(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
18 October 2018 (18.10.2018)

WIPO | PCT

(10) **International Publication Number**
WO 2018/191688 A2

(51) **International Patent Classification:**
F24F 11/00 (2018.01)

(21) **International Application Number:**
PCT/US2018/027610

(22) **International Filing Date:**
13 April 2018 (13.04.2018)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
62/485,784 14 April 2017 (14.04.2017) US

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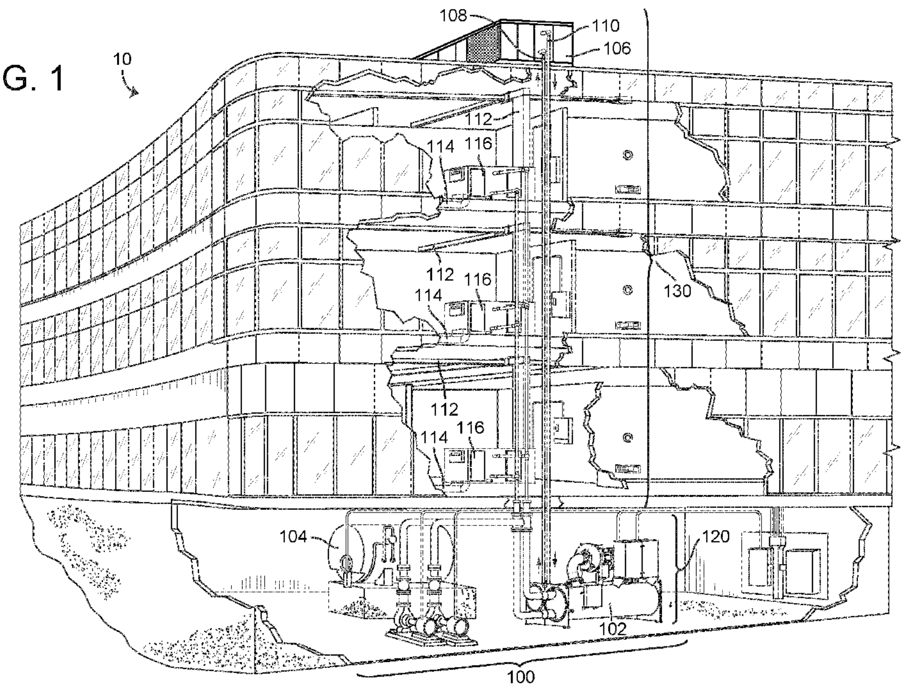
(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) **Title:** THERMOSTAT WITH EXHAUST FAN CONTROL FOR AIR QUALITY AND HUMIDITY CONTROL

FIG. 1



(57) **Abstract:** A system for controlling air quality of a building space includes an air quality sensor configured to sense the air quality of the building space, an exhaust fan configured to exhaust air from inside the building space to outside the building space, a switch device configured to control the exhaust fan to exhaust the air from inside the building space to outside the building space, and a controller comprising a processing circuit. The processing circuit is configured to determine an air quality level of the building space based on the air quality sensor, determine whether the air quality level is less than an air quality threshold, and cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to a determination that the air quality level is less than the air quality threshold.

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[Continued on next page]

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

THERMOSTAT WITH EXHAUST FAN CONTROL FOR AIR QUALITY AND HUMIDITY CONTROL

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 62/485,784 filed April 14, 2017, the entire disclosure of which is incorporated by reference herein.

BACKGROUND

[0002] The present invention relates generally to thermostats and more particularly to the improved control of a building or space's heating, ventilating, and air conditioning (HVAC) system through the use of exhaust fans within a building to improve and control air quality and humidity of the building.

[0003] A thermostat is, in general, a component of an HVAC control system. Traditional thermostats sense the temperature of a system and control components of the HVAC system in order to maintain a setpoint. A thermostat may be designed to control a heating or cooling system or an air conditioner. Thermostats are manufactured in many ways, and use a variety of sensors to measure temperature and other desired parameters of a system.

[0004] Conventional thermostats are configured for one-way communication to connected components, and to control HVAC systems by turning on or off certain components or by regulating flow. Each thermostat may include a temperature sensor and a user interface. The user interface typically includes a display for presenting information to a user and one or more user interface elements for receiving input from a user. To control the temperature of a building or space, a user adjusts the setpoint via the thermostat's user interface.

SUMMARY

[0005] One implementation of the present disclosure is a heating, ventilation, and air conditioning (HVAC) system for controlling air quality of a building space. The system includes an air quality sensor configured to sense the air quality of the building space, an exhaust fan configured to exhaust air from inside the building space to outside the building space, and a switch device configured to control the exhaust fan to exhaust the air from inside the building space to outside the building space. The system includes a controller

including a processing circuit communicably coupled to the switch device. The processing circuit is configured to determine an air quality level of the building space based on the air quality sensed by the air quality sensor, determine whether the air quality level is less than an air quality threshold, and cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to a determination that the air quality level is less than the air quality threshold.

[0006] In some embodiments, the processing circuit of the controller is configured to cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space for a predefined length of time during a particular time period and cause the switch device to not operate the exhaust fan to exhaust air from inside the building space to outside the building space for a total amount of the predefined length of time in response to a determination that the air quality level is greater than the air quality threshold.

[0007] In some embodiments, the system includes a supply fan configured to supply air from outside the building space to inside the building space. In some embodiments, the processing circuit of the controller is configured to cause the supply fan to supply the air from outside the building space to inside the building space in response to the determination that the air quality level is below the air quality threshold.

[0008] In some embodiments, the processing circuit of the controller is configured to determine a runtime of the exhaust fan, the runtime is a length of time that the exhaust fan has run during a particular time period, determine whether the runtime of the exhaust fan is greater than, equal to, or less than a predefined runtime, cause the switch device to operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the runtime of the exhaust fan is less than the predefined runtime, and cause the switch device to not operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is below the air quality threshold and a determination that the runtime of the exhaust fan is greater than or equal to the predefined runtime.

[0009] In some embodiments, the processing circuit of the controller is configured to receive or determine an outdoor air quality level, determine whether the outdoor air quality level is less than an outdoor air quality threshold, cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is greater than the outdoor air quality threshold, and cause the switch device to not operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is less than the outdoor air quality threshold.

[0010] In some embodiments, the air quality level is based on at least one of a humidity level, a temperature level, a carbon dioxide concentration level, and a volatile organic compound (VOC) concentration level. In some embodiments, the processing circuit is configured to determine whether the air quality level is less than the air quality threshold by determining that the at least of the humidity level, the temperature level, the carbon dioxide (CO_2) concentration level, and the VOC concentration level is greater than a particular threshold.

[0011] In some embodiments, the system includes a multiple air quality sensors including the air quality sensor and one or more other air quality sensors. In some embodiments, the air quality sensors include two or more of a humidity sensor, a temperature sensor, a CO_2 sensor, and a VOC sensor.

[0012] In some embodiments, the processing circuit of the controller is configured to determine whether an outdoor air temperature (OAT) is less than a predefined OAT threshold and an indoor air humidity (IAH) level is greater than an IAH setpoint and cause the switch device to operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is below the air quality threshold and a determination that the OAT is less than the predefined OAT threshold and the IAH level is greater than the IAH setpoint.

[0013] In some embodiments, the processing circuit of the controller is configured to operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to one or more heating or cooling devices associated with the building space being in operation to cause the building space to be heated or cooled. In some embodiments, the controller is a thermostat, wherein the processing circuit of the thermostat is configured to control the one or more heating or cooling devices associated with the building space to heat or cool the building space.

[0014] In some embodiments, the system includes a second air quality sensor configured to sense a second air quality associated with a sub-portion of the building space, wherein the exhaust fan is located within the sub-portion of the building space. In some embodiments, the switch device is configured to determine a second air quality level associated with the sub-portion of the building space based on the second air quality sensor and control the sub-portion of the building space by controlling the exhaust fan to exhaust air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the second air quality level.

[0015] In some embodiments, the switch device is configured to determine whether the second air quality value is below a second air quality threshold and control the sub-portion of the building space by controlling the exhaust fan to exhaust the air from inside the sub-portion of the building space to outside the sub-portion of the building space in response to a determination that the second air quality value is below the second air quality threshold.

[0016] In some embodiments, the system includes a supply fan configured to supply air from outside the building space to inside the building space. In some embodiments, the switch device is configured to provide an indication to control the supply fan to the controller in response to the determination that the second air quality value is below the second air quality threshold. In some embodiments, the processing circuit of the controller is configured to receive the indication to control the supply fan from the switch device and control the supply fan to supply air from outside the building space to inside the building space in response to receiving the indication to control the supply fan from the control circuit of the switch.

[0017] In some embodiments, the second air quality sensor is a humidity sensor configured to sense a humidity of the sub-portion of the building space. In some embodiments, the switch device is configured to determine a humidity level of the sub-portion of the building space based on the humidity sensed by the humidity sensor and control the sub-portion of the building space by controlling the exhaust fan to exhaust the air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the humidity level.

[0018] In some embodiments, the switch device is configured to control the sub-portion of the building space by controlling the exhaust fan to exhaust the air from inside the sub-portion of the building space to outside the sub-portion of the building space in response to a determination that the humidity level is greater than a predefined humidity threshold.

[0019] In some embodiments, the air quality sensor is located within a sub-portion of the building space and the exhaust fan is located within the sub-portion of the building space. In some embodiments, the air quality sensed by the air quality sensors is an air quality associated with the sub-portion of the building space. In some embodiments, the switch device is configured to determine a second air quality level associated with the sub-portion of the building space based on the air quality associated with the sub-portion of the building space sensed by the air quality sensor and control the sub-portion of the building space by controlling the exhaust fan to exhaust air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the second air quality level.

[0020] In some embodiments, the system includes a supply fan configured to circulate air within the building space and an air inlet configured to allow air from outside the building space to enter the building space. In some embodiments, the supply fan circulating the air within the building space and the exhaust fan exhausting the air from inside the building space to outside the building space causes the air from outside the building space to enter the building space via the air inlet. In some embodiments, the processing circuit of the controller is configured to cause the supply fan to circulate the air within the building space in response to the determination that the air quality level is below the air quality threshold.

[0021] In some embodiments, the exhaust fan is configured to exhaust the air from inside the building space to outside the building space causing air outside the building space to enter the building space. In some embodiments, the processing circuit of the controller is configured to determine whether the air outside the building space is dry by determining whether an outdoor air temperature (OAT) is less than a predefined OAT threshold and cause the switch device to operate the exhaust fan to exhaust the air from inside the building space to outside the building space causing the air outside the building space to enter the building space causing the building space to be dehumidified in response to a determination that the OAT is less than the predefined OAT threshold.

[0022] Another implementation of the present disclosure is a method for controlling air quality of a building space. The method includes determining, by a controller, an air quality level of the building space based on the air quality sensed by an air quality sensor, determining, by the controller, whether the air quality level is less than an air quality threshold, and causing, by the controller, a switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to a determination that the air quality level is less than the air quality threshold.

[0023] In some embodiments, the method includes receiving or determining, by the controller, an outdoor air quality level, determining, by the controller, whether the outdoor air quality level is less than or greater than an outdoor air quality threshold, and causing, by the controller, a switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to a determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is greater than the outdoor air quality threshold. In some embodiments, the method includes causing, by the controller, the switch device to not operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is less than the outdoor air quality threshold. In some embodiments, the method includes causing, by the controller, a supply fan of the building space to supply air from outside the building space to inside the building space in response to the determination that the air quality level is less than the air quality threshold and the determination that the outdoor air quality level is greater than the outdoor air quality threshold and causing, by the controller, the supply fan to not supply air from outside the building space to inside the building space in response to the determination that the air quality level is less than the air quality threshold and the determination that the outdoor air quality level is less than the outdoor air quality threshold.

[0024] In some embodiments, the exhaust fan is located within the sub-portion of the building space. In some embodiments, the method includes determining, by the switch device, a second air quality level associated with a sub-portion of the building space based on a second air quality sensor and controlling, by the switch device, the sub-portion of the building space by controlling the exhaust fan to exhaust air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the second air quality level.

[0025] In some embodiments, the method includes causing, by the controller, a supply fan of the building space to supply air from outside the building space to inside the building space in response to the determination that the air quality level is less than the air quality threshold and the determination that the outdoor air quality level is greater than the outdoor air quality threshold and causing, by the controller, the supply fan to not supply air from outside the building space to inside the building space in response to the determination that the air quality level is less than the air quality threshold and the determination that the outdoor air quality level is less than the outdoor air quality threshold.

[0026] In some embodiments, the method includes providing, by the switch device, an indication to control the supply fan to the controller in response to the determination that the second air quality value is below the second air quality threshold, the supply fan configured to supply air from outside the building space to inside the building space, receiving, by the controller, the indication to control the supply fan from the switch device, and controlling, by the controller, the supply fan to supply air from outside the building space to inside the building space in response to receiving the indication to control the supply fan from the control circuit of the switch.

[0027] Another implementation of the present disclosure is a controller for controlling air quality of a building space. The controller includes an air quality sensor configured to sense the air quality of the building space and a processing. The processing circuit is configured to determine an air quality level of the building space based on the air quality sensed by the air quality sensor, determine whether the air quality level is less than an air quality threshold, cause a switch device of the building space to operate an exhaust fan to exhaust air from inside the building space to outside the building space in response to a determination that the air quality level is less than the air quality threshold, and cause a supply fan of the building space to supply air from outside the building space to inside the building space in response to the determination that the air quality level is below the air quality threshold, wherein the supply fan configured to supply air from outside the building space to inside the building space.

[0028] In some embodiments, the processing circuit is configured to receive or determine an outdoor air quality level, determine whether the outdoor air quality level is less than an outdoor air quality threshold, cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space and cause the supply fan of the building space to supply air from outside the building space to inside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is greater than the outdoor air quality threshold, and cause the switch device to not operate the exhaust fan to exhaust the air from inside the building space to outside the building space cause the supply fan of the building space to not supply air from outside the building space to inside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is less than the outdoor air quality threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Various objects, aspects, features, and advantages of the disclosure will become more apparent and better understood by referring to the detailed description taken in conjunction with the accompanying drawings, in which like reference characters identify corresponding elements throughout. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements.

[0030] FIG. 1 is a drawing of a building equipped with a HVAC system, according to an exemplary embodiment.

[0031] FIG. 2 is a drawing of multiple zones and floors of the building of FIG. 1 equipped with control devices, according to an exemplary embodiment.

[0032] FIG. 3 is a block diagram of a waterside system that may be used in conjunction with the building of FIGS. 1-2, according to an exemplary embodiment.

[0033] FIG. 4 is a block diagram of an airside system that may be used in conjunction with the building of FIGS. 1-2, according to an exemplary embodiment.

[0034] FIG. 5 is a drawing of the connections and sensors of the control device of FIG. 2 and FIG. 4, according to an exemplary embodiment.

[0035] FIG. 6 is a diagram of a communications system located in the building of FIGS. 1 and 2, according to an exemplary embodiment.

