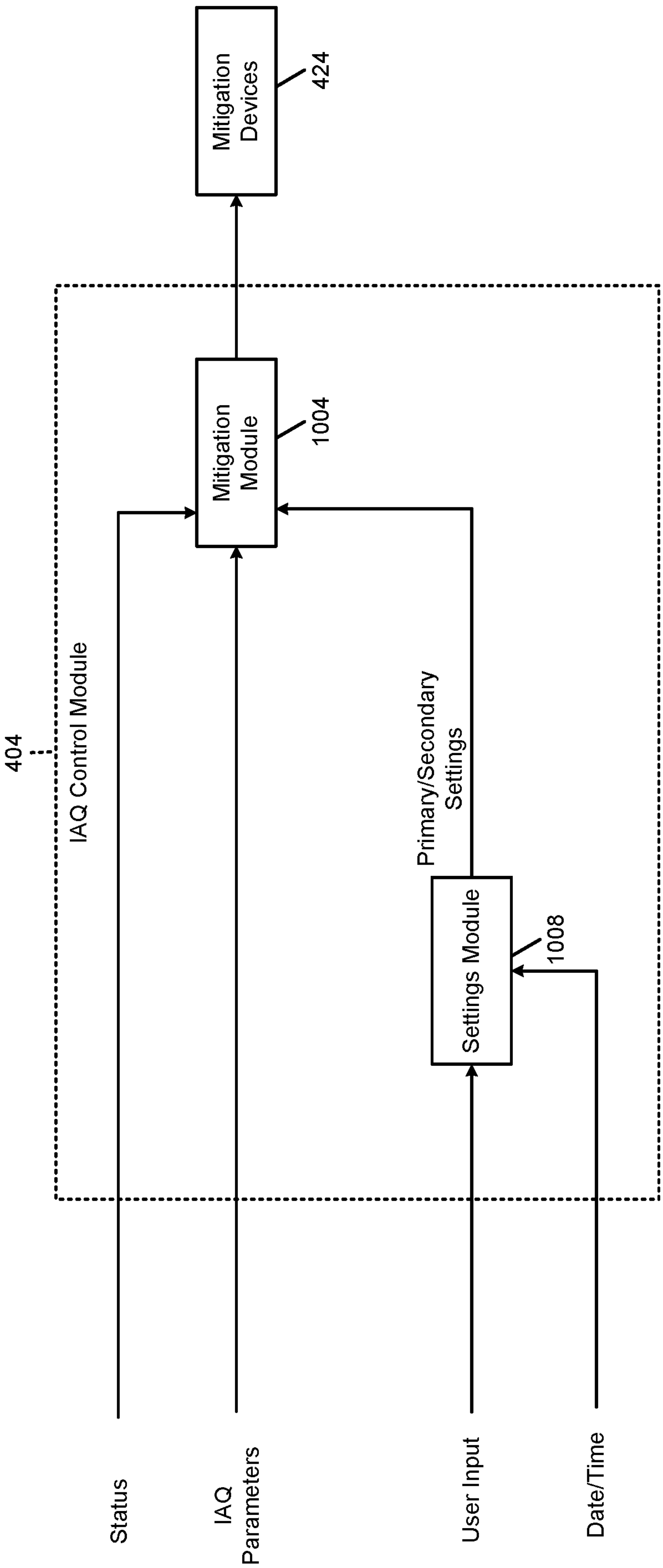

Mitigation Devices
424
Mitigation Module
1004
404
IAQ Control Module
Primary/Secondary Settings
Settings Module
1008
Status
IAQ Parameters
User Input
Date/Time

