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(54) HVAC CONTROL SYSTEM AND METHOD

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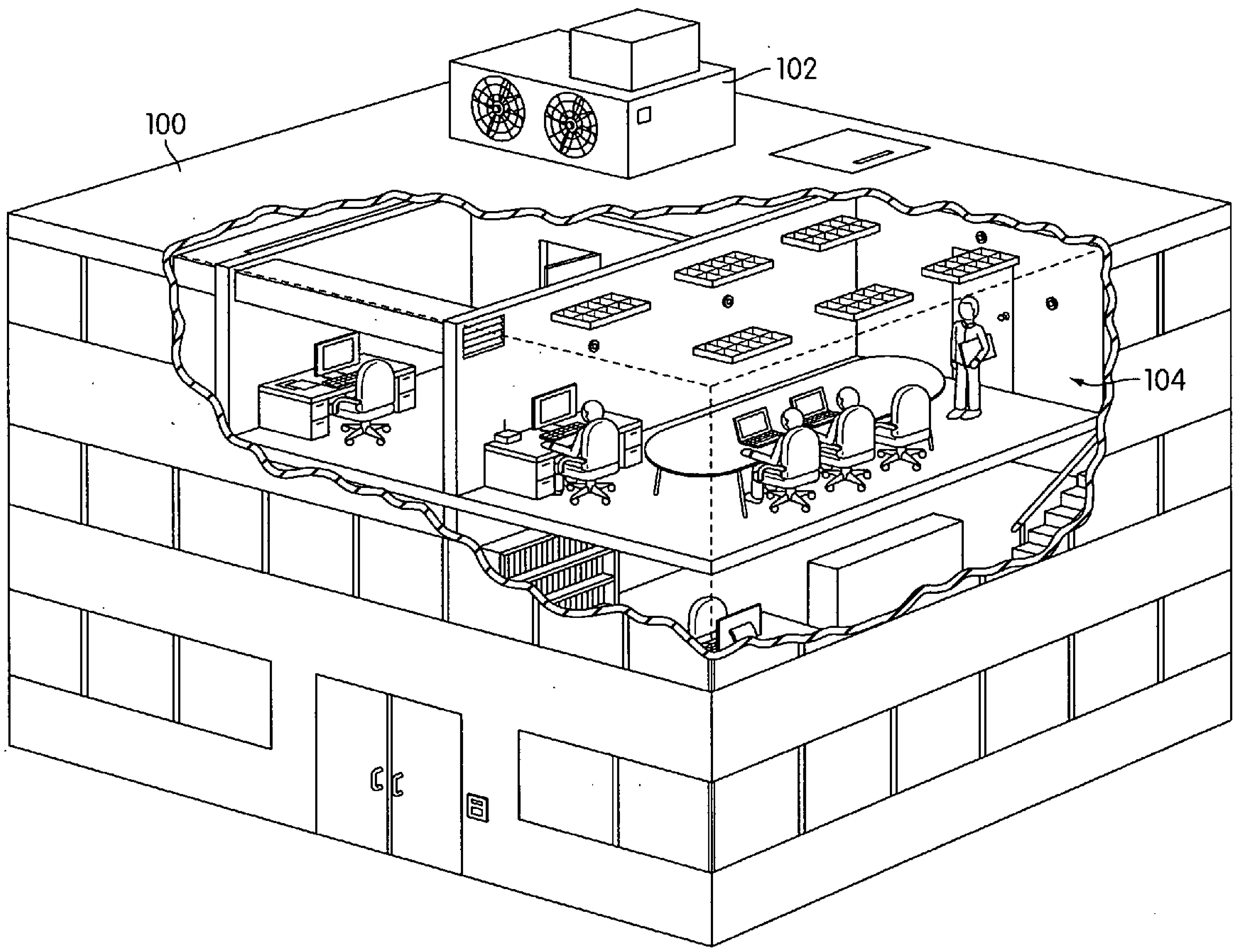
(57) **ABSTRACT**

An HVAC control system configured to control the environment of a building zone includes a means for determining a number of people occupying the building zone and a means for determining properties of other heat transferring objects located within the building zone. The HVAC control system may also include a controller, the controller being configured to compute a projected heat gain in a building zone based on the determined number of people occupying the building zone and the determined properties of the other heat transferring objects located within the building zone. The controller may use the computed projected heat gain to determine a zone ventilation setpoint for the building zone.