[0036] FIG. 7 is a block diagram illustrating the control device of FIGS. 2, 3, and 5 in greater detail, according to an exemplary embodiment.

[0037] FIG. 8 is a block diagram of a switch device for controlling an exhaust fan, according to some embodiments.

[0038] FIG. 9 is a sectional view of an illustration of a building including an HVAC system, according to some embodiments.

[0039] FIG. 10 is a flow diagram illustrating an exhaust fan control process, according to some embodiments.

[0040] FIG. 11 is a flow diagram illustrating a local exhaust fan control process, according to some embodiments.

DETAILED DESCRIPTION

Overview

[0041] Referring generally to the FIGURES, a user control device is shown, according to various exemplary embodiments. The user control device can be a thermostat used in any HVAC system, room, environment, or system within which it is desired to control and/or observe environmental conditions (e.g., temperature, humidity, air quality, etc.). The thermostat may be a device adjusted by a user and configured to control building equipment to control an environmental condition (e.g., temperature) of a system.

[0042] The thermostat can collect data about a space and the occupants of the space with various sensors (e.g., temperature sensors, humidity sensors, acoustic sensors, optical sensors, gas and other chemical sensors, biometric sensors, motion sensors, etc.) and user inputs. The thermostat may utilize data collected from a single room, multiple rooms, an entire building, and/or multiple buildings to control the air quality of the rooms and/or buildings. The data may be analyzed by the thermostat to control one or more components within the building associated with the HVAC system, e.g., supply fans and/or exhaust fans.

[0043] A fresh air inlet of a building for brining fresh air into the building can be supplemented using an exhaust fan. The thermostat can communicate with and/or control the exhaust fan. The exhaust fan may be a specially installed exhaust fans or using an existing exhaust fan of the building. A user may install a remotely-controllable switch device on each of the exhaust fans (e.g., a bathroom exhaust fan, a laundry room exhaust fan, a cooking vent, etc.), the switch device communicably coupled to the thermostat. The switch device may be a "smart switch" that can communicate with sensors for receiving temperature, humidity, air quality, and other sensed parameters within the home. The "smart switch" can control the exhaust fans based on data it gathers, communicate control commands to the thermostat, and/or receive control commands from the thermostat. The thermostat can control the exhaust fans via the switch devices to maintain a healthy air quality and/or humidity level within the building.

[0044] In some embodiments, the thermostat can improve internal air quality by controlling a fresh air intake based on an indoor air quality, e.g., by running a supply fan. For example, some buildings may have an outdoor air intake connected to a return air duct feeding a furnace and/or air handler of the building. While this can allow some fresh air to come into the building, there may be lack of negative pressure in the building to force fresh air into the building to maintain a pressure equalization. In this regard, the thermostat can run the exhaust fans causing a negative pressure within the building, thus maintaining the pressure equalization.

[0045] The thermostat and/or the switch device can control indoor air quality and/or normal HVAC equipment operation (e.g., building heating, building cooling, etc.). For example, the thermostat and/or the switch device can control indoor air quality of the building by operating exhaust fans in conjunction with the normal operation of the HVAC equipment. Also, the thermostat and/or switch device can control indoor air quality of a particular space of the building by operating exhaust fans in conjunction with, or independent of, the normal operation of the HVAC equipment.

[0046] The supply fan controlled by the thermostat can pull air from outside the building into the building and/or circulate air within the building. The building may include an air inlet allowing air from outside the building into a return air path of the supply fan. The thermostat can negatively pressure the building by turning on the exhaust fan and/or by running the supply fan. This can cause a ventilation effect in the building where more outdoor air is forced into the building.

[0047] Furthermore, the thermostat can dehumidify the building by controlling the exhaust fan and/or the supply fan. The thermostat can pull fresh dry air from outside the building (e.g., in cold and/or fall winter months) to dehumidify the building (e.g., ventilation of the building). The thermostat can be configured to use indoor air humidity and/or outdoor air temperature to determine whether the air outside the building is dry enough to dehumidify the building (e.g., based on max moisture content for a given outdoor temperature) and/or whether the building requires dehumidification. This functionality can allow the thermostat to dehumidify the building in cold months by running the exhaust fan and/or supply air fan in cold months when the outdoor conditions are sufficient to reduce the humidity of the building.

Building Management System and HVAC System

[0048] Referring now to FIGS. 1-4, an exemplary building management system (BMS) and HVAC system in which the systems and methods of the present disclosure may be implemented are shown, according to an exemplary embodiment. Referring particularly to

FIG. 1, a perspective view of a building 10 is shown. Building 10 is served by a BMS. A BMS is, in general, a system of devices configured to control, monitor, and manage equipment in or around a building or building area. A BMS can include, for example, a HVAC system, a security system, a lighting system, a fire alerting system, any other system that is capable of managing building functions or devices, or any combination thereof.

[0049] The BMS that serves building 10 includes an HVAC system 100. HVAC system 100 may include a multiple HVAC devices (e.g., heaters, chillers, air handling units, pumps, fans, thermal energy storage, etc.) configured to provide heating, cooling, ventilation, or other services for building 10. For example, HVAC system 100 is shown to include a waterside system 120 and an airside system 130. Waterside system 120 may provide a heated or chilled fluid to an air handling unit of airside system 130. Airside system 130 may use the heated or chilled fluid to heat or cool an airflow provided to building 10. An exemplary waterside system and airside system which may be used in HVAC system 100 are described in greater detail with reference to FIGS. 2-3.

[0050] HVAC system 100 is shown to include a chiller 102, a boiler 104, and a rooftop air handling unit (AHU) 106. Waterside system 120 may use boiler 104 and chiller 102 to heat or cool a working fluid (e.g., water, glycol, etc.) and may circulate the working fluid to AHU 106. In various embodiments, the HVAC devices of waterside system 120 may be located in or around building 10 (as shown in FIG. 1) or at an offsite location such as a central plant (e.g., a chiller plant, a steam plant, a heat plant, etc.). The working fluid may be heated in boiler 104 or cooled in chiller 102, depending on whether heating or cooling is required in building 10. Boiler 104 may add heat to the circulated fluid, for example, by burning a combustible material (e.g., natural gas) or using an electric heating element. Chiller 102 may place the circulated fluid in a heat exchange relationship with another fluid (e.g., a refrigerant) in a heat exchanger (e.g., an evaporator) to absorb heat from the circulated fluid. The working fluid from chiller 102 and/or boiler 104 may be transported to AHU 106 via piping 108.

[0051] AHU 106 may place the working fluid in a heat exchange relationship with an airflow passing through AHU 106 (e.g., via one or more stages of cooling coils and/or heating coils). The airflow may be, for example, outside air, return air from within building 10, or a combination of both. AHU 106 may transfer heat between the airflow and the working fluid to provide heating or cooling for the airflow. For example, AHU 106 may include one or more fans or blowers configured to pass the airflow over or through a heat exchanger containing the working fluid. The working fluid may then return to chiller 102 or boiler 104 via piping 110.

[0052] Airside system 130 may deliver the airflow supplied by AHU 106 (i.e., the supply airflow) to building 10 via air supply ducts 112 and may provide return air from building 10 to AHU 106 via air return ducts 114. In some embodiments, airside system 130 includes multiple variable air volume (VAV) units 116. For example, airside system 130 is shown to include a separate VAV unit 116 on each floor or zone of building 10. VAV units 116 may include dampers or other flow control elements that can be operated to control an amount of the supply airflow provided to individual zones of building 10. In other embodiments, airside system 130 delivers the supply airflow into one or more zones of building 10 (e.g., via supply ducts 112) without using intermediate VAV units 116 or other flow control elements. AHU 106 may include various sensors (e.g., temperature sensors, pressure sensors, etc.) configured to measure attributes of the supply airflow. AHU 106 may receive input from sensors located within AHU 106 and/or within the building zone and may adjust the flow rate, temperature, or other attributes of the supply airflow through AHU 106 to achieve setpoint conditions for the building zone.

[0053] Referring now to FIG. 2, building 10 is shown in greater detail, according to an exemplary embodiment. Building 10 may have multiple zones. In FIG. 2, building 10 has zones, 202, 204, 206, 208, 210, and 212. In building 10, the zones each correspond to a separate floor. In various embodiments, the zones of building 10 may be rooms, sections of a floor, multiple floors, etc. Each zone may have a corresponding control device 214. In some embodiments, control device 214 is at least one of a thermostat, a sensor, a controller, a display device, a concierge device, a medical monitor device, etc. Control device 214 may take input from users. The input may be an environmental setpoint, a concierge question, a payment, etc. In some embodiments, control device 214 can cause music and/or building announcements to be played in one or more of zones 202-212, cause the temperature and/or humidity to be regulated in one or more of zones 202-212, and/or any other control action.

[0054] In some embodiments, control device 214 can monitor the health of an occupant 216 of building 10. In some embodiments, control device 214 monitors heat signatures, heartrates, and any other information that can be collected from cameras, medical devices, and/or any other health related sensor. In some embodiments, building 10 has wireless transmitters 218 in each or some of zones 202-212. The wireless transmitters 218 may be routers, coordinators, and/or any other device broadcasting radio waves. In some embodiments, wireless transmitters 218 form a Wi-Fi network, a Zigbee network, a Bluetooth network, and/or any other kind of network.

[0055] In some embodiments, occupant 216 has a mobile device that can communicate with wireless transmitters 218. Control device 214 may use the signal strengths between the mobile device of occupant 216 and the wireless transmitters 218 to determine what zone the occupant is in. In some embodiments, control device 214 causes temperature setpoints, music and/or other control actions to follow occupant 216 as the occupant 216 moves from one zone to another zone (i.e., from one floor to another floor).

[0056] In some embodiments, display devices 214 are connected to a building management system, a weather server, and/or a building emergency sensor(s). In some embodiments, display devices 214 may receive emergency notifications from the building management system, the weather server, and/or the building emergency sensor(s). Based on the nature of the emergency, display devices 214 may give directions to an occupant of the building. In some embodiments, the direction may be to respond to an emergency (e.g., call the police, hide and turn the lights off, etc.) In various embodiments, the directions given to the occupant (e.g., occupant 216) may be navigation directions. For example, zone 212 may be a safe zone with no windows an individual (e.g., occupant 216). If the display devices 214 determine that there are high winds around building 10, the control device 214 may direct occupants of zones 202-210 to zone 212 if zone 212 has no windows.

[0057] Referring now to FIG. 3, a block diagram of a waterside system 300 is shown, according to an exemplary embodiment. In various embodiments, waterside system 300 may supplement or replace waterside system 120 in HVAC system 100 or may be implemented separate from HVAC system 100. When implemented in HVAC system 100, waterside system 300 may include a subset of the HVAC devices in HVAC system 100 (e.g., boiler 104, chiller 102, pumps, valves, etc.) and may operate to supply a heated or chilled fluid to AHU 106. The HVAC devices of waterside system 300 may be located within building 10 (e.g., as components of waterside system 120) or at an offsite location such as a central plant.

[0058] In FIG. 3, waterside system 300 is shown as a central plant having a plurality of subplants 302-312. Subplants 302-312 are shown to include a heater subplant 302, a heat recovery chiller subplant 304, a chiller subplant 306, a cooling tower subplant 308, a hot thermal energy storage (TES) subplant 310, and a cold thermal energy storage (TES) subplant 312. Subplants 302-312 consume resources (e.g., water, natural gas, electricity, etc.) from utilities to serve the thermal energy loads (e.g., hot water, cold water, heating, cooling, etc.) of a building or campus. For example, heater subplant 302 may be configured to heat water in a hot water loop 314 that circulates the hot water between heater subplant 302 and building 10. Chiller subplant 306 may be configured to chill water in a cold water loop 316 that circulates the cold water between chiller subplant 306 building 10. Heat recovery chiller subplant 304 may be configured to transfer heat from cold water loop 316 to hot water loop 314 to provide additional heating for the hot water and additional cooling for the cold water. Condenser water loop 318 may absorb heat from the cold water in chiller subplant 306 and reject the absorbed heat in cooling tower subplant 308 or transfer the absorbed heat to hot water loop 314. Hot TES subplant 310 and cold TES subplant 312 may store hot and cold thermal energy, respectively, for subsequent use.

[0059] Hot water loop 314 and cold water loop 316 may deliver the heated and/or chilled water to air handlers located on the rooftop of building 10 (e.g., AHU 106) or to individual floors or zones of building 10 (e.g., VAV units 116). The air handlers push air past heat exchangers (e.g., heating coils or cooling coils) through which the water flows to provide heating or cooling for the air. The heated or cooled air may be delivered to individual zones of building 10 to serve the thermal energy loads of building 10. The water then returns to subplants 302-312 to receive further heating or cooling.

[0060] Although subplants 302-312 are shown and described as heating and cooling water for circulation to a building, it is understood that any other type of working fluid (e.g., glycol, CO2, etc.) may be used in place of or in addition to water to serve the thermal energy loads. In other embodiments, subplants 302-312 may provide heating and/or cooling directly to the building or campus without requiring an intermediate heat transfer fluid. These and other variations to waterside system 300 are within the teachings of the present disclosure.

[0061] Each of subplants 302-312 may include a variety of equipment configured to facilitate the functions of the subplant. For example, heater subplant 302 is shown to include a plurality of heating elements 320 (e.g., boilers, electric heaters, etc.) configured to add heat to the hot water in hot water loop 314. Heater subplant 302 is also shown to include several pumps 322 and 324 configured to circulate the hot water in hot water loop 314 and to control the flow rate of the hot water through individual heating elements 320.

Chiller subplant 306 is shown to include a plurality of chillers 332 configured to remove heat from the cold water in cold water loop 316. Chiller subplant 306 is also shown to include several pumps 334 and 336 configured to circulate the cold water in cold water loop 316 and to control the flow rate of the cold water through individual chillers 332.

[0062] Heat recovery chiller subplant 304 is shown to include a plurality of heat recovery heat exchangers 326 (e.g., refrigeration circuits) configured to transfer heat from cold water loop 316 to hot water loop 314. Heat recovery chiller subplant 304 is also shown to include several pumps 328 and 330 configured to circulate the hot water and/or cold water through heat recovery heat exchangers 326 and to control the flow rate of the water through individual heat recovery heat exchangers 226. Cooling tower subplant 208 is shown to include a plurality of cooling towers 338 configured to remove heat from the condenser water in condenser water loop 318. Cooling tower subplant 308 is also shown to include several pumps 340 configured to circulate the condenser water in condenser water loop 318 and to control the flow rate of the condenser water through individual cooling towers 338.

[0063] Hot TES subplant 310 is shown to include a hot TES tank 342 configured to store the hot water for later use. Hot TES subplant 310 may also include one or more pumps or valves configured to control the flow rate of the hot water into or out of hot TES tank 342. Cold TES subplant 312 is shown to include cold TES tanks 344 configured to store the cold water for later use. Cold TES subplant 312 may also include one or more pumps or valves configured to control the flow rate of the cold water into or out of cold TES tanks 344.