FIG. 10

FIG. 11

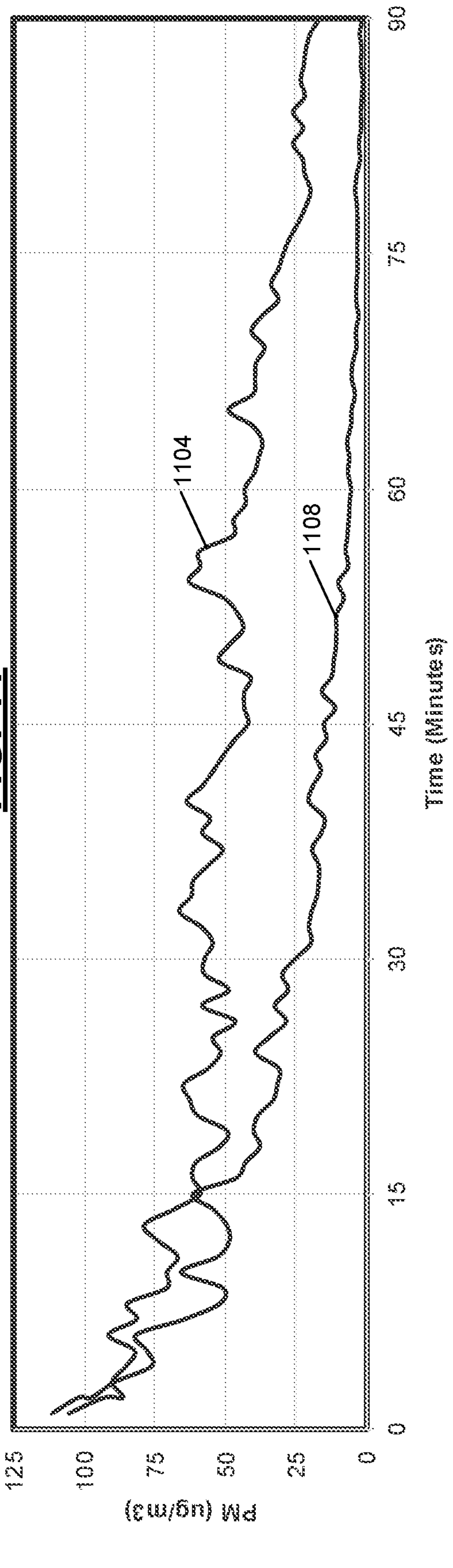

PM (ug/m3)
125
100
75
50
25
0
Time (Minutes)
0
15
30
45
60
75
90
1104
1108

FIG. 12

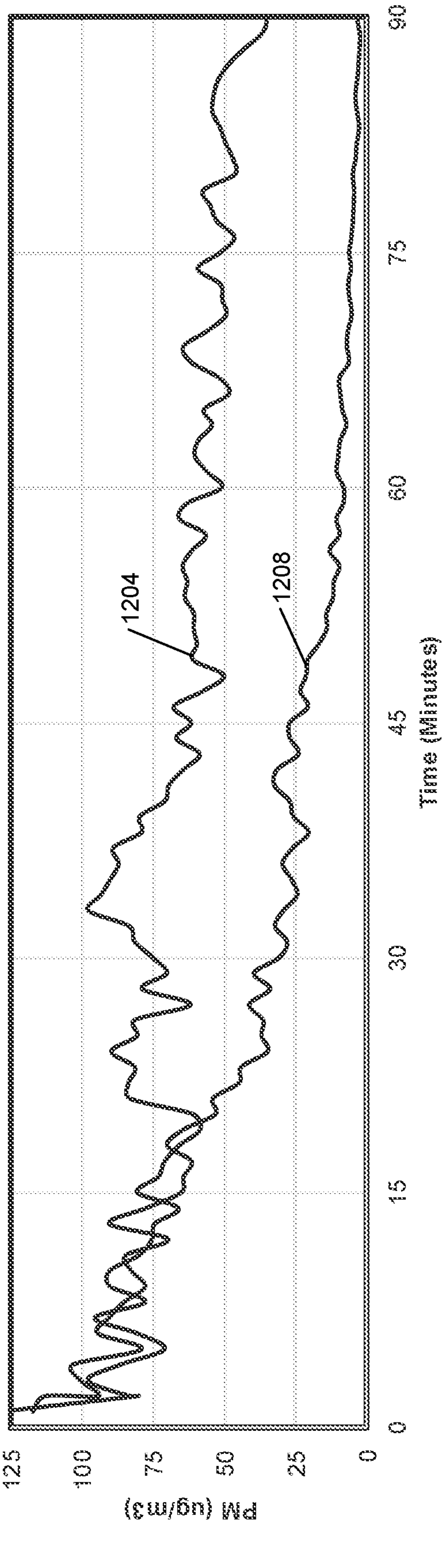