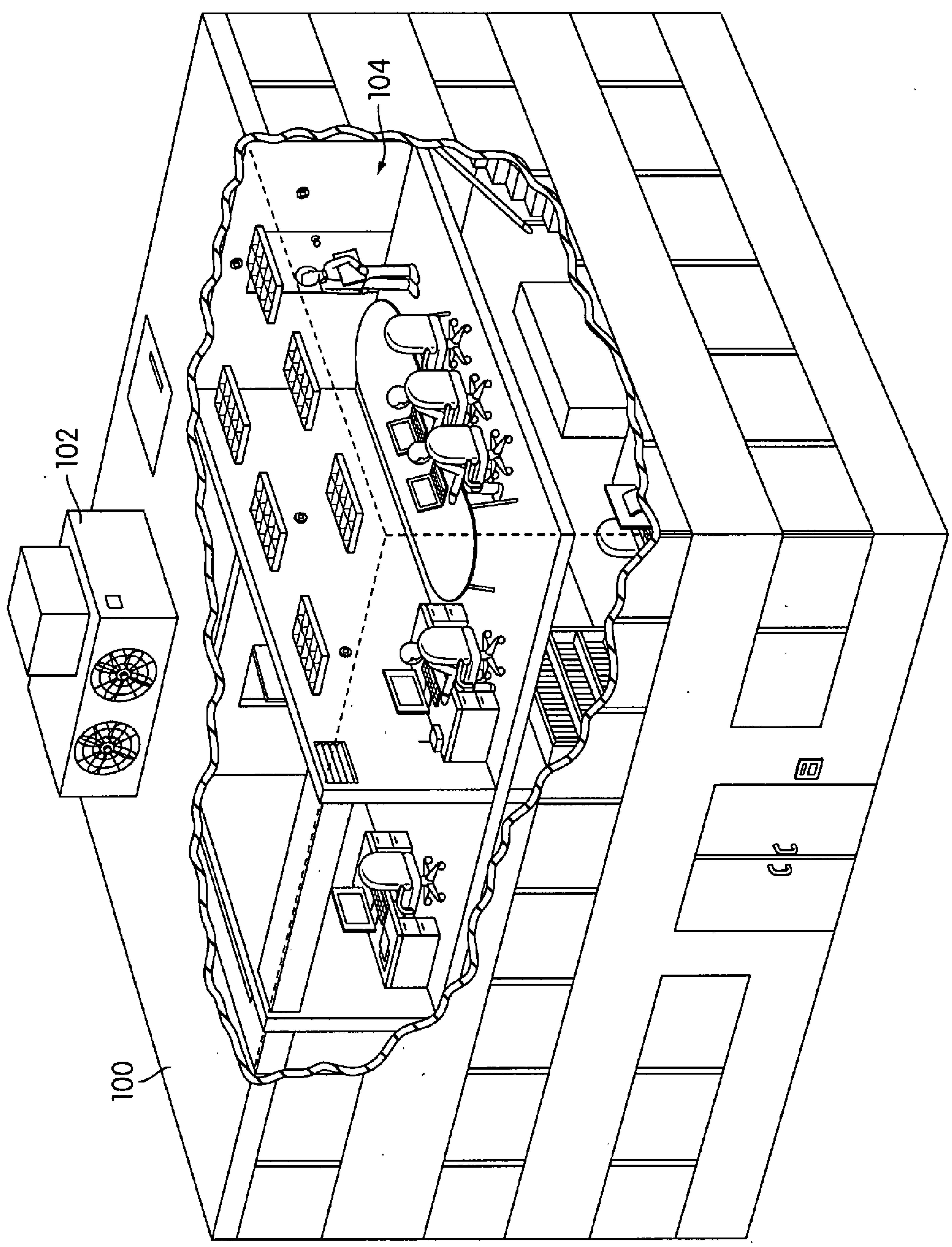


FIG. 1

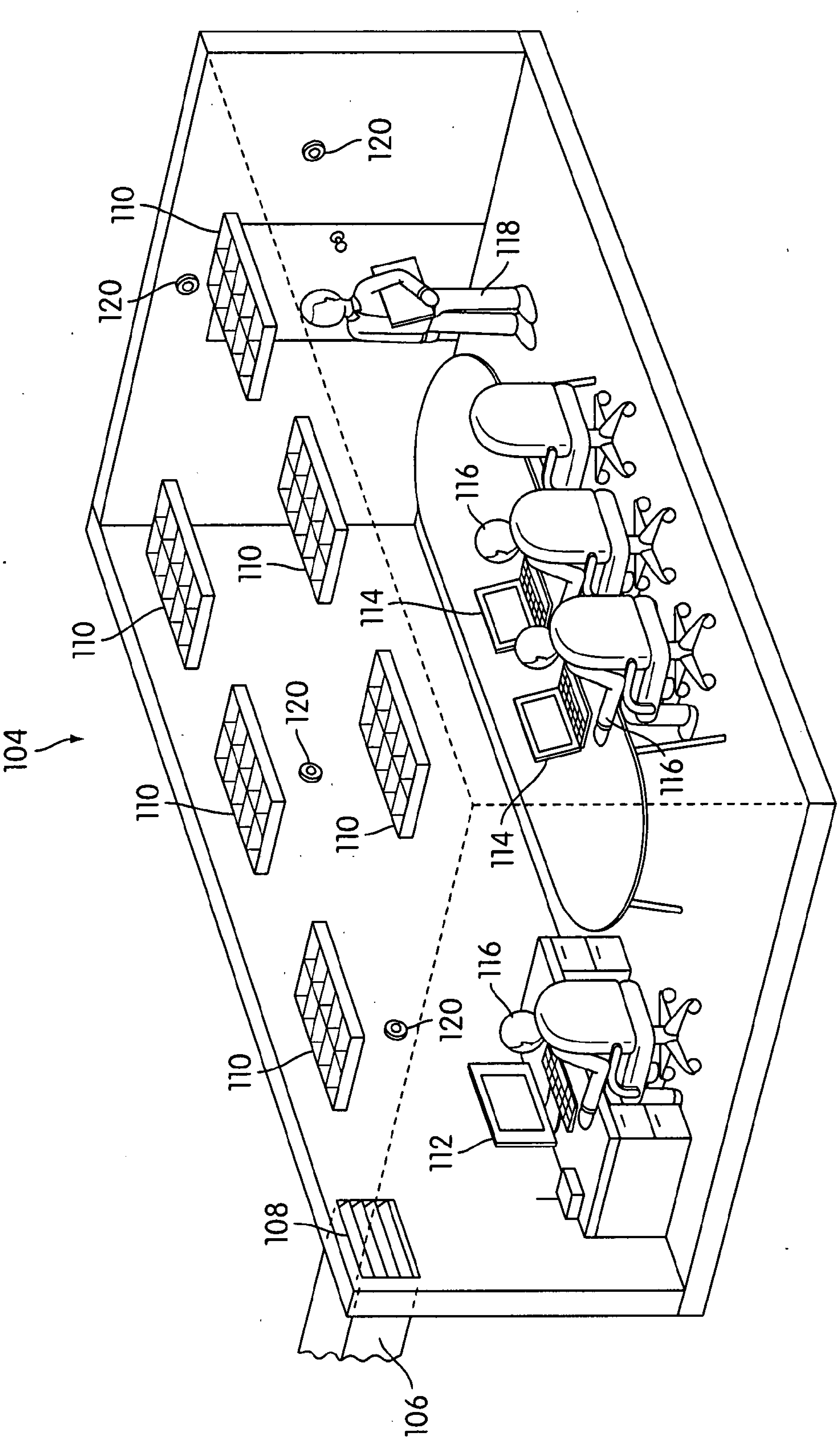


FIG. 2

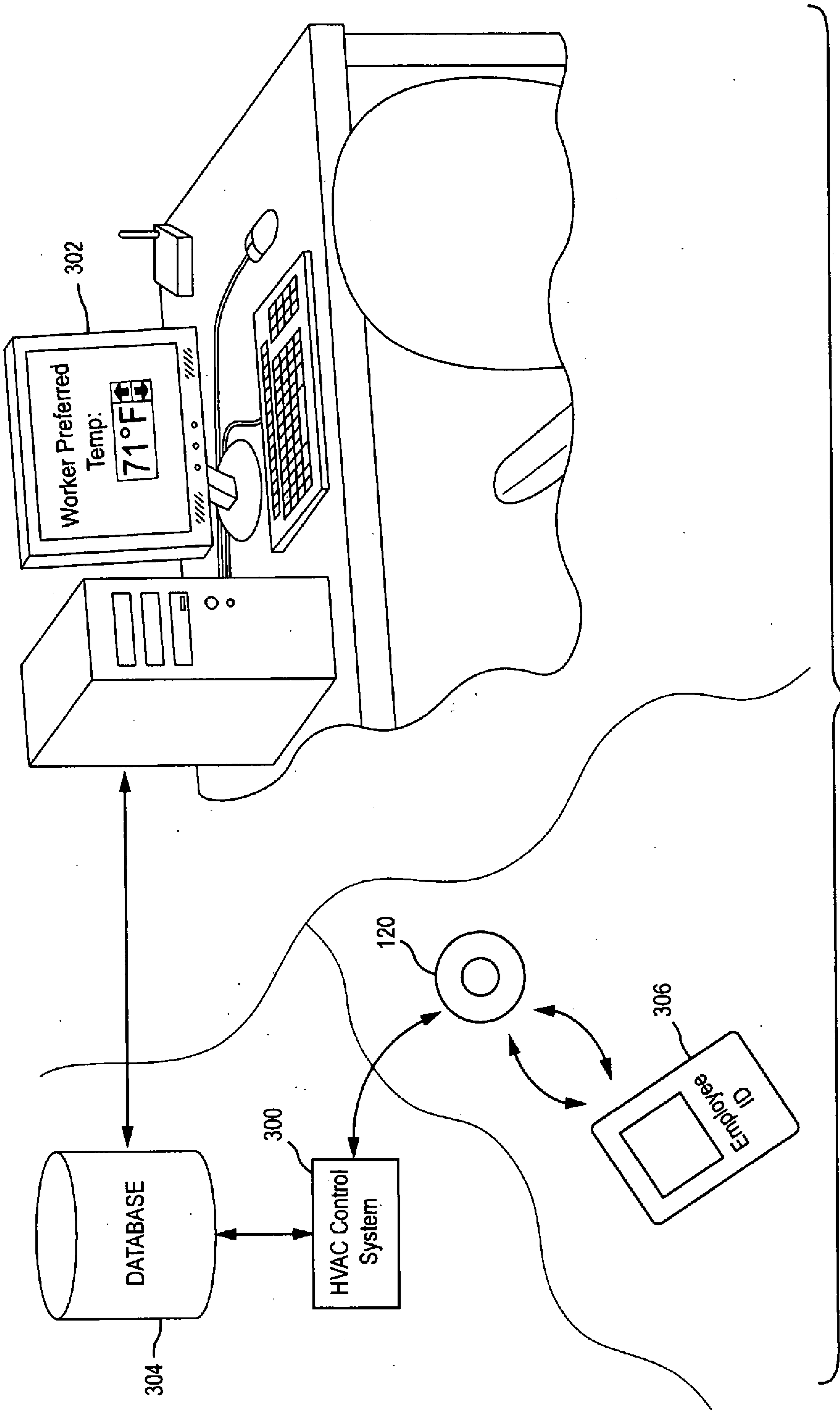

302
Worker Preferred
Temp:
71°F
120
306
Employee
ID
300
HVAC Control
System
DATABASE
304

FIG. 3