[0064] In some embodiments, one or more of the pumps in waterside system 300 (e.g., pumps 322, 324, 328, 330, 334, 336, and/or 340) or pipelines in waterside system 300 include an isolation valve associated therewith. Isolation valves may be integrated with the pumps or positioned upstream or downstream of the pumps to control the fluid flows in waterside system 300. In various embodiments, waterside system 300 may include more, fewer, or different types of devices and/or subplants based on the particular configuration of waterside system 300 and the types of loads served by waterside system 300.

[0065] Referring now to FIG. 4, airside system 400 is shown to include an economizer-type air handling unit (AHU) 402. Economizer-type AHUs vary the amount of outside air and return air used by the air handling unit for heating or cooling. For example, AHU 402 may receive return air 404 from building zone 406 via return air duct 408 and may deliver supply air 410 to building zone 406 via supply air duct 412. In some embodiments, AHU

402 is a rooftop unit located on the roof of building 10 (e.g., AHU 106 as shown in FIG. 1) or otherwise positioned to receive both return air 404 and outside air 414. AHU 402 may be configured to operate exhaust air damper 416, mixing damper 418, and outside air damper 420 to control an amount of outside air 414 and return air 404 that combine to form supply air 410. Any return air 404 that does not pass through mixing damper 418 may be exhausted from AHU 402 through exhaust damper 416 as exhaust air 422.

[0066] Each of dampers 416-420 may be operated by an actuator. For example, exhaust air damper 416 may be operated by actuator 424, mixing damper 418 may be operated by actuator 426, and outside air damper 420 may be operated by actuator 428. Actuators 424-428 may communicate with an AHU controller 430 via a communications link 432. Actuators 424-428 may receive control signals from AHU controller 430 and may provide feedback signals to AHU controller 430. Feedback signals may include, for example, an indication of a current actuator or damper position, an amount of torque or force exerted by the actuator, diagnostic information (e.g., results of diagnostic tests performed by actuators 424-428), status information, commissioning information, configuration settings, calibration data, and/or other types of information or data that may be collected, stored, or used by actuators 424-428. AHU controller 430 may be an economizer controller configured to use one or more control algorithms (e.g., state-based algorithms, extremum seeking control (ESC) algorithms, proportional-integral (PI) control algorithms, proportional-integral-derivative (PID) control algorithms, model predictive control (MPC) algorithms, feedback control algorithms, etc.) to control actuators 424-428.

[0067] Still referring to FIG. 4, AHU 402 is shown to include a cooling coil 434, a heating coil 436, and a fan 438 positioned within supply air duct 412. Fan 438 may be configured to force supply air 410 through cooling coil 434 and/or heating coil 436 and provide supply air 410 to building zone 406. AHU controller 430 may communicate with fan 438 via communications link 440 to control a flow rate of supply air 410. In some embodiments, AHU controller 430 controls an amount of heating or cooling applied to supply air 410 by modulating a speed of fan 438.

[0068] Cooling coil 434 may receive a chilled fluid from waterside system 200 (e.g., from cold water loop 316) via piping 442 and may return the chilled fluid to waterside system 200 via piping 444. Valve 446 may be positioned along piping 442 or piping 444 to control a flow rate of the chilled fluid through cooling coil 474. In some embodiments, cooling coil 434 includes multiple stages of cooling coils that can be independently activated and deactivated (e.g., by AHU controller 430, by BMS controller 466, etc.) to modulate an amount of cooling applied to supply air 410.

[0069] Heating coil 436 may receive a heated fluid from waterside system 200 (e.g., from hot water loop 314) via piping 448 and may return the heated fluid to waterside system 200 via piping 450. Valve 452 may be positioned along piping 448 or piping 450 to control a flow rate of the heated fluid through heating coil 436. In some embodiments, heating coil 436 includes multiple stages of heating coils that can be independently activated and deactivated (e.g., by AHU controller 430, by BMS controller 466, etc.) to modulate an amount of heating applied to supply air 410.

[0070] Each of valves 446 and 452 may be controlled by an actuator. For example, valve 446 may be controlled by actuator 454 and valve 452 may be controlled by actuator 456. Actuators 454-456 may communicate with AHU controller 430 via communications links 458-460. Actuators 454-456 may receive control signals from AHU controller 430 and may provide feedback signals to controller 430. In some embodiments, AHU controller 430 receives a measurement of the supply air temperature from a temperature sensor 462 positioned in supply air duct 412 (e.g., downstream of cooling coil 434 and/or heating coil 436). AHU controller 430 may also receive a measurement of the temperature of building zone 406 from a temperature sensor 464 located in building zone 406.

[0071] In some embodiments, AHU controller 430 operates valves 446 and 452 via actuators 454-456 to modulate an amount of heating or cooling provided to supply air 410 (e.g., to achieve a set point temperature for supply air 410 or to maintain the temperature of supply air 410 within a set point temperature range). The positions of valves 446 and 452 affect the amount of heating or cooling provided to supply air 410 by cooling coil 434 or heating coil 436 and may correlate with the amount of energy consumed to achieve a desired supply air temperature. AHU 402 may control the temperature of supply air 410 and/or building zone 406 by activating or deactivating coils 434-436, adjusting a speed of fan 438, or a combination of both.

[0072] Still referring to FIG. 4, airside system 400 is shown to include a building management system (BMS) controller 466 and a control device 214. BMS controller 466 may include one or more computer systems (e.g., servers, supervisory controllers, subsystem controllers, etc.) that serve as system level controllers, application or data servers, head nodes, or master controllers for airside system 400, waterside system 200, HVAC system 100, and/or other controllable systems that serve building 10. BMS controller 466 may communicate with multiple downstream building systems or subsystems (e.g., HVAC system 100, a security system, a lighting system, waterside system 200, etc.) via a communications link 470 according to like or disparate protocols (e.g., LON, BACnet, etc.). In various embodiments, AHU controller 430 and BMS controller 466 may be separate (as shown in FIG. 4) or integrated. In an integrated implementation, AHU controller 430 may be a software module configured for execution by a processor of BMS controller 466.

[0073] In some embodiments, AHU controller 430 receives information from BMS controller 466 (e.g., commands, set points, operating boundaries, etc.) and provides information to BMS controller 466 (e.g., temperature measurements, valve or actuator positions, operating statuses, diagnostics, etc.). For example, AHU controller 430 may provide BMS controller 466 with temperature measurements from temperature sensors 462-464, equipment on/off states, equipment operating capacities, and/or any other information that can be used by BMS controller 466 to monitor or control a variable state or condition within building zone 406.

[0074] Control device 214 may include one or more of the user control devices. Control device 214 may include one or more human-machine interfaces or client interfaces (e.g., graphical user interfaces, reporting interfaces, text-based computer interfaces, client-facing web services, web servers that provide pages to web clients, etc.) for controlling, viewing, or otherwise interacting with HVAC system 100, its subsystems, and/or devices. Control device 214 may be a computer workstation, a client terminal, a remote or local interface, or any other type of user interface device. Control device 214 may be a stationary terminal or a mobile device. For example, control device 214 may be a desktop computer, a computer server with a user interface, a laptop computer, a tablet, a smartphone, a PDA, or any other type of mobile or non-mobile device. Control device 214 may communicate with BMS controller 466 and/or AHU controller 430 via communications link 472.

[0075] Referring now to FIG. 5, control device 214 is shown as a connected smart hub or private area network (PAN), according to some embodiments. Control device 214 may include a variety of sensors and may be configured to communicate with a variety of external systems or devices. For example, control device 214 may include temperature sensors 502, speakers 504, leak detection system 508, health monitoring sensors 510, humidity sensors 514, occupancy sensors 516, a light detection sensors 518, proximity sensor 520, carbon dioxide sensors 522, energy consumption sensors 524, volatile organic compound (VOC) sensors 526, or any of a variety of other sensors. Alternatively, control device 214 may receive input from external sensors configured to measure such variables. The external sensors may not communicate over a PAN network but may communicate with control device 214 via an IP based network and/or the Internet.

[0076] In some embodiments, the temperature sensors 502, the humidity sensors 514, the carbon dioxide sensors 522, and the VOC sensors 526 may be located at different locations within a building or home. Additionally, one or more of the temperature sensors 502, the humidity sensors 514, the carbon dioxide sensors 522, and the VOC sensors 526 may be located outside of the building or home to measure aspects of the outside air, such as outdoor temperature, outdoor humidity, carbon dioxide levels and VOC levels in the outside air. In further embodiments, the control device 214 may communicate with sensors both inside the building or home as well as outside the building or home.

[0077] In some embodiments, speakers 504 are located locally as a component of control device 214. Speakers 504 may be low power speakers used for playing audio to the immediate occupant of control device 214 and/or occupants of the zone in which control device 214 is located. In some embodiments, speakers 504 may be remote speakers connected to control device 214 via a network. In some embodiments, speakers 504 are a building audio system, an emergency alert system, and/or alarm system configured to broadcast building wide and/or zone messages or alarms.

[0078] Control device 214 may communicate with a remote camera 506, a shade control system 512, a leak detection system 508, an HVAC system, or any of a variety of other external systems or devices which may be used in a home automation system or a building automation system. Control device 214 may provide a variety of monitoring and control interfaces to allow a user to control all of the systems and devices connected to control device 214. Exemplary user interfaces and features of control device 214 are described in greater detail below.

[0079] Referring now to FIG. 6, a block diagram of communications system 600 is shown, according to some embodiments. System 600 can be implemented in a building (e.g. building 10) and is shown to include control device 214, network 602, air quality sensors 604, building emergency sensor(s) 606, weather server(s) 608, building management system 610, and user device 612. System 600 connects devices, systems, and servers via network 602 so that building information, HVAC controls, emergency information, navigation directions, and other information can be passed between devices (e.g., control device 214, user device 612, and/or building emergency sensor(s) 606 and servers and systems (e.g., weather server(s) 608 and/or building management system 610). In some embodiments, control device 214 is connected to speakers 504 as described with reference to FIG. 5.

[0080] In some embodiments, network 602 communicatively couples the devices, systems, and servers of system 600. In some embodiments, network 602 is at least one of and/or a combination of a Wi-Fi network, a wired Ethernet network, a Zigbee network, and a Bluetooth network. Network 602 may be a local area network or a wide area network (e.g., the Internet, a building WAN, etc.) and may use a variety of communications protocols (e.g., BACnet, IP, LON, etc.) Network 602 may include routers, modems, and/or network switches.

[0081] In some embodiments, control device 214 is configured to receive emergency information, navigation directions, occupant information, concierge information, air quality information, and any other information via network 602. In some embodiments, the information is received from building management system 610 via network 602. In various embodiments, the information is received from the Internet via network 602. In some embodiments, control device 214 is at least one of, or a combination of, a thermostat, a humidistat, a light controller, and any other wall mounted and/or hand held device. In some embodiments, the control device 214 is connected to one or more air quality sensors 604. Air quality sensors 604 can include temperature sensors, humidity sensors, carbon dioxide sensors, VOC sensors, etc. In some embodiments, control device 214 is connected to building emergency sensor(s) 606. In some embodiments, building emergency sensor(s) 606 are sensors which detect building emergencies. Building emergency sensor(s) 606 may be smoke detectors, carbon monoxide detectors, carbon dioxide detectors (e.g., carbon dioxide sensors 522), an emergency button (e.g., emergency pull handles, panic buttons, a manual fire alarm button and/or handle, etc.) and/or any other emergency sensor. In some embodiments, the emergency sensor(s) include actuators. The actuators may be building emergency sirens and/or building audio speaker systems (e.g., speakers 504), automatic door and/or window control (e.g., shade control system 512), and any other actuator used in a building.

[0082] In some embodiments, control device 214 may be communicatively coupled to weather server(s) 608 via network 602. In some embodiments, the control device 214 may be configured to receive weather alerts (e.g., high and low daily temperature, five day forecast, thirty day forecast, etc.) from weather server(s) 608. Control device 214 may be configured to receive emergency weather alerts (e.g., flood warnings, fire warnings, thunder storm warnings, winter storm warnings, etc.) In some embodiments, control device 214 may be configured to display emergency warnings via a user interface of control device 214 when control device 214 receives an emergency weather alert from weather server(s) 608. The control device 214 may be configured to display emergency warnings based on the data received from building emergency sensor(s) 606. In some embodiments, the control device 214 may cause a siren (e.g., speakers 504 and/or building emergency sensor(s) 606) to alert occupants of the building of an emergency, cause all doors to become locked and/or unlocked, cause an advisory message be broadcast through the building, and control any other actuator or system necessary for responding to a building emergency. In further embodiments, the weather server(s) 608 may be configured to provide air quality information to the control device 214. For example, the weather server(s) 608 may provide air quality information such as pollen levels, mold levels, particulate levels, etc.

[0083] In some embodiments, control device 214 is configured to communicate with building management system 610 via network 602. Control device 214 may be configured to transmit environmental setpoints (e.g., temperature setpoint, humidity setpoint, etc.) to building management system 610. In some embodiments, building management system 610 may be configured to cause zones of a building (e.g., building 10) to be controlled to the setpoint received from control device 214. In further embodiments, the building management system 610 may be configured to control one or more fans or ventilators to provide air flow into and out of a building (e.g. building 10). In some embodiments, building management system 610 may be configured to control the lighting of a building. In some embodiments, building management system 610 may be configured to transmit emergency information to control device 214. In some embodiments, the emergency information is a notification of an active shooter lockdown, a tornado warning, a flood warning, a thunderstorm warning, and/or any other warning. In some embodiments, building management system 610 is connected to various weather servers or other web servers from which building management system 610 receives emergency warning information. In various embodiments, building management system is a computing system of a hotel. Building management system 610 may keep track of hotel occupancy, may relay requests to hotel staff, and/or perform any other functions of a hotel computing system.

[0084] Control device 214 can be configured to communicate with user device 612 via network 602. In some embodiments, user device 612 is a smartphone, a tablet, a laptop computer, and/or any other mobile and/or stationary computing device. In some embodiments, user device 612 communicates calendar information to control device 214. In some embodiments, the calendar information is stored and/or entered by a user into calendar application. In some embodiments, calendar application is at least one of Outlook, Google Calendar, Fantastical, Shifts, CloudCal, DigiCal, and/or any other calendar application. In some embodiments, control device 214 receives calendar information from the calendar application such as times and locations of appointments, times and locations of meetings, and/or any other information. Control device 214 may be configured to display building map direction to a user associated with user device 612 and/or any other information.

[0085] In some embodiments, a user may press a button on a user interface of control device 214 indicating a building emergency. The user may be able to indicate the type of emergency (e.g., fire, flood, active shooter, etc.) Control device 214 may communicate an alert to building management system 610, user device 612, and any other device, system, and/or server.