PM (ug/m3)
125
100
75
50
25
0
Time (Minutes)
0
15
30
45
60
75
90
1204
1208

FIG. 13

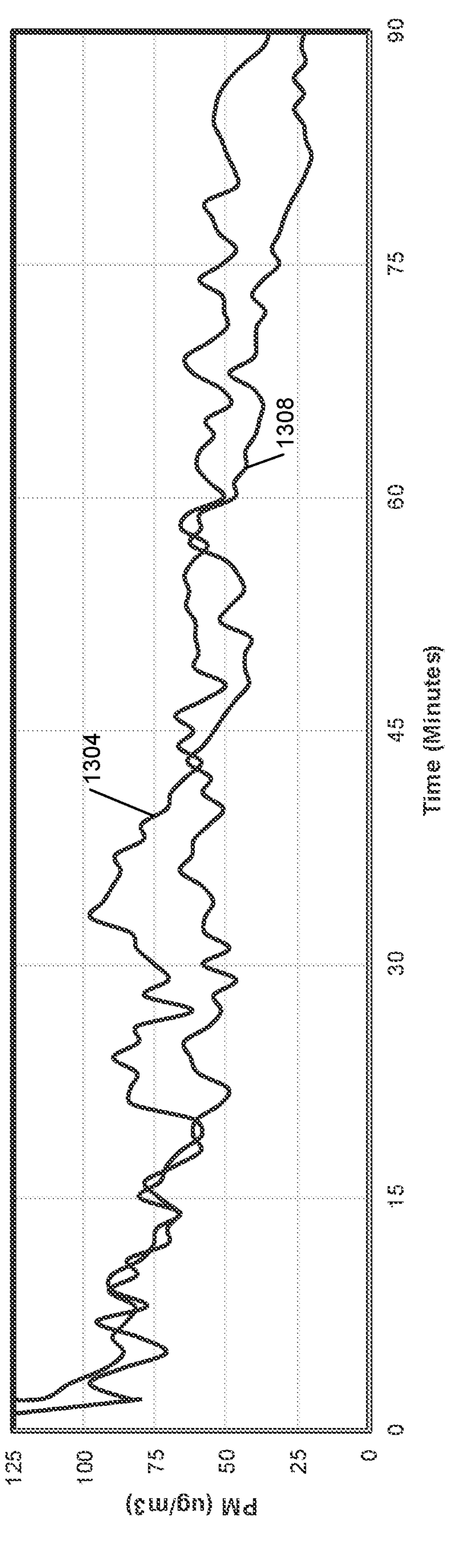
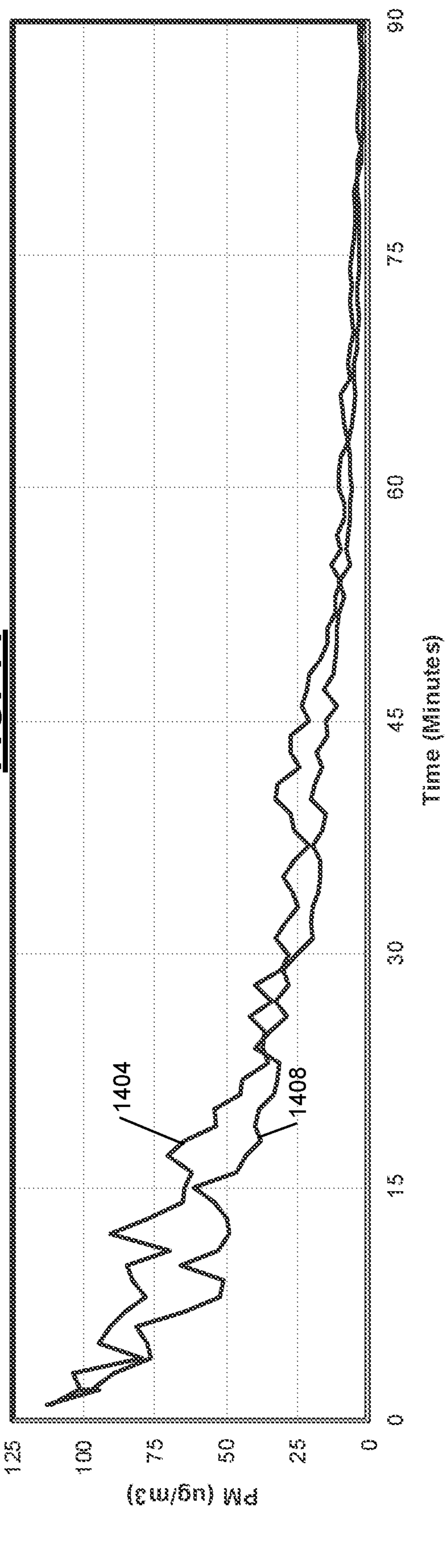