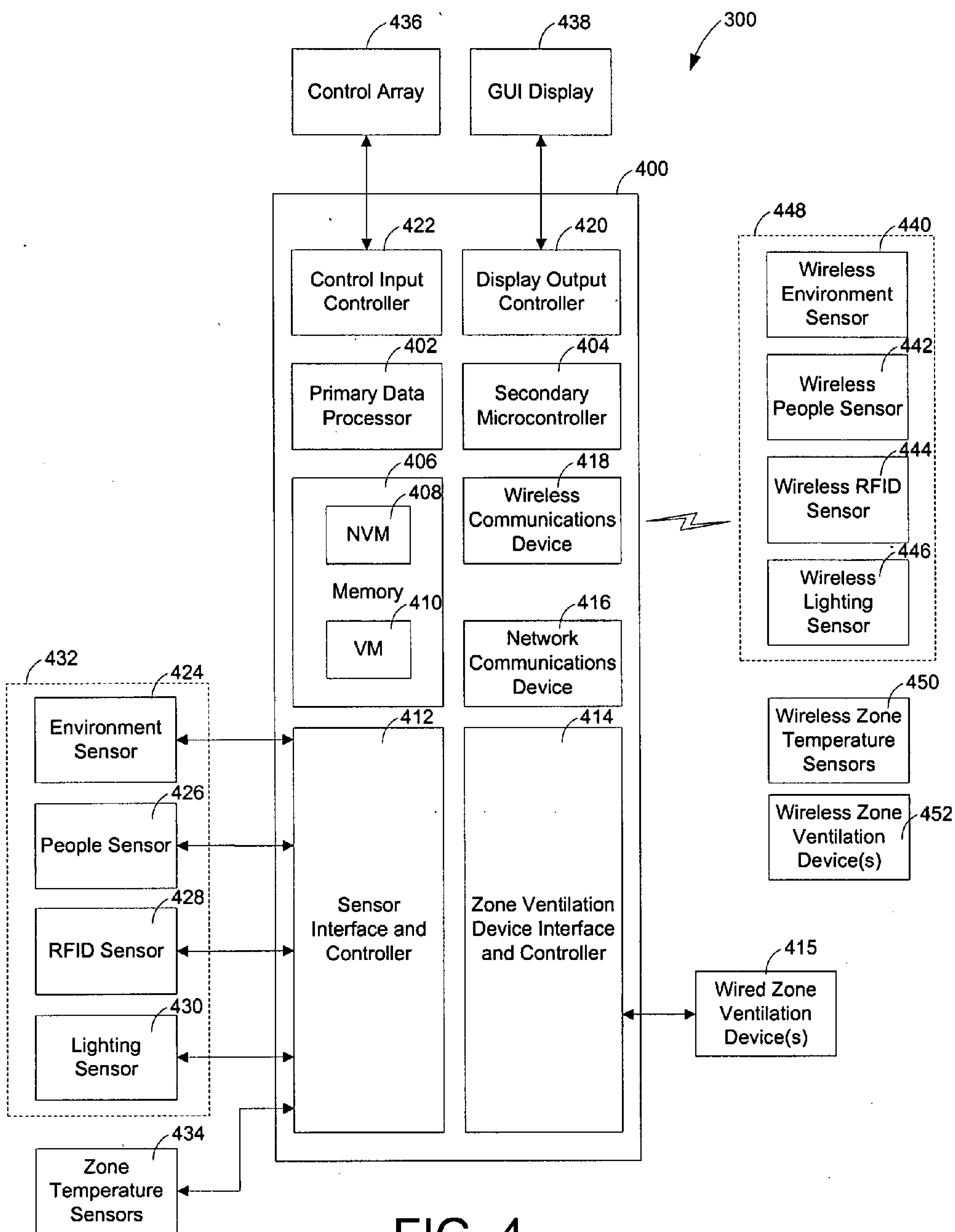

300
436
Control Array
438
GUI Display
400
422
Control Input Controller
420
Display Output Controller
402
Primary Data Processor
404
Secondary Microcontroller
406
408
NVM
Memory
410
VM
418
Wireless Communications Device
416
Network Communications Device
412
Sensor Interface and Controller
414
Zone Ventilation Device Interface and Controller
448
440
Wireless Environment Sensor
442
Wireless People Sensor
444
Wireless RFID Sensor
446
Wireless Lighting Sensor
450
Wireless Zone Temperature Sensors
452
Wireless Zone Ventilation Device(s)
415
Wired Zone Ventilation Device(s)
432
424
Environment Sensor
426
People Sensor
428
RFID Sensor
430
Lighting Sensor
434
Zone Temperature Sensors