[0086] Referring now to FIG. 7, a block diagram illustrating control device 214 in greater detail is shown, according to some embodiments. Control device 214 is shown to include a variety of user interface devices 702. User interface 702 may be configured to receive input from a user and provide output to a user in various forms. For example, user interface devices 702 are shown to include a touch-sensitive panel 704, an electronic display 706, ambient lighting 708, speakers 710 (e.g., speakers 504), and an input device 712. Input device 712 may include a microphone configured to receive voice commands from a user, a keyboard or buttons, switches, dials, or any other user-operable input device. It is contemplated that user interface devices 702 may include any type of device configured to receive input from a user and/or provide an output to a user in any of a variety of forms (e.g., touch, text, video, graphics, audio, vibration, etc.).

[0087] The control device 214 may also include, or be in communication with, a number of sensors 714. The sensors may be configured to measure a variable state or condition of the environment in which control device 214 is installed. For example, sensors 714 are shown to include a temperature sensor 716, a humidity sensor 718, an air quality sensor 720, a proximity sensor 722, a camera 724, a microphone 726, a light sensor 728, and a vibration sensor 730. The sensors 714 may be configured to measure various air quality sensor 720 may be configured to measure any of a variety of air quality variables such as oxygen level, carbon dioxide level, carbon monoxide level, allergens, pollutants, smoke, VOCs, etc. Proximity sensor 722 may include one or more sensors configured to detect the presence of people or devices proximate to control device 214. For example, proximity sensor 722 may include a near-field communications (NFC) sensor, a radio frequency identification (RFID) sensor, a Bluetooth sensor, a capacitive proximity sensor, a biometric sensor, or any other sensor configured to detect the presence of a person or device. Camera 724 may include a visible light camera, a motion detector camera, an infrared camera, an ultraviolet camera, an optical sensor, or any other type of camera. Light sensor 728 may be configured to measure ambient light levels. Vibration sensor 730 may be configured to measure vibrations from earthquakes or other seismic activity at the location of control device 214.

[0088] Still referring to FIG. 7, control device 214 is shown to include a communications interface 732 and a processing circuit 734. Communications interface 732 may include wired or wireless interfaces (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications with various systems, devices, or networks. For example, communications interface 732 may include an Ethernet card and port for sending and receiving data via an Ethernet-based communications network and/or a Wi-Fi transceiver for communicating via a wireless communications network. Communications interface 732 may be configured to communicate via local area networks or wide area networks (e.g., the Internet, a building WAN, etc.) and may use a variety of communications protocols (e.g., BACnet, IP, LON, etc.).

[0089] Communications interface 732 may include a network interface configured to facilitate electronic data communications between control device 214 and various external systems or devices (e.g., network 602, building management system 610, HVAC equipment 738, user device 612, etc.) For example, control device 214 may receive information from building management system 610 or HVAC equipment 738 indicating one or more measured states of the controlled building (e.g., temperature, humidity, electric loads, etc.) and one or more states of the HVAC equipment 738 (e.g., equipment status, power consumption, equipment availability, etc.). In some embodiments, HVAC equipment 738 may be lighting systems, building systems, actuators, chillers, heaters, and/or any other building equipment and/or system. Communications interface 732 may receive inputs from building management system 610 or HVAC equipment 738 and may provide operating parameters (e.g., on/off decisions, set points, etc.) to building management system 610 or HVAC equipment 738. The operating parameters may cause building management system 610 to activate, deactivate, or adjust a set point for various types of home equipment or building equipment in communication with control device 214.

[0090] Processing circuit 734 is shown to include a processor 740 and memory 742. Processor 740 may be a general purpose or specific purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a group of processing components, or other suitable processing components. Processor 740 may be configured to execute computer code or instructions stored in memory 742 or received from other computer readable media (e.g., CDROM, network storage, a remote server, etc.).

[0091] Memory 742 may include one or more devices (e.g., memory units, memory devices, storage devices, etc.) for storing data and/or computer code for completing and/or facilitating the various processes described in the present disclosure. Memory 742 may include random access memory (RAM), read-only memory (ROM), hard drive storage, temporary storage, non-volatile memory, flash memory, optical memory, or any other suitable memory for storing software objects and/or computer instructions. Memory 742 may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. Memory 742 may be communicably connected to processor 740 via processing circuit 734 and may include computer code for executing (e.g., by processor 740) one or more processes described herein.

[0092] For example, memory 742 is shown to include a fan control module 744 and a switch control module 746. The fan control module 744 may be configured to operate one or more fans associated with an HVAC system of a building. The switch control module 746 may be configured to control one or more switch devices located within the building. Switch devices are described in more detail below. Further, other modules, such as voice command and control modules, building modules, payment modules, hotel modules, healthcare modules, occupancy modules, emergency modules and the like may also be included in the memory 742. The functions of some of these modules is described in greater detail below.

[0093] In some embodiments, the control device 214 can be configured to control building equipment, e.g., indoor and/or outdoor equipment (e.g., heatpumps, furnaces, AHUs, air conditioners, etc.) to heat and/or cool a building. Whenever the control device 214 causes the building equipment to heat and/or cool the building, the control device 214 may simultaneously cause an exhaust fan to run dispelling stale air from inside the building to outside the building and/or run a supply fan to bring fresh air into the building. However, the control device 214 can also control the exhaust fan and/or supply an independent of the heating and/or cooling of the building.

Exhaust Fan Control

[0094] Referring now to FIG. 8, a block diagram illustrating a smart, or intelligent, switch device 800 is shown, according to some embodiments. A smart switch may be any switch with an ability to communicate with a network or other control device, such as control device 214. The switch device 800 is shown to include a processing circuit 802. The processing circuit 802 includes a processor 804 and a memory 806. The processor 804 may be a general purpose or specific purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a group of processing components, or other suitable processing components. The processor 804 may be configured to execute computer code or instructions stored in the memory 806 or received from other computer readable media (e.g., CDROM, network storage, a remote server, etc.).

[0095] The memory 806 may include one or more devices (e.g., memory units, memory devices, storage devices, etc.) for storing data and/or computer code for completing and/or facilitating the various processes described in the present disclosure. The memory 806 may include random access memory (RAM), read-only memory (ROM), hard drive storage, temporary storage, non-volatile memory, flash memory, optical memory, or any other suitable memory for storing software objects and/or computer instructions. The memory 806 may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure.

[0096] The memory 806 may be communicably connected to processor 804 via the processing circuit 802 and may include computer code for executing (e.g., by processor

804) one or more processes described herein. For example, the memory 806 is shown to include a device control module 808. The device control module 808 may be configured to control a power switch 810 of the switch device 800 to provide power to a connected device, such as an exhaust fan 812.

[0097] The switch device 800 may further include a communication interface 814. The communication interface 814 may include wired or wireless interfaces (e.g., jacks, antennas, transmitters, receivers, transceivers, wire terminals, etc.) for conducting data communications with various systems, devices, or networks. For example, the communication interface 814 may include an Ethernet card and port for sending and receiving data via an Ethernet-based communications network and/or a Wi-Fi transceiver for communicating via a wireless communications network. The communication interface 814 may be configured to communicate via local area networks or wide area networks (e.g., the Internet, a building WAN, etc.) and may use a variety of communications protocols (e.g., BACnet, IP, LON, etc.).

[0098] The communication interface 814 may include a network interface configured to facilitate electronic data communications between control device 214 and various external systems or devices, such as network 602. For example, the switch device 800 may receive information from the control device 214. For example, the control device 214 may provide operating instructions to the switch device 800, such as when to provide power to the exhaust fan 812. The information received from the control device 214 may include information provided by one or more sensors, such as air quality sensors 604. Other information received from the control device 214 may include data or commands from the HVAC equipment 738. The communication interface 814 may further be in communication with one or more sensors 816. The sensors 816 may be air quality sensors, humidity sensors, temperature sensors, and the like. In some embodiments, the sensors 816 may instead of, or in addition to, be integrated into the switch device 800. For example, the switch device 800 may include integrated humidity sensors, air quality sensors, temperature sensors, and the like. In some embodiments, the sensors 816 may be a combination of integrated and external sensors.

[0099] By using a switch device 800, the ability of the control device 214 to control additional components within a building can be supplemented. Further, by using switch devices 800, existing devices, such as exhaust fans, can be retrofitted to be controlled by the control device 214. This can be advantageous where it would be difficult or economically impractical to install new equipment.

[0100] Turning now to FIG. 9, a sectional view of an illustration of a building 900 is shown, according to some embodiments. The building may include a first zone 902, a second zone 904, and a third zone 906. In one embodiment, the first zone 902 and the second zone 904 are rooms in a building, and the third zone 906 is a basement. However, the building 900 may have other configurations, including different zone types and different numbers of zones. The building 900 may further include an indoor unit 908, an exhaust fan 812, a number of sensors 912, a switch device 800, and a control device, such as control device 214, described elsewhere herein. The exhaust fan 812 may be a bathroom fan, a laundry room fan, a cooking vent, etc.

[0101] In one embodiment, the sensors 912 may be humidity sensors, air quality sensors, temperature sensors, or a combination thereof. While shown as being internal to the building 900, it is contemplated that one or multiple of the sensors 912 may be external to the building for measuring outside air parameters. In one embodiment, the sensors 912 may in communication with the control device 214. In other embodiments, the sensors 912 may be in communication with the switch device 800. In some embodiments, the sensors 912 may in communication with both the control device 214 and the switch device 800.

[0102] The switch device 800 may be in communication with the exhaust fan 812. In some embodiments, the switch device 800 can be configured to control the operation of the exhaust fan 812. For example, the switch device 800 may be configured to selectively provide power to the exhaust fan 812 to cause the exhaust fan 812 to run or to not run. In some embodiments, the switch device 800 may include a manual switch to allow a user to operate the exhaust fan 812. In this regard, the switch device 800 may be a wall switch, e.g., similar to a light switch, that can be installed in a wall where a conventional switch might be located. This can allow the control device 214 to operate the exhaust fan 812 in addition to allowing a user to manually switch the exhaust fan 812 on or off.

[0103] The switch device 800, as described above, may further be capable of operating the exhaust fan 812 based on determining that certain parameters are met, as will be described below. In one embodiment, the switch device 800 may further be in communication with the control device 214, and may receive commands or data from the control device 214. In one embodiment, the exhaust fan 812 is configured to exhaust air from building 900 via an exhaust duct 914. Exhausting the air from the interior of the building 900 to the outside atmosphere can generate a negative pressure within the building 900. Further, exhausting the air from the interior of the building 900 to the outside atmosphere can aid in reducing humidity in one or more portions of the building 900. Creating a negative pressure may allow fresh air to enter the building 900, e.g., enter the building 900 via the outdoor air inlet 920.

[0104] The indoor unit 908 may be a furnace and/or an AHU (e.g., a roof top unit). The indoor unit 908 may provide conditioned air to the building 900 via one or more air supply ducts 916. The indoor unit 908 may heat and/or cool the air supplied to the building 900 to reach a temperature set point commanded by the control device 214. The indoor unit 908 may intake inside air via one or more air return ducts 918. The return air may be supplemented with outside air via outdoor air inlet 920. By supplementing the return air with outdoor air, the air quality within the building 900 may be improved.

[0105] The indoor unit 908 may include a supply fan 909 configured to supply air from outside the building 900 to the building 900. The supply fan 909 can be operated by the control device 214. The control device 214 can provide a command to the supply fan 909 to run and/or not run. Furthermore, the control device 214 can cause the indoor unit 908 to heat and/or cool the building 900 while running the supply fan 909. In some embodiments, in response to poor indoor air quality, the control device 214 can run the supply fan 909 with the exhaust fan 812 or independent from the exhaust fan 812 to exhaust air from inside the building 900 to outside the building 900 (via the exhaust fan 812) and bring fresh air into the building 900 (via the supply fan 909 and the outdoor air inlet 920). In some embodiments, the supply fan 909 is a standalone device mounted in the wall of the building 900 configured to bring fresh air into the building 900. For example, in some embodiments, the supply fan 909 is an exhaust fan mounted in an inverse manner such that fresh air is supplied to the building 900 from outside the building 900.

[0106] Turning to FIG. 10, a flow chart illustrating a process 1000 for controlling one or more exhaust fans, such as exhaust fan 812, to improve air quality in a building is shown, according to some embodiments. By controlling the exhaust fans, supplemental fresh air may be provided to the building by creating additional negative pressure within the building, thereby allowing more outside air to enter the building, such as via outdoor inlet 920. This can allow existing exhaust fans to be controlled to supplement the operation of an HVAC system associated with the building. While process 1100 is primarily described with reference to control device 214, the switch device 800 and/or the control device 214 can be configured to perform some and/or all of the process 1100.

[0107] The process 1000 may start at process block 1102. For example purposes, the process 1000 will be described in regards to the building 900 described above. However, other implementations are contemplated. Further, the various process steps described below may be performed by the control device 214, the switch device 800, or a combination thereof. At process block 1004, the building air quality is measured. In one embodiment, the one or more sensors, such as sensors 912, may output data related to the building air quality. For example, the sensors may provide information such as humidity measurements, temperature measurements, carbon dioxide measurements, VOC measurements, or other air quality measurements. In some embodiments, the building air quality measurements are provided to the control device 214 for processing. In other embodiments, the switch device 800 may receive the air quality measurements for processing.

[0108] At process block 1006 it is determined whether the air quality is good or bad based on the building air quality measurements. In some embodiments, the control device 214 determines whether the air quality is good or bad. In some embodiments, the switch device 800 may determine whether air quality is good or bad. The air quality may be determined to be good or bad based on evaluating certain measured air quality values. For example, VOC levels, CO2 levels, pollen levels, particulate levels, humidity, temperature and/or other values may be evaluated to determine whether the air quality is good or bad. These values may be compared against predefined threshold levels, which can provide an indication of whether the air quality average is good or bad. For example, where none of the measured values exceeds the predefined threshold levels, the air quality may be determined to be good. In contrast, if one or more of the measured values exceeds a threshold value, the air quality average may be determined to be bad. In some embodiments, a certain number of measured values may need to exceed the predefined thresholds for the air quality to be considered bad. In some embodiments, the various air quality values may be evaluated to generate an air quality "score." The score may be a numerical value (e.g. 1–100), an alphabetical value (e.g. A–F), or other representative value. The score may then be used to determine whether the air quality is good or bad. For example, using a numerical value scoring system where zero is the highest air quality score (e.g. best air quality), and one hundred is the lowest air quality score (e.g. worst air quality), a score above fifty may indicate that the air quality average is "bad." However, it is contemplated that other scores may be used to determine whether the air quality average is good or bad. As another example, a high value (e.g., 100) may indicate good air quality while a low value (e.g., 0) may indicate a low air quality. If the air quality is above a predefined amount, this may indicate that the air quality is good and then the exhaust fan 914 does not need to run. However, if the air quality is below the predefined amount, this may indicate that the air quality is bad and the exhaust fan 914 does need to run.