PM (ug/m3)
125
100
75
50
25
0
0
15
30
45
60
75
90
Time (Minutes)
1304
1308

FIG. 14


PM (ug/m3)
125
100
75
50
25
0
0
15
30
45
60
75
90
Time (Minutes)
1404
1408

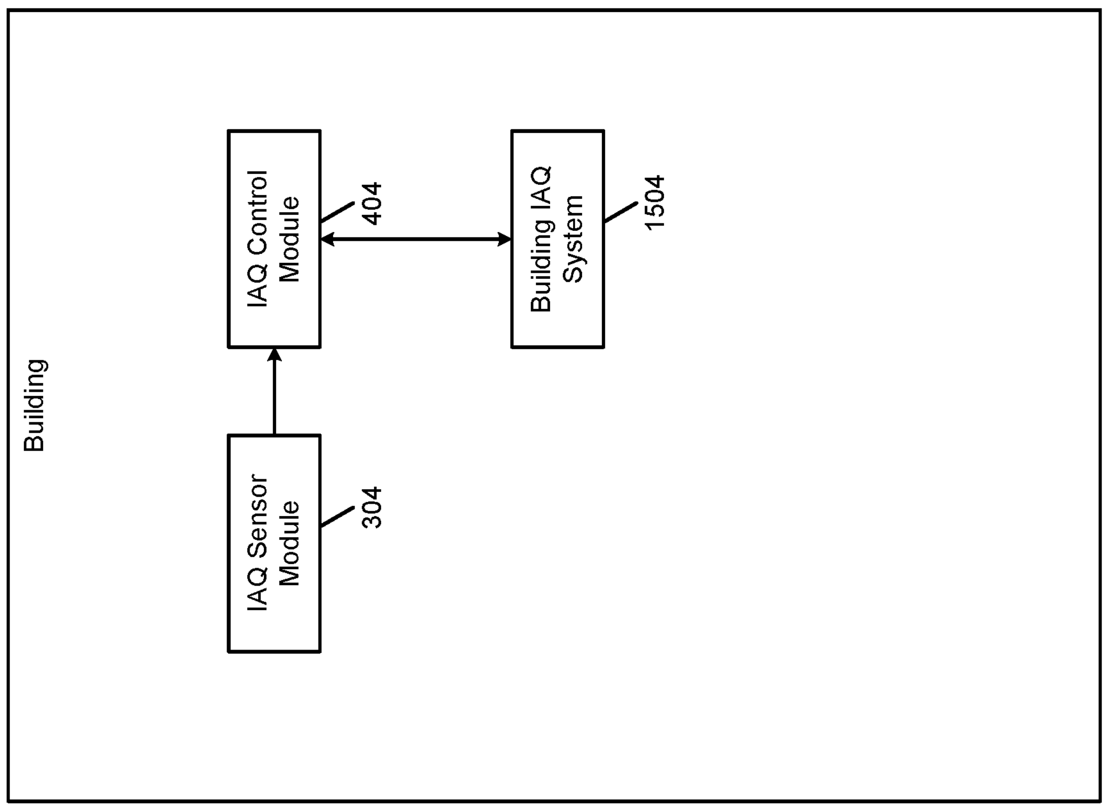

Building
IAQ Sensor Module
304
IAQ Control Module
404
Building IAQ System
1504

FIG. 15

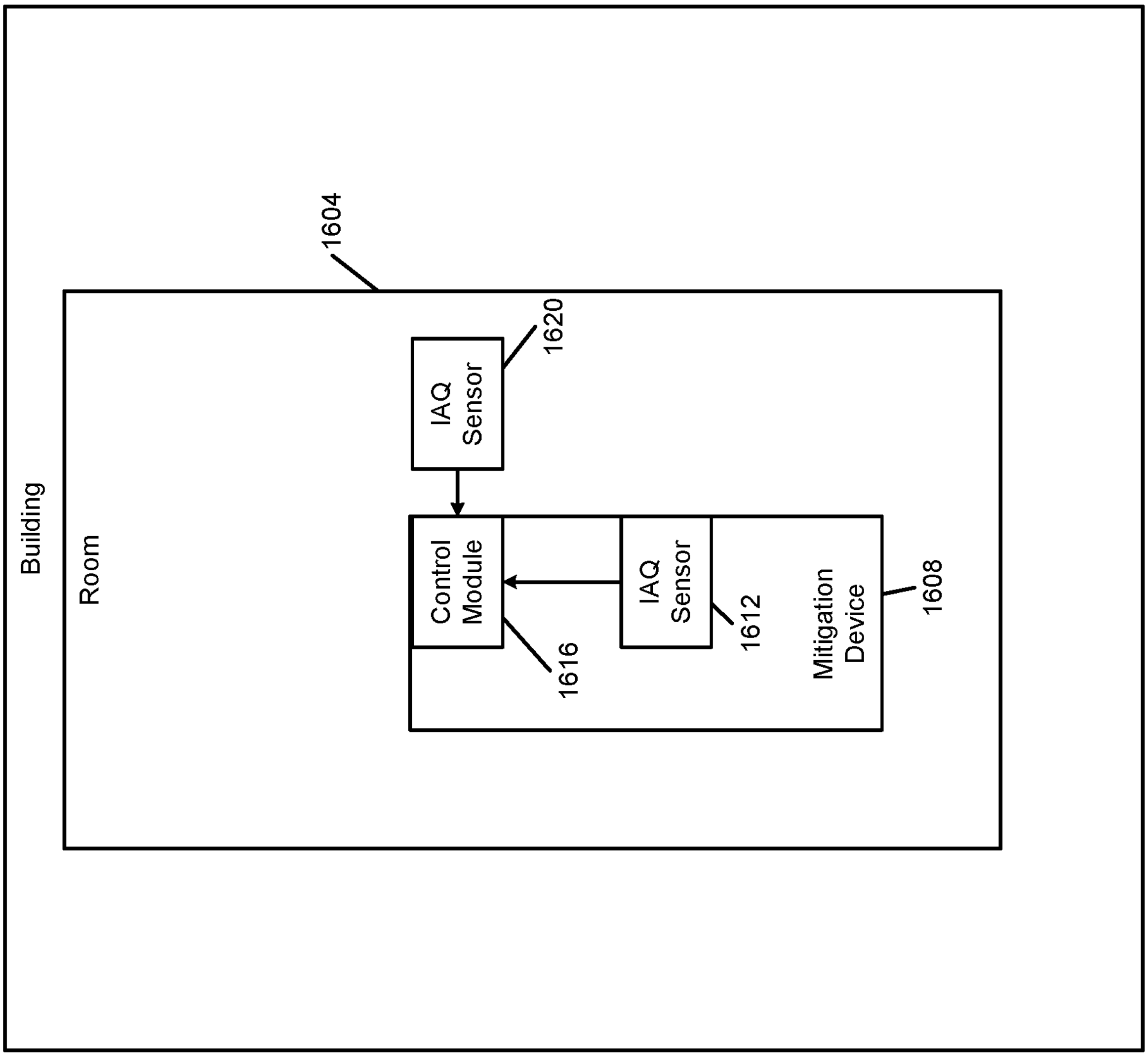

Building
Room
1604
IAQ Sensor
1620
Control Module
1616
IAQ Sensor
1612
Mitigation Device
1608