FIG. 4

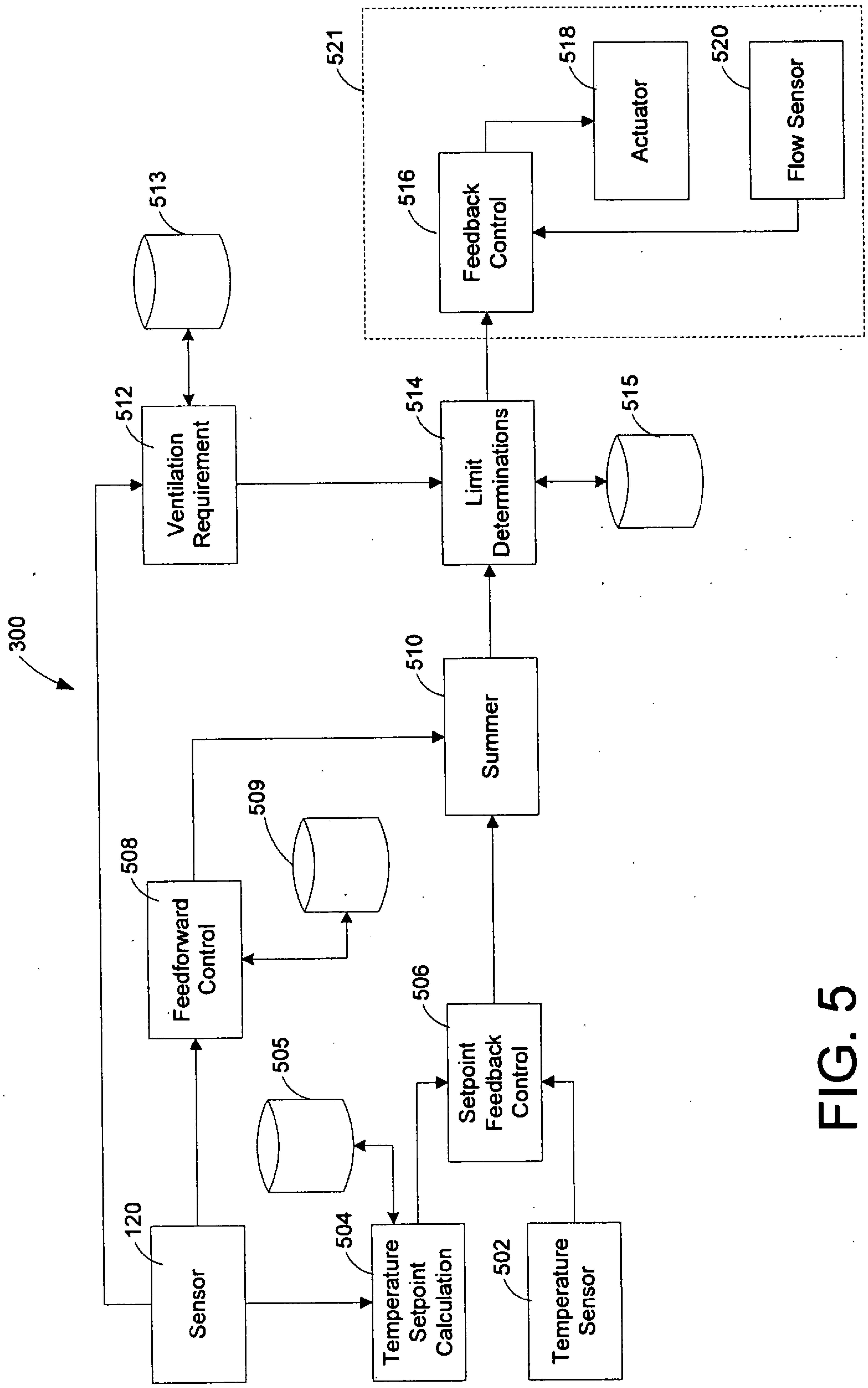