[0109] If the air quality is determined to be good at process block 1006, the control device 214 (or the switch device 800) determines if the outdoor air temperature is less than a predefined amount (e.g., 50°F), and if the indoor ambient humidity (IAH) is greater than an IAH setpoint (SP) at process block 1008. If the OAT is not less than the predefined amount or the IAH is not greater than the IAH setpoint, the exhaust fan 812 is not allowed to run at process block 1010. In some embodiments, it may be determined not to run the exhaust fans with an HVAC supply fan. However, the exhaust fan may still be able to be operated directly by a user via the switch device 800. The process may then end at process block 1012.

[0110] If the OAT is less than the predefined amount and the IAH is greater than the IAH SP, the process 1000 proceeds to process block 1014. If the air quality is determined to be bad at block 1006, the process 1000 also proceeds to process block 1014. At process block 1014, the control device 214 determines if the outdoor air conditions are favorable for operation of the exhaust fan 812. The control device 214 may evaluate outdoor air conditions, such as temperature, humidity, etc. to determine if the outdoor air conditions are favorable for operating the exhaust fan. For example, where the outdoor temperature is too high or too low, or the humidity level is too high or too low, the conditions may be determined not to be favorable for operation of the exhaust fan. Specific examples may include determining that the outside air conditions are unfavorable when the temperature is above 90°F, or if the humidity level is over 75%. By evaluating the outdoor air conditions the exhaust fan may be allowed to run automatically in most situations unless the outdoor conditions are extremely poor (i.e., exceptionally cold in winter, or exceptionally hot and humid in the summer). The outdoor conditions can be determined to be good or bad in a similar manner as at block 1006.

[0111] In some embodiments, block 1014 may be optional. For example, the process 1000 may always assume that outdoor air quality conditions are good. Similarly, the process 1000 might assume that the outdoor air quality conditions are better than the indoor air quality conditions and therefore anytime the indoor air quality is poor, regardless of the outdoor air quality, the exhaust fan 812 and/or the supply fan 909 can be run.

[0112] If the outdoor air conditions are not favorable, the exhaust fan 812 is not operated at process block 1010 as described above. If the outside air conditions are determined to be favorable, the process proceeds to process block 1016. At process block 1016 the control device 214 (or the switch device 800) determines if the exhaust fan 812 runtime over a given period of time exceeds the maximum runtime for a given time frame. For example, a runtime over a twenty-four hour period of the exhaust fan 812 is evaluated to determine if it exceeds a max runtime in the same twenty-four hour period. In other embodiments, the period of time may be a calendar day. However, other amount of time are also contemplated, such as one hour, twelve hours, and the like. By determining if the exhaust fan 812 has operated over a given period of time for more than a maximum runtime, the control device 214 (or the switch device 800) can prevent running the exhaust fan when exhaust-based ventilation isn't enough to keep the humidity or air quality level under control. For example, if the exhaust based ventilation is insufficient to maintain the desired or required humidity and/or air quality levels, this may be reflected in the exhaust fan 812 being operated more than an allowable amount in the given time period. By not allowing the exhaust fan 812 to be operated more than an allowable amount in a given time period, damage to the exhaust fan 812 may be prevented. The control device 214 can record, using various timers or timing devices, how long the exhaust fan 812 has been running during the particular time period.

[0113] If the exhaust fan 812 is determined to have exceeded the maximum allowable runtime for the given time period, the exhaust fan 812 is not operated at process block 1010. If the exhaust fan 812 is determined to not have exceeded the maximum allowable runtime for the given time period, the exhaust fan 812 may be operated in conjunction with an HVAC supply fan at process block 1018, e.g., the supply fan 909. In one embodiment, the control device 214 may instruct the switch device 800 to operate the exhaust fan when the HVAC supply fan is in operation. In other embodiments, the control device 214 may simply inform the switch device 800 that the HVAC supply fan is running, and the switch device 800 may then operate the exhaust fan. The process 1000 may then end at process block 1012.

[0114] In some embodiments, a minimum exhaust fan runtime can be used to control the exhaust fan 812 by the control device 214. For example, a user may set and/or adjust the minimum exhaust fan runtime via the user interface 702. For example, the control device 214 can operate the exhaust fan 812 for at least the minimum exhaust fan runtime during a predefined time period, e.g., an hour, a day, a week, etc. If the indoor air quality is determined to be good, the control device 214 can skip the minimum exhaust fan runtime in part or in its entirety to save energy.

[0115] Turning now to FIG. 11, a flow chart illustrating a local exhaust fan control process 1100 is shown, according to some embodiments. The process 1100 may allow for a local controller, such as the switch device 800 to respond to adverse humidity or air quality conditions within a local portion of a building (e.g. room, zone, etc.) that the exhaust fan is installed in. For example, in reference to FIG. 9, the switch device 800 may provide local control of exhaust fan 812 based on the conditions within the first zone 902. While process 1100 is primarily described with reference to switch device 800, the switch device 800 and/or the control device 214 can be configured to perform some and/or all of the process 1100.

[0116] The process may be initiated at process block 1102. At process block 1104, a local air quality is measured. As described above, the local air quality may be associated with a specific location within a building. For example, the first zone 902 of building 900. In one embodiment, one or more sensors, such as sensors 912, may output data related to the local air quality to the switch device 800. For example, the sensors 912 may provide information such as humidity measurements, temperature measurements, carbon dioxide measurements, VOC measurements, or other local air quality measurements. In some embodiments, the local air quality measurements are provided to the switch device 800 for processing.

[0117] At process block 1106 it is determined whether the local air quality is good or bad based on the building air quality measurements. In some embodiments, the switch device 800 determines whether the local air quality is good or bad. The air quality may be determined to be good or bad based on evaluating certain measured air quality values. For example, VOC levels, CO2 levels, pollen levels, particulate levels, humidity, temperature and/or other values may be evaluated to determine whether the air quality is good or bad. These values may be compared against predefined threshold levels, which can provide an indication of whether the air quality average is good or bad. For example, where none of the measured values exceeds the predefined threshold levels, the air quality may be determined to be good.

[0118] In contrast, if one or more of the measured values exceeds a threshold value, the air quality average may be determined to be bad. In some embodiments, a certain number of measured values may need to exceed the predefined thresholds for the air quality to be considered bad. In some embodiments, the various air quality values may be evaluated to generate an air quality "score." The score may be a numerical value (e.g. 1–100), an alphabetical value (e.g. A–F), or other representative value. The score may then be used to determine whether the air quality is good or bad.

[0119] For example, using a numerical value scoring system where zero is the highest air quality score (e.g. best air quality), and one hundred is the lowest air quality score (e.g. worst air quality), a score above fifty may indicate that the air quality average is "bad." As another example, high alphabetical values, e.g., A, may represent the best air quality while a low air quality may be represented by an alphabetical value, e.g., F. If the alphabetical value is above or equal to "C," the local air quality may be good. If the air quality is less than C, the local air quality may be bad. However, it is contemplated that other scores may be used to determine whether the air quality average is good or bad.

[0120] If the local air quality is determined to be bad, the switch device 800 operates the exhaust fan 812 at process block 1108. In some embodiments, the switch device 800 may operate the exhaust fan 812 for a predetermined period of time. For example, the switch device 800 may operate the exhaust fan 812 for five minutes. In other embodiments, the switch device 800 may operate the exhaust fan 812 until the local air quality is no longer bad, or until the exhaust fan 812 operation exceeds a maximum runtime. The process may then end at process block 1110.

[0121] If the air quality is determined to be good at process block 1106, the switch device 800 determines if the local humidity exceeds a predetermined threshold at process block 1112. The local humidity may be affected by having multiple persons in the local area. Where the local area is a bathroom, a shower may increase the humidity of the local area. In some embodiments, the predetermined threshold may by 70%. However, threshold values above 70% or below 70% are also contemplated. If the local humidity level is determined to not exceed the predetermined threshold, the exhaust fan 812 is not operated unless an HVAC system calls for it at process block 1114. For example, the control device 214, as described above, may instruct the switch device 800 to operate the exhaust fan when the HVAC supply fan is in operation. The process may then end at process block 1110. If the local humidity is determined to be high at process block 1112, the exhaust fan 812 may be run at process block 1108 as described above.

[0122] In some embodiments, if the exhaust fan 812 is run by the switch device 800, the exhaust fan 812 may communicate a supply fan run command to the control device 214 to run a supply fan, e.g., a supply fan of the indoor unit 908. In response to receiving the supply fan run command from the switch device 800, the control device 214 can cause the supply fan to run. Running both the exhaust fan 812 by the switch device 800 and the supply fan by the control device 214 may move good air from outside the building 900 to inside the building 900 and bad air from inside the building 900 to outside the building 900. The exhaust fan 812 can cause a negative pressure exhausting air from inside the building 900 to outside the building 900. The supply fan can bring fresh air in from the inlet 920.

Configuration of Exemplary Embodiments

[0123] The construction and arrangement of the systems and methods as shown in the various exemplary embodiments are illustrative only. Although only a few embodiments have been described in detail in this disclosure, many modifications are possible (e.g., variations in sizes, dimensions, structures, shapes and proportions of the various elements, values of parameters, mounting arrangements, use of materials, colors, orientations, etc.). For example, the position of elements may be reversed or otherwise varied and the nature or number of discrete elements or positions may be altered or varied. Accordingly, all such modifications are intended to be included within the scope of the present disclosure. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. Other substitutions, modifications, changes, and omissions may be made in the design, operating conditions and arrangement of the exemplary embodiments without departing from the scope of the present disclosure.

[0124] The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

[0125] Although the figures show a specific order of method steps, the order of the steps may differ from what is depicted. Also two or more steps may be performed concurrently or with partial concurrence. Such variation will depend on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations could be accomplished with standard programming techniques with rule based logic and other logic to accomplish the various connection steps, processing steps, comparison steps and decision steps.

WHAT IS CLAIMED IS:

1. A heating, ventilation, and air conditioning (HVAC) system for controlling air quality of a building space, the system comprising:

an air quality sensor configured to sense the air quality of the building space;

an exhaust fan configured to exhaust air from inside the building space to outside the building space;

a switch device configured to control the exhaust fan to exhaust the air from inside the building space to outside the building space; and

a controller comprising a processing circuit communicably coupled to the switch device, wherein the processing circuit of the controller is configured to:

determine an air quality level of the building space based on the air quality sensed by the air quality sensor;

determine whether the air quality level is less than an air quality threshold; and

cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to a determination that the air quality level is less than the air quality threshold.

2. The system of Claim 1, wherein the processing circuit of the controller is configured to:

cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space for a predefined length of time during a particular time period; and

cause the switch device to not operate the exhaust fan to exhaust air from inside the building space to outside the building space for a total amount of the predefined length of time in response to a determination that the air quality level is greater than the air quality threshold.

3. The system of Claim 1, further comprising a supply fan configured to circulate air within the building space and an air inlet configured to allow air from outside the building space to enter the building space, wherein the supply fan circulating the air within the building space and the exhaust fan exhausting the air from inside the building space to

outside the building space causes the air from outside the building space to enter the building space via the air inlet;

wherein the processing circuit of the controller is configured to cause the supply fan to circulate the air within the building space in response to the determination that the air quality level is below the air quality threshold.

4. The system of claim 1, wherein the processing circuit of the controller is configured to:

determine a runtime of the exhaust fan, wherein the runtime is a length of time that the exhaust fan has run during a particular time period;

determine whether the runtime of the exhaust fan is greater than, equal to, or less than a predefined runtime;

cause the switch device to operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the runtime of the exhaust fan is less than the predefined runtime; and

cause the switch device to not operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is below the air quality threshold and a determination that the runtime of the exhaust fan is greater than or equal to the predefined runtime.

5. The system of claim 1, wherein the processing circuit of the controller is configured to:

receive or determine an outdoor air quality level;

determine whether the outdoor air quality level is less than an outdoor air quality threshold;

cause the switch device to operate the exhaust fan to exhaust air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is greater than the outdoor air quality threshold; and

cause the switch device to not operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is less than the air quality threshold and a determination that the outdoor air quality level is less than the outdoor air quality threshold.

6. The system of claim 1, wherein the air quality level is based on at least one of a humidity level, a temperature level, a carbon dioxide concentration level, and a volatile organic compound (VOC) concentration level, wherein the processing circuit is configured to determine whether the air quality level is less than the air quality threshold by determining that the at least of the humidity level, the temperature level, the carbon dioxide (CO_2) concentration level, and the VOC concentration level is greater than a particular threshold.

7. The system of claim 1, further comprising a plurality of air quality sensors comprising the air quality sensor and one or more other air quality sensors, wherein the plurality of air quality sensors comprise two or more of a humidity sensor, a temperature sensor, a CO_2 sensor, and a VOC sensor.

8. The system of Claim 1, wherein the exhaust fan is configured to exhaust the air from inside the building space to outside the building space causing air outside the building space to enter the building space;

wherein the processing circuit of the controller is configured to:

determine whether the air outside the building space is dry by determining whether an outdoor air temperature (OAT) is less than a predefined OAT threshold; and

cause the switch device to operate the exhaust fan to exhaust the air from inside the building space to outside the building space causing the air outside the building space to enter the building space causing the building space to be dehumidified in response to a determination that the OAT is less than the predefined OAT threshold.

9. The system of Claim 1, wherein the processing circuit of the controller is configured to:

determine whether an OAT is less than a predefined OAT threshold and an indoor air humidity (IAH) level is greater than an IAH setpoint; and

cause the switch device to operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to the determination that the air quality level is below the air quality threshold and a determination that the OAT is less than the predefined OAT threshold and the IAH level is greater than the IAH setpoint.

10. The system of claim 1, wherein the processing circuit of the controller is configured to operate the exhaust fan to exhaust the air from inside the building space to outside the building space in response to one or more heating or cooling devices associated with the building space being in operation to cause the building space to be heated or cooled;

wherein the controller is a thermostat, wherein the processing circuit of the thermostat is configured to control the one or more heating or cooling devices associated with the building space to heat or cool the building space.

11. The system of claim 1, wherein the air quality sensor is located within a sub-portion of the building space and the exhaust fan is located within the sub-portion of the building space, wherein the air quality sensed by the air quality sensors is an air quality associated with the sub-portion of the building space;

wherein the switch device is configured to:

determine a second air quality level associated with the sub-portion of the building space based on the air quality associated with the sub-portion of the building space sensed by the air quality sensor; and

control the sub-portion of the building space by controlling the exhaust fan to exhaust air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the second air quality level.

12. The system of claim 1, further comprising a second air quality sensor configured to sense a second air quality associated with a sub-portion of the building space, wherein the exhaust fan is located within the sub-portion of the building space;

wherein the switch device is configured to:

determine a second air quality level associated with the sub-portion of the building space based on the second air quality sensor; and

control the sub-portion of the building space by controlling the exhaust fan to exhaust air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the second air quality level.

determine whether the second air quality value is below a second air quality threshold; and

control the sub-portion of the building space by controlling the exhaust fan to exhaust the air from inside the sub-portion of the building space to outside the sub-portion of the building space in response to a determination that the second air quality value is below the second air quality threshold.