FIG. 16

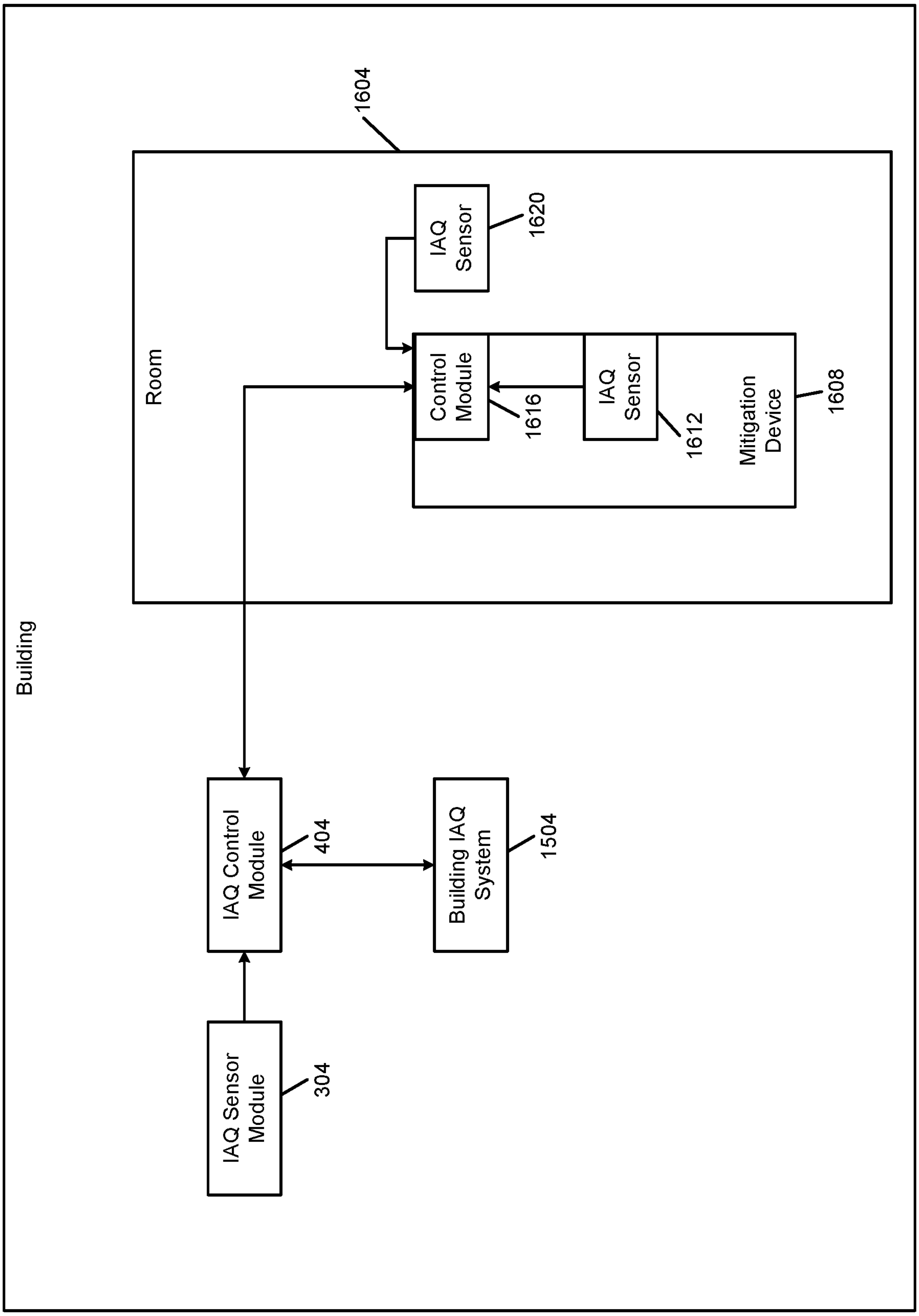

Building
Room
1604
IAQ Sensor
1620
Control Module
1616
IAQ Sensor
1612
Mitigation Device
1608
IAQ Control Module
404
Building IAQ System
1504
IAQ Sensor Module
304