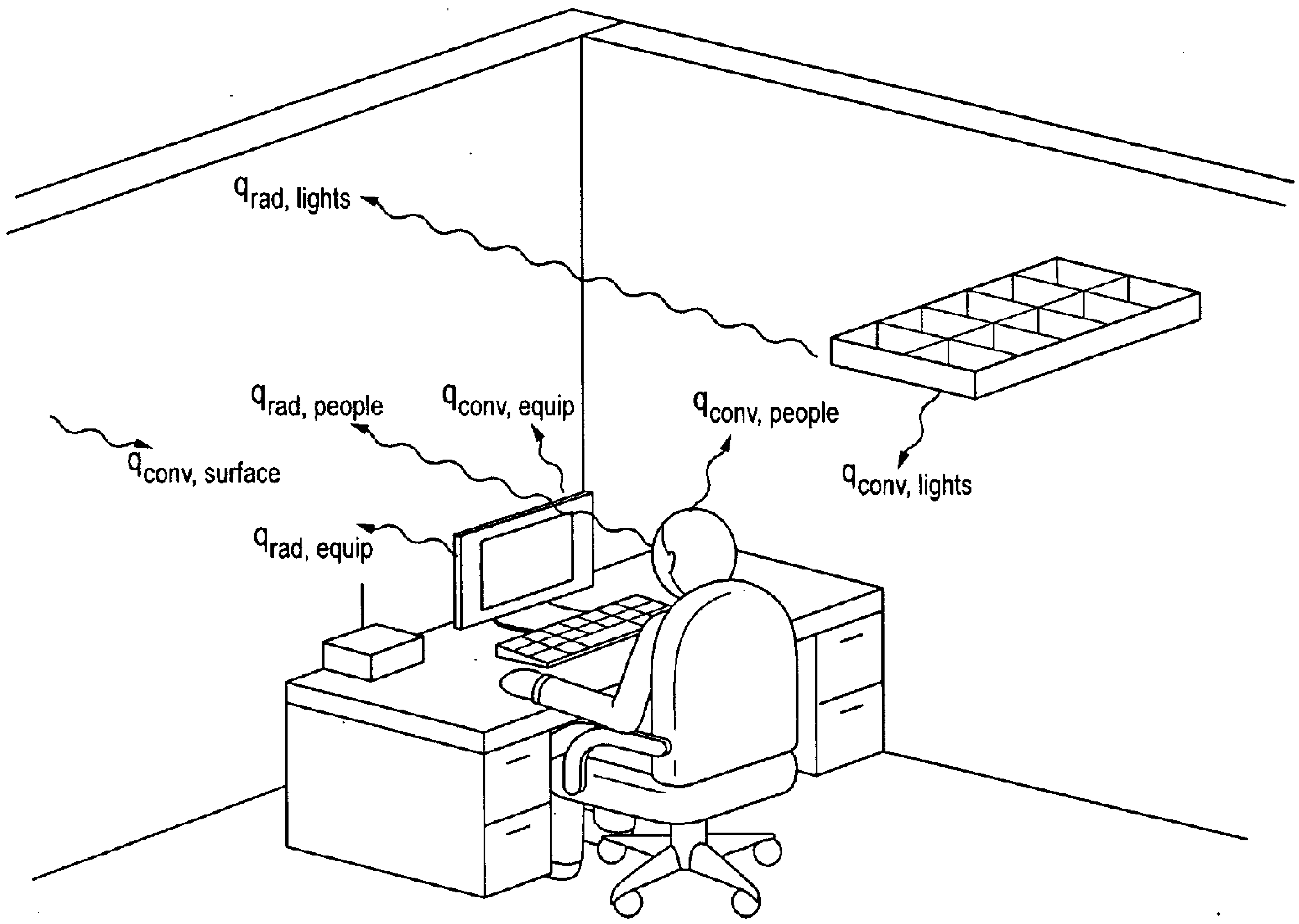