13. The system of Claim 12, wherein the second air quality sensor is a humidity sensor configured to sense a humidity of the sub-portion of the building space;

wherein the switch device is configured to:

determine a humidity level of the sub-portion of the building space based on the humidity sensed by the humidity sensor; and

control the sub-portion of the building space by controlling the exhaust fan to exhaust the air from inside the sub-portion of the building space to outside the sub-portion of the building space based on the humidity level.

14. The system of Claim 12, further comprising a supply fan configured to supply air from outside the building space to inside the building space;

wherein the switch device is configured to provide an indication to control the supply fan to the controller in response to the determination that the second air quality value is below the second air quality threshold.

15. The system of Claim 14, wherein the processing circuit of the controller is configured to:

receive the indication to control the supply fan from the switch device; and

control the supply fan to supply air from outside the building space to inside the building space in response to receiving the indication to control the supply fan from the control circuit of the switch.

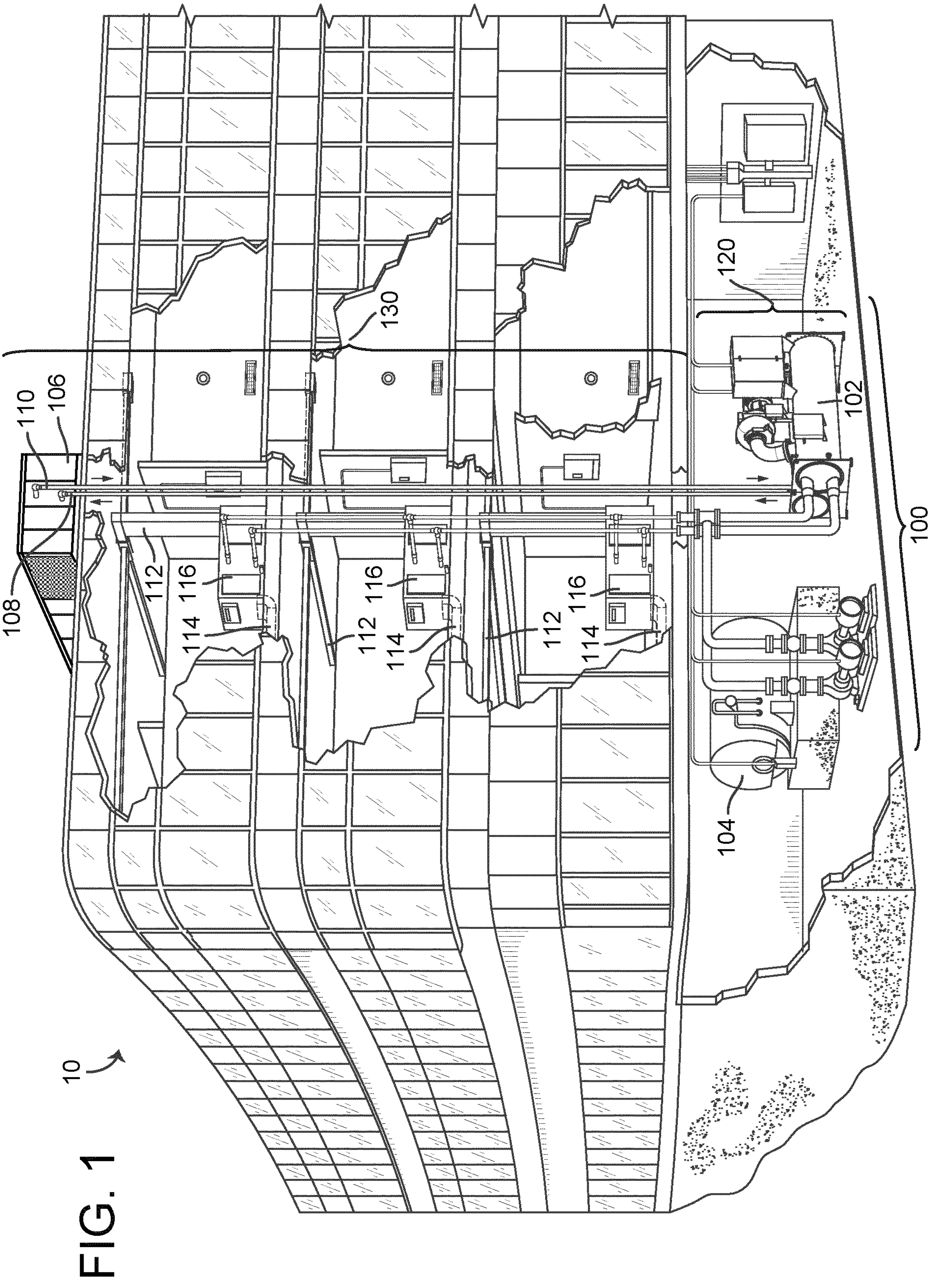
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FIG. 1

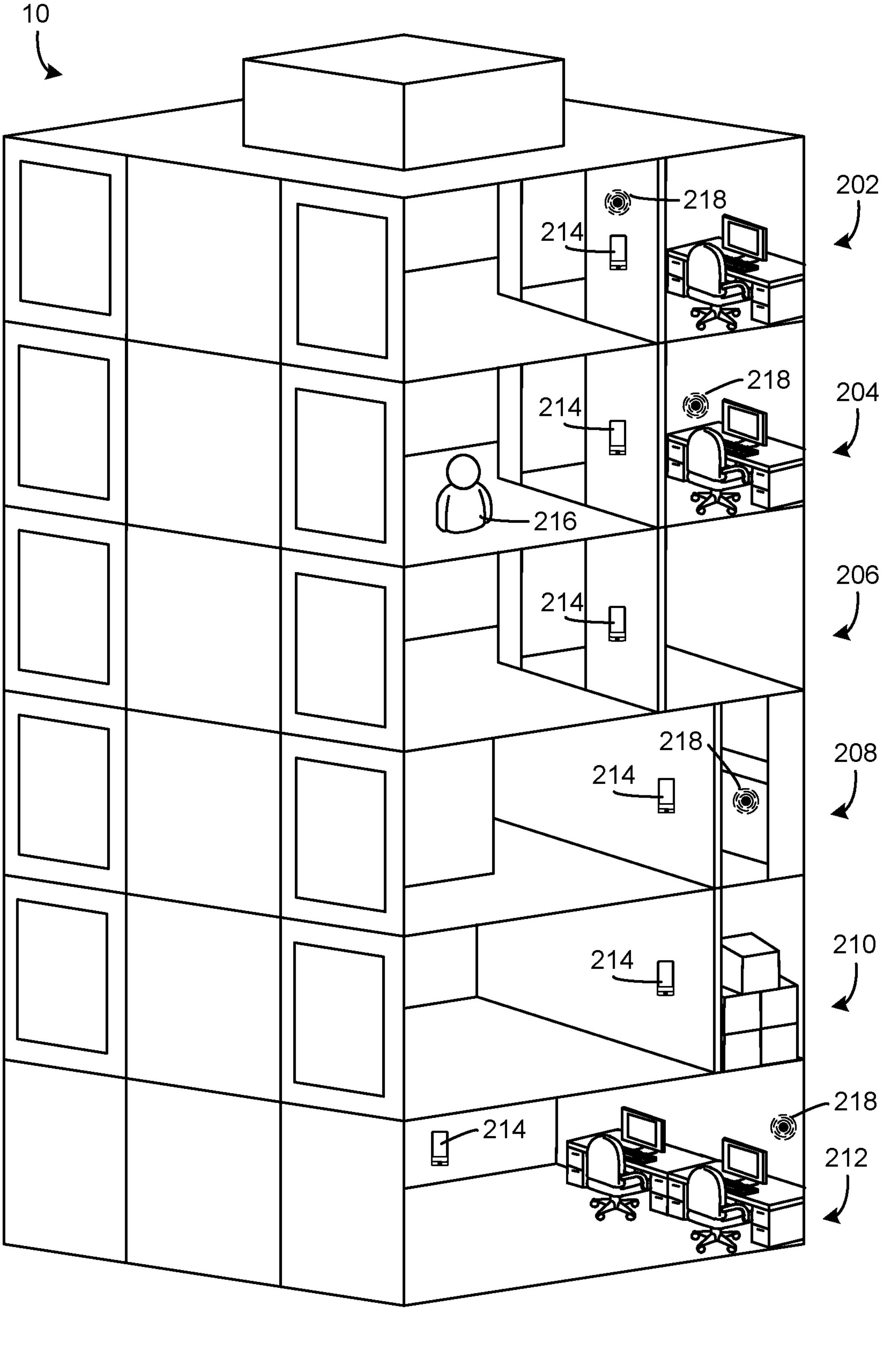
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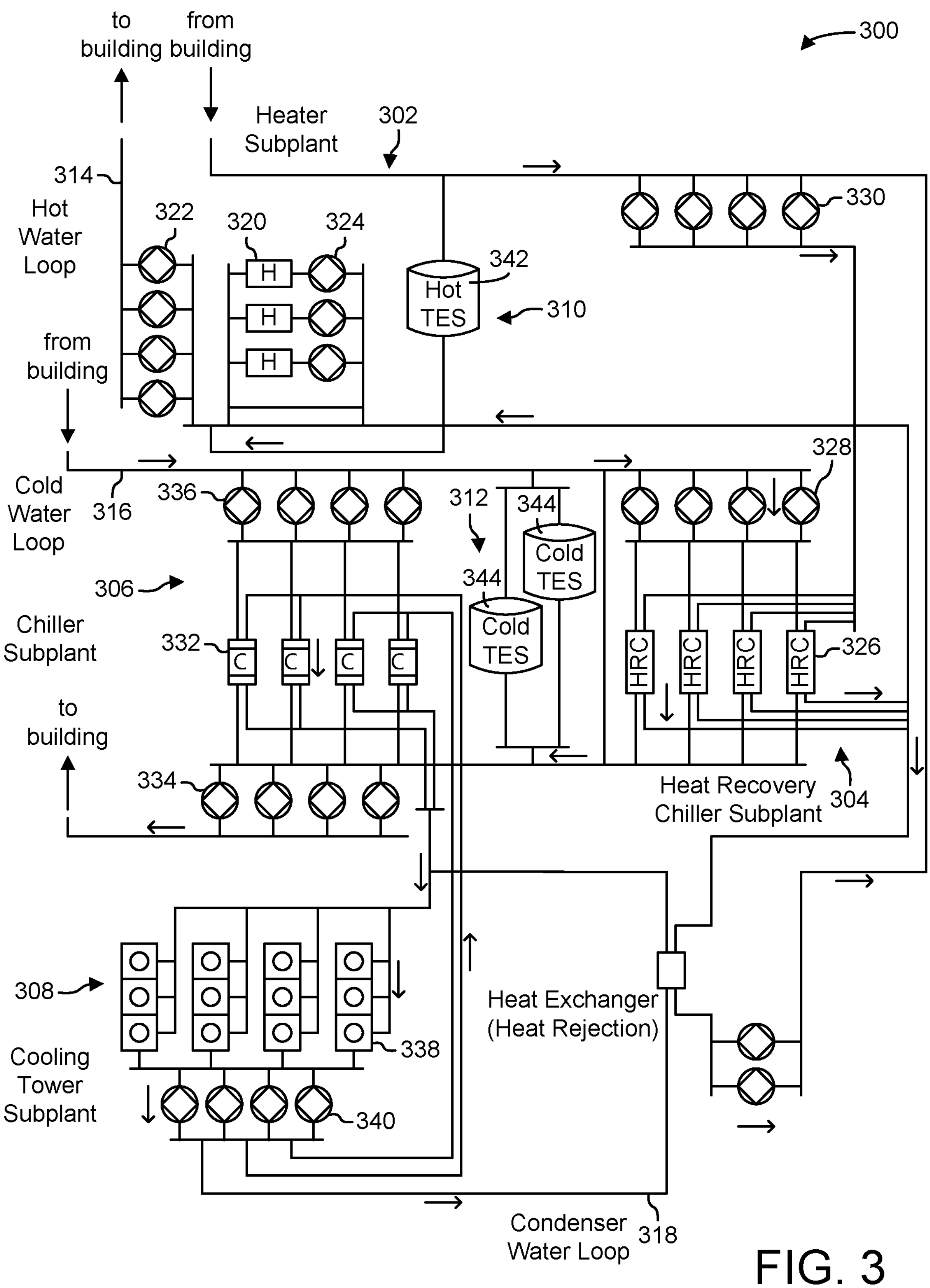
FIG. 2



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Hot Water Loop
322
320
324
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Hot TES
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from building
Cold Water Loop
316
336
312
344
Cold TES
344
Cold TES
328
306
Chiller Subplant
332
C
C
C
C
HRC
HRC
HRC
HRC
326
to building
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Cooling Tower Subplant
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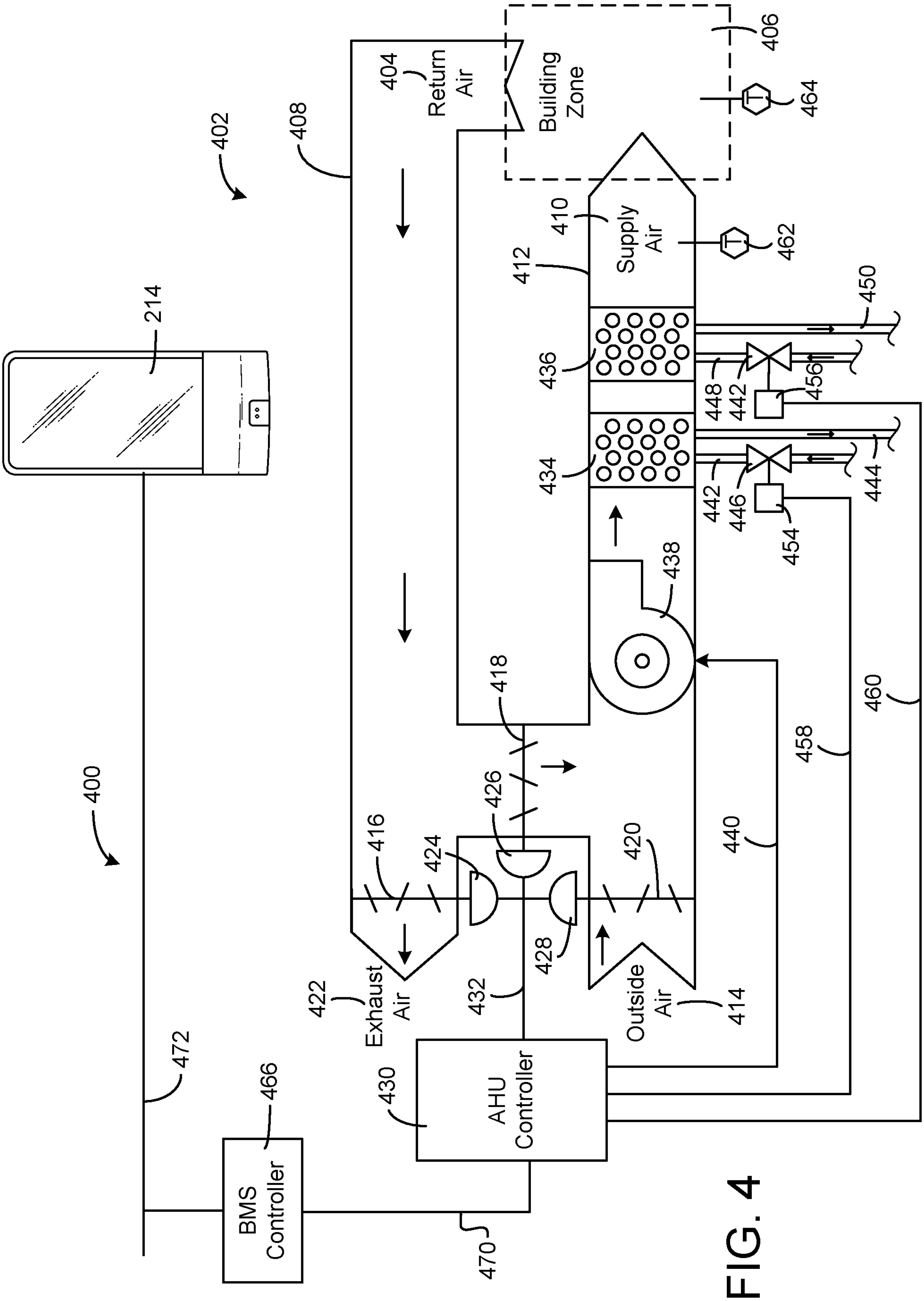
Heat Exchanger (Heat Rejection)
Condenser Water Loop
318