FIG. 17

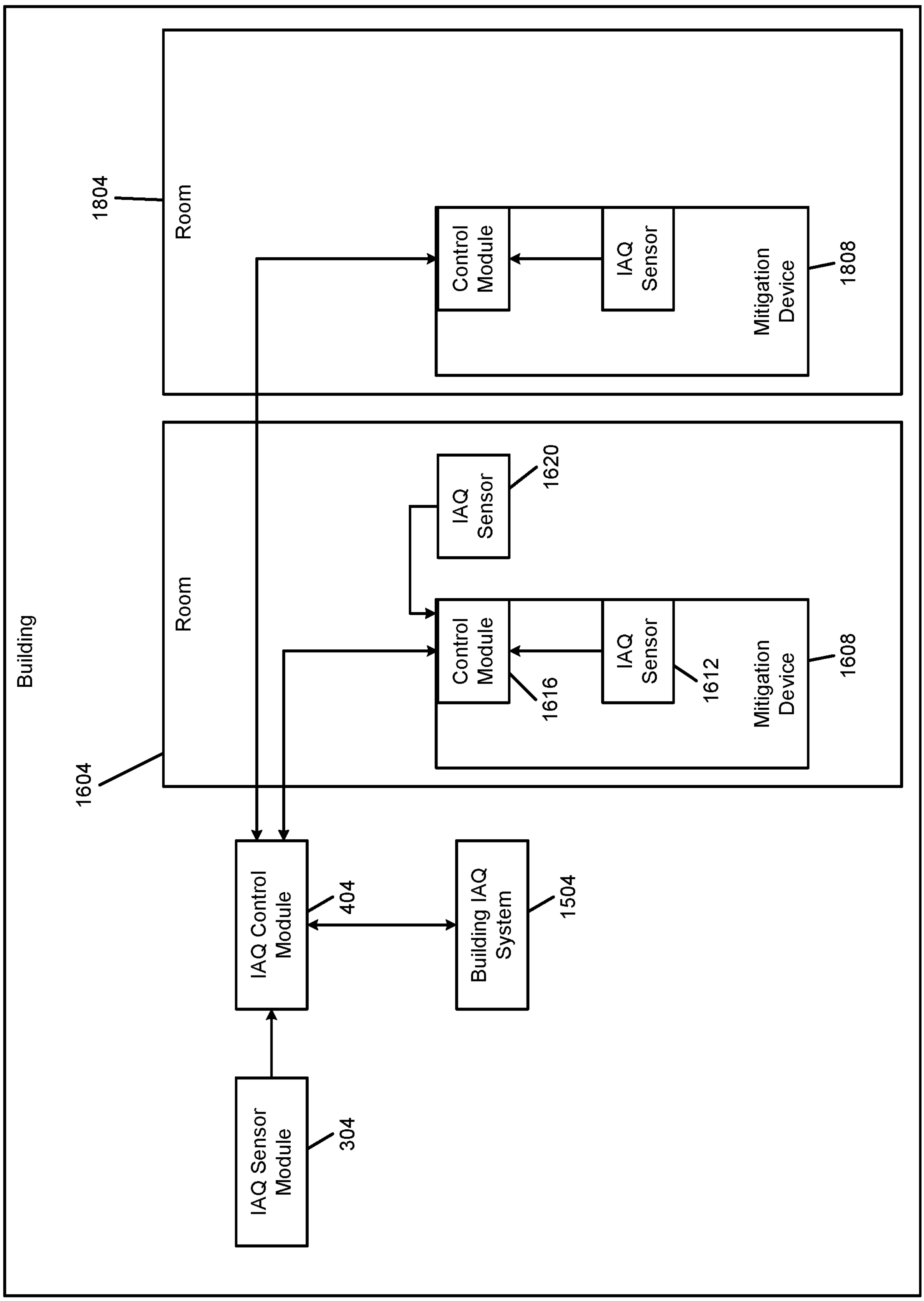

Building
Room
1804
Control Module
IAQ Sensor
Mitigation Device
1808
Room
1604
IAQ Sensor
1620
Control Module
1616
IAQ Sensor
1612
Mitigation Device
1608
IAQ Control Module
404
Building IAQ System
1504
IAQ Sensor Module
304

FIG. 18

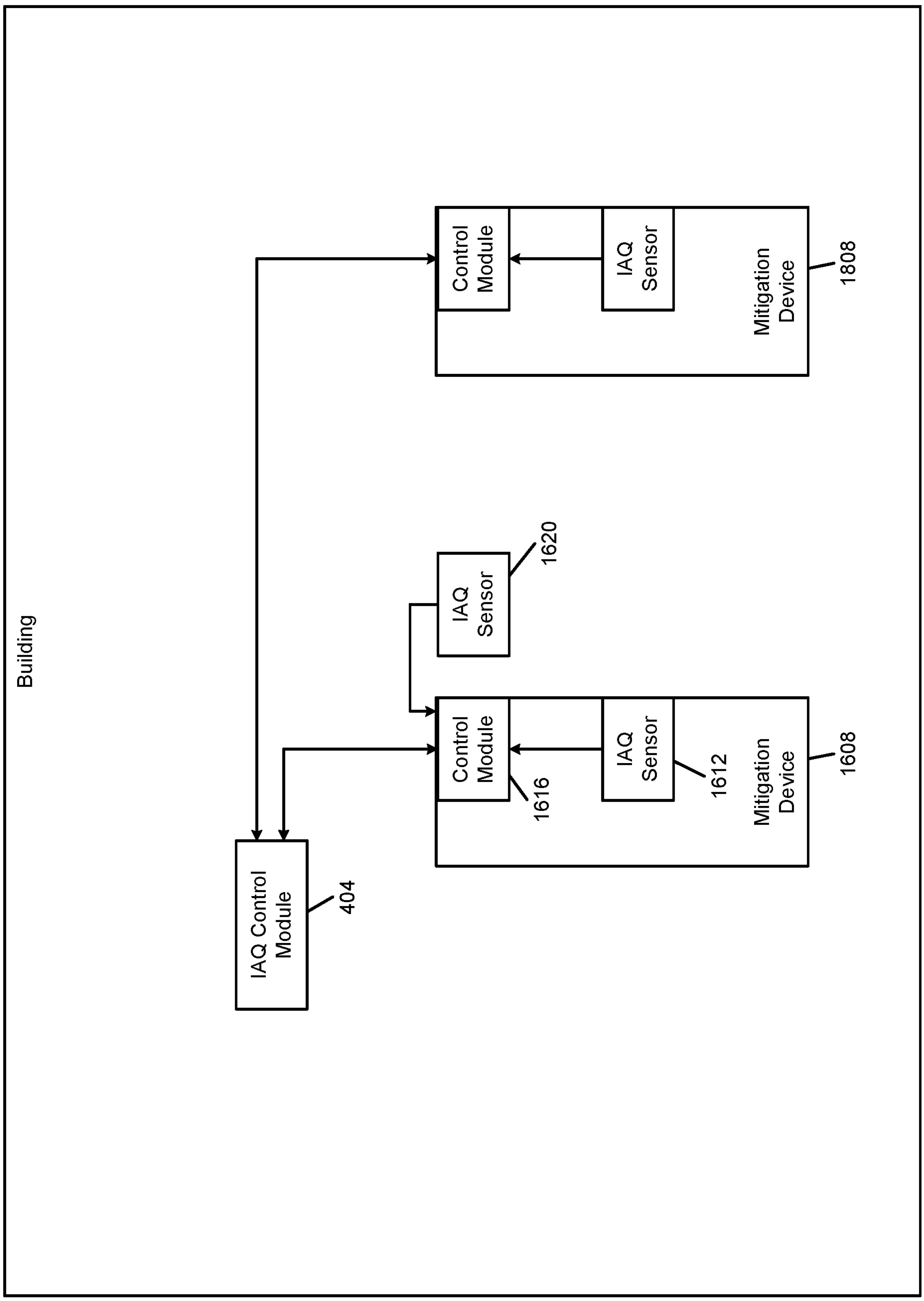

Building
IAQ Control Module
404
Control Module
1616
IAQ Sensor
1612
Mitigation Device
1608
IAQ Sensor
1620
Control Module
IAQ Sensor
Mitigation Device
1808

FIG. 19

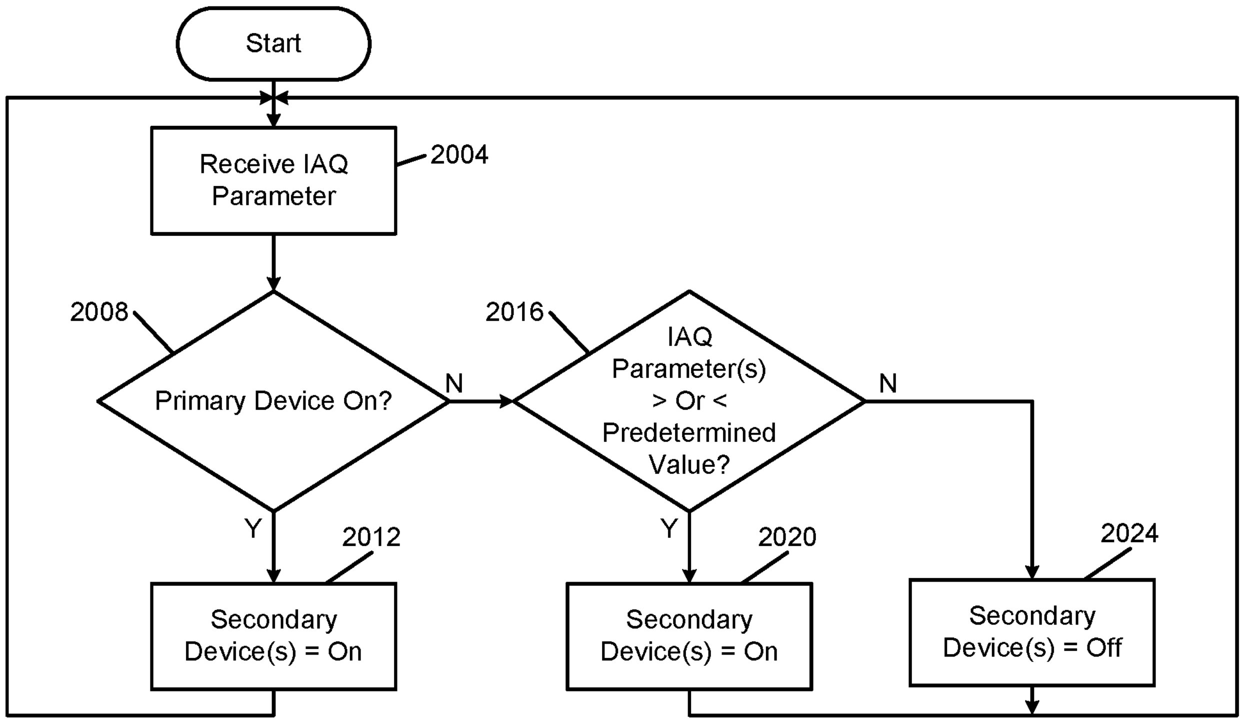

Start
Receive IAQ Parameter
2004
2008
Primary Device On?
N
Y
2012
Secondary Device(s) = On
2016
IAQ Parameter(s) > Or < Predetermined Value?
N
Y
2020
Secondary Device(s) = On
2024
Secondary Device(s) = Off