FIG. 3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Building Zone
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Supply Air
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414
Outside Air
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426
428
430
AHU Controller
432
434
436
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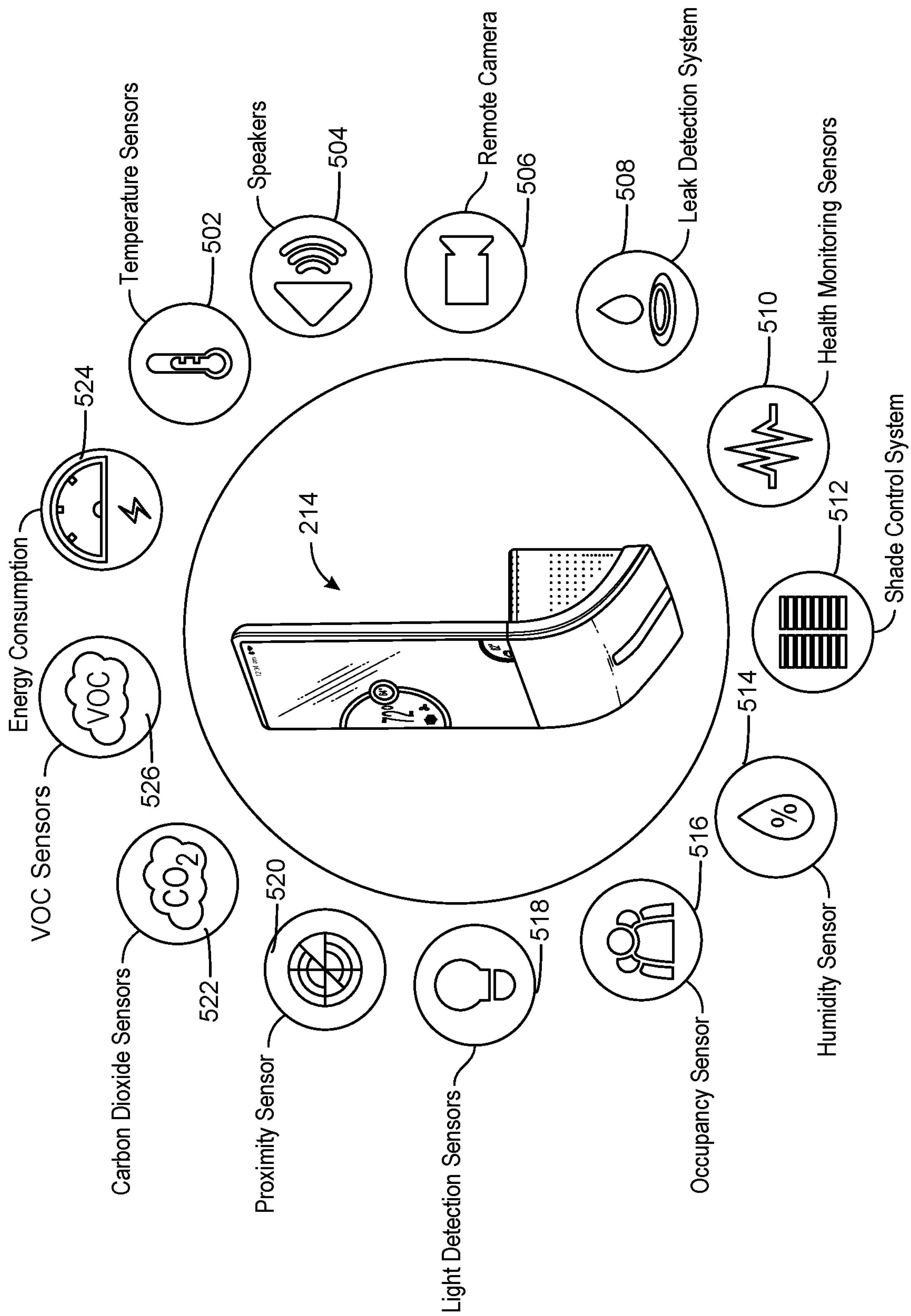
BMS Controller
470
472

FIG. 4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VOC
Energy Consumption
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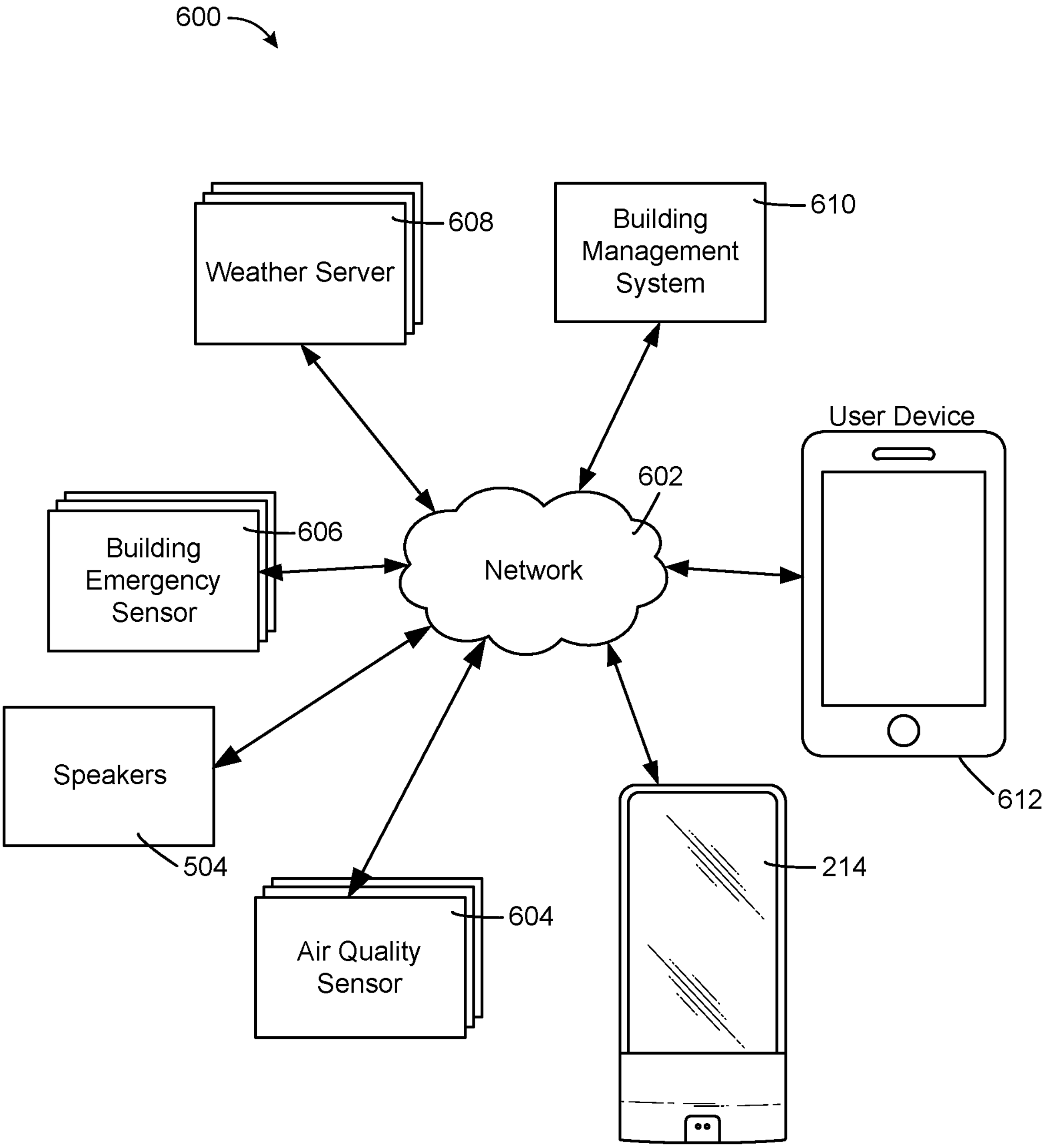
FIG. 5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Weather Server
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Building Management System
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User Device
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Building Emergency Sensor
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Speakers
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Air Quality Sensor
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214
612

FIG. 6

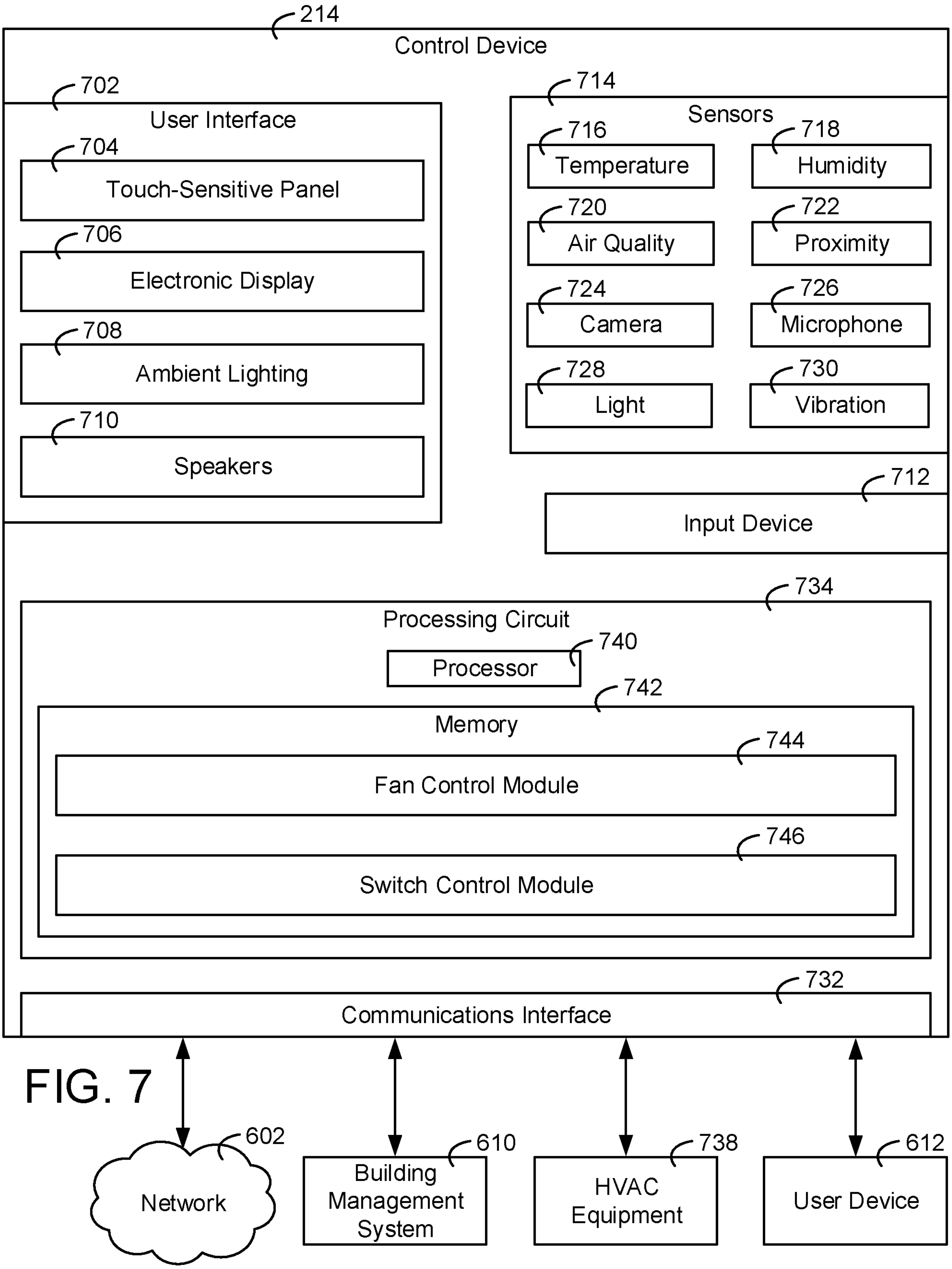

214
Control Device
702
User Interface
704
Touch-Sensitive Panel
706
Electronic Display
708
Ambient Lighting
710
Speakers
714
Sensors
716
Temperature
718
Humidity
720
Air Quality
722
Proximity
724
Camera
726
Microphone
728
Light
730
Vibration
712
Input Device
734
Processing Circuit
740
Processor
742
Memory
744
Fan Control Module
746
Switch Control Module
732
Communications Interface
602
Network
610
Building Management System
738
HVAC Equipment
612
User Device