FIG. 20

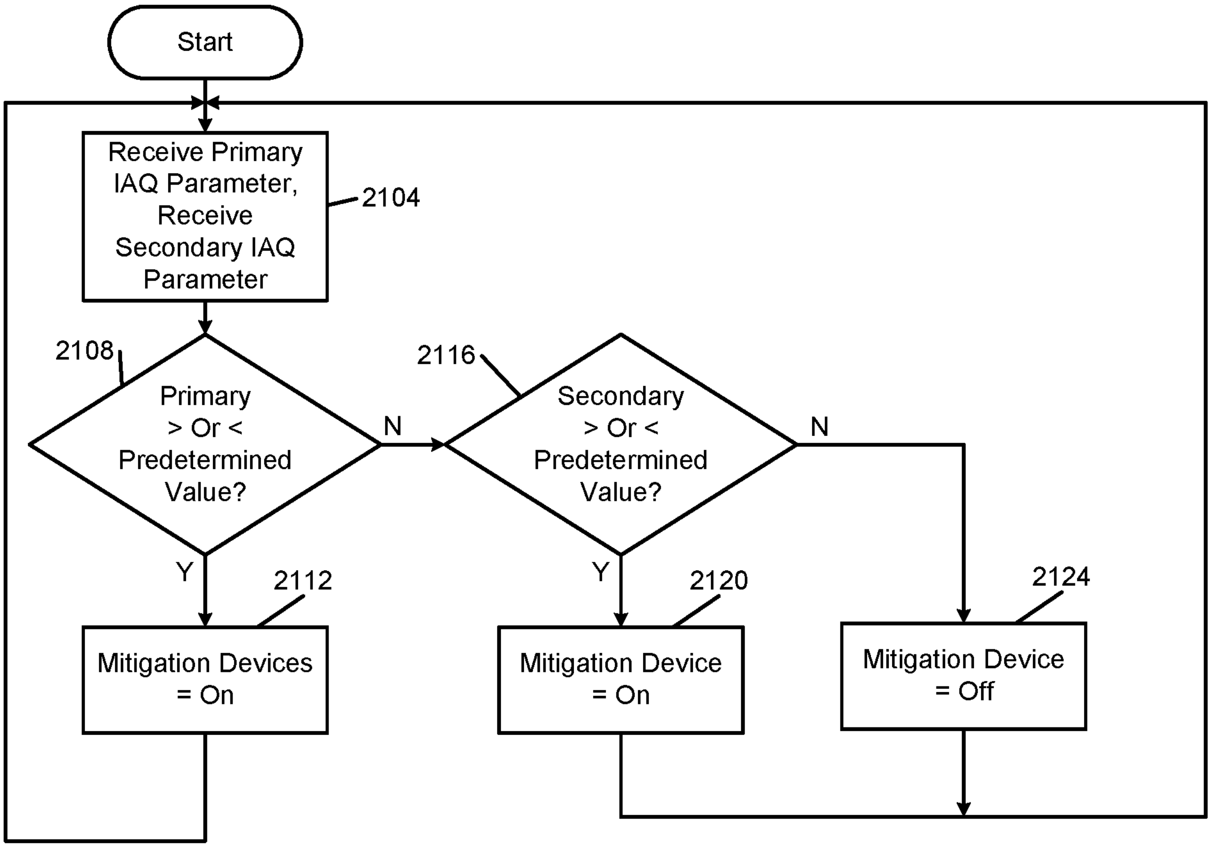

Start
Receive Primary IAQ Parameter, Receive Secondary IAQ Parameter
2104
2108
Primary > Or < Predetermined Value?
N
Y
2112
Mitigation Devices = On
2116
Secondary > Or < Predetermined Value?
N
Y
2120
Mitigation Device = On
2124
Mitigation Device = Off

FIG. 21

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/028410

A. CLASSIFICATION OF SUBJECT MATTER

F24F 11/59(2018.01)i, F24F 11/62(2018.01)i, F24F 110/20(2018.01)i, F24F 110/66(2018.01)i, F24F 110/70(2018.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F24F 11/59; F24F 11/00; F24F 7/00; F25B 13/00; G05B 13/00; G05B 13/02; G05B 15/00; G05D 23/00; G06F 1/32; G08B 17/10; G08B 17/12; F24F 11/62; F24F 110/20; F24F 110/66; F24F 110/70

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: air conditioning, HVAC, indoor air, parameter, mitigation, sensor, humidity, carbon dioxide

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017-0103633 A1 (OTIS ELEVATOR COMPANY) 13 April 2017 See paragraphs [0034]-[0038], [0056]-[0057], [0071], claims 1, 5, and figure 1.	1-22
A	US 2010-0241287 A1 (NISHINO et al.) 23 September 2010 See paragraphs [0073]-[0086] and figures 2-3.	1-22
A	US 6711470 B1 (HARTENSTEIN et al.) 23 March 2004 See column 11, line 54 - column 12, line 10 and figure 5.	1-22
A	US 2016-0116181 A1 (AIRADVICE FOR HOMES, INC.) 28 April 2016 See claim 1 and figure 1.	1-22
A	US 7809472 B1 (SILVA et al.) 05 October 2010 See claim 1 and figures 2-3.	1-22

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 August 2019 (07.08.2019)	**07 August 2019 (07.08.2019)**

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		WO 2016-069635 A1	06/05/2016
US 7809472 B1	05/10/2010	None	