FIG. 7

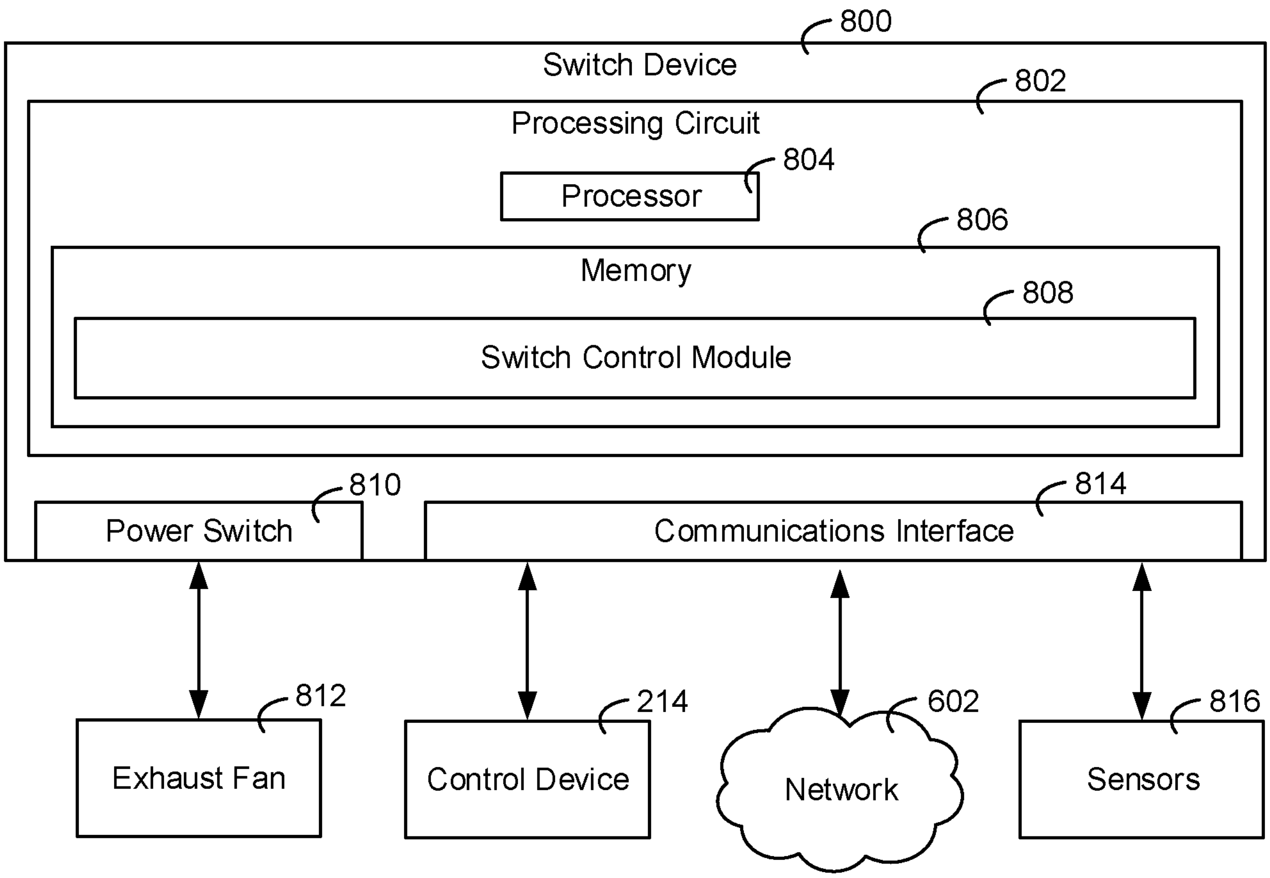

800
Switch Device
802
Processing Circuit
804
Processor
806
Memory
808
Switch Control Module
810
Power Switch
814
Communications Interface
812
Exhaust Fan
214
Control Device
602
Network
816
Sensors

FIG. 8

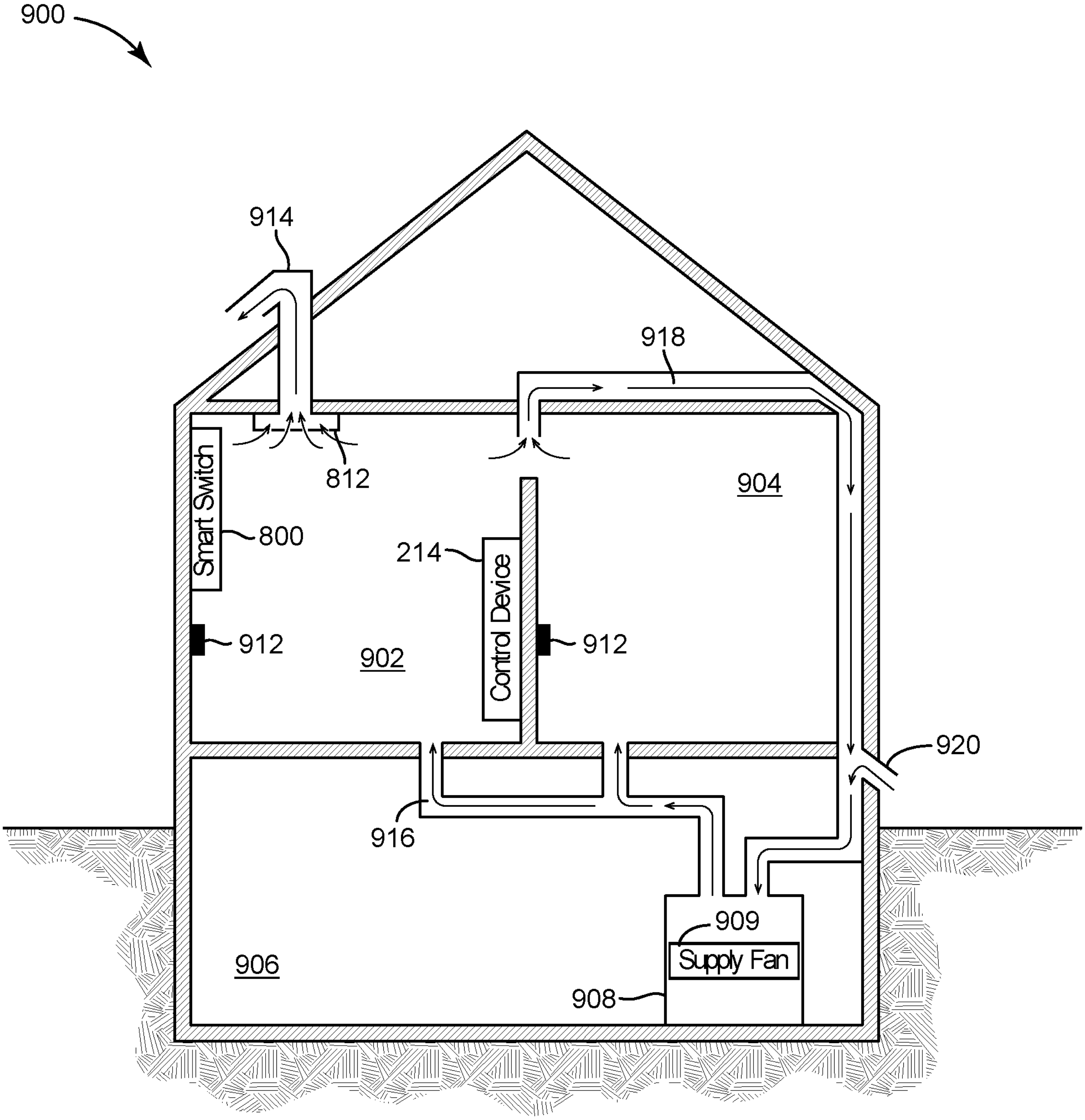
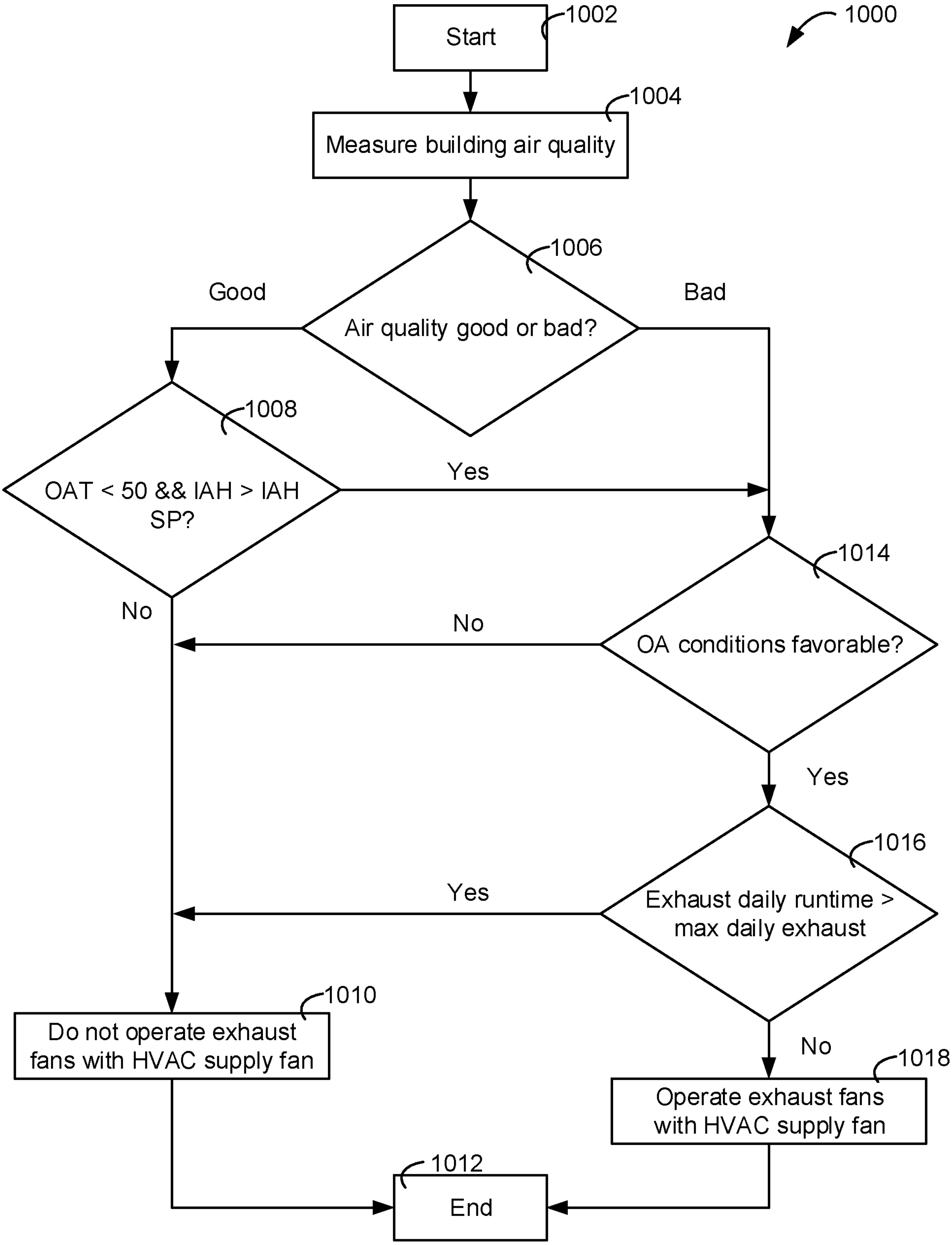

900
914
918
812
904
Smart Switch
800
214
Control Device
912
902
912
920
916
909
Supply Fan
906
908

FIG. 9



1000
Start
1002
Measure building air quality
1004
Air quality good or bad?
1006
Good
Bad
OAT < 50 && IAH > IAH SP?
1008
Yes
No
OA conditions favorable?
1014
No
Yes
Exhaust daily runtime > max daily exhaust
1016
Yes
No
Do not operate exhaust fans with HVAC supply fan
1010
Operate exhaust fans with HVAC supply fan
1018
End
1012

FIG. 10

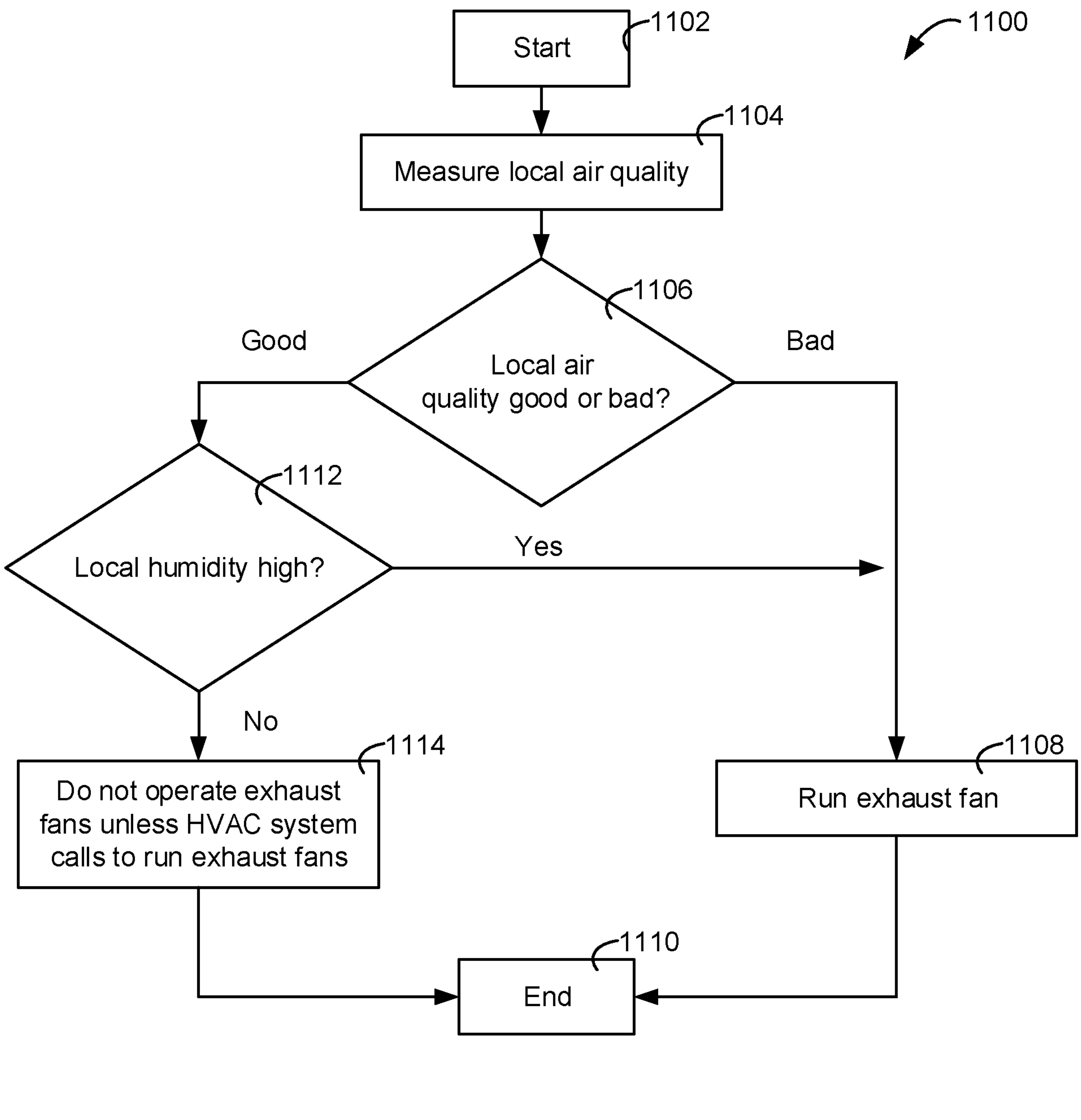

1100
Start
1102
Measure local air quality
1104
Local air quality good or bad?
1106
Good
Bad
Local humidity high?
1112
Yes
No
Do not operate exhaust fans unless HVAC system calls to run exhaust fans
1114
Run exhaust fan
1108
End
1110

FIG. 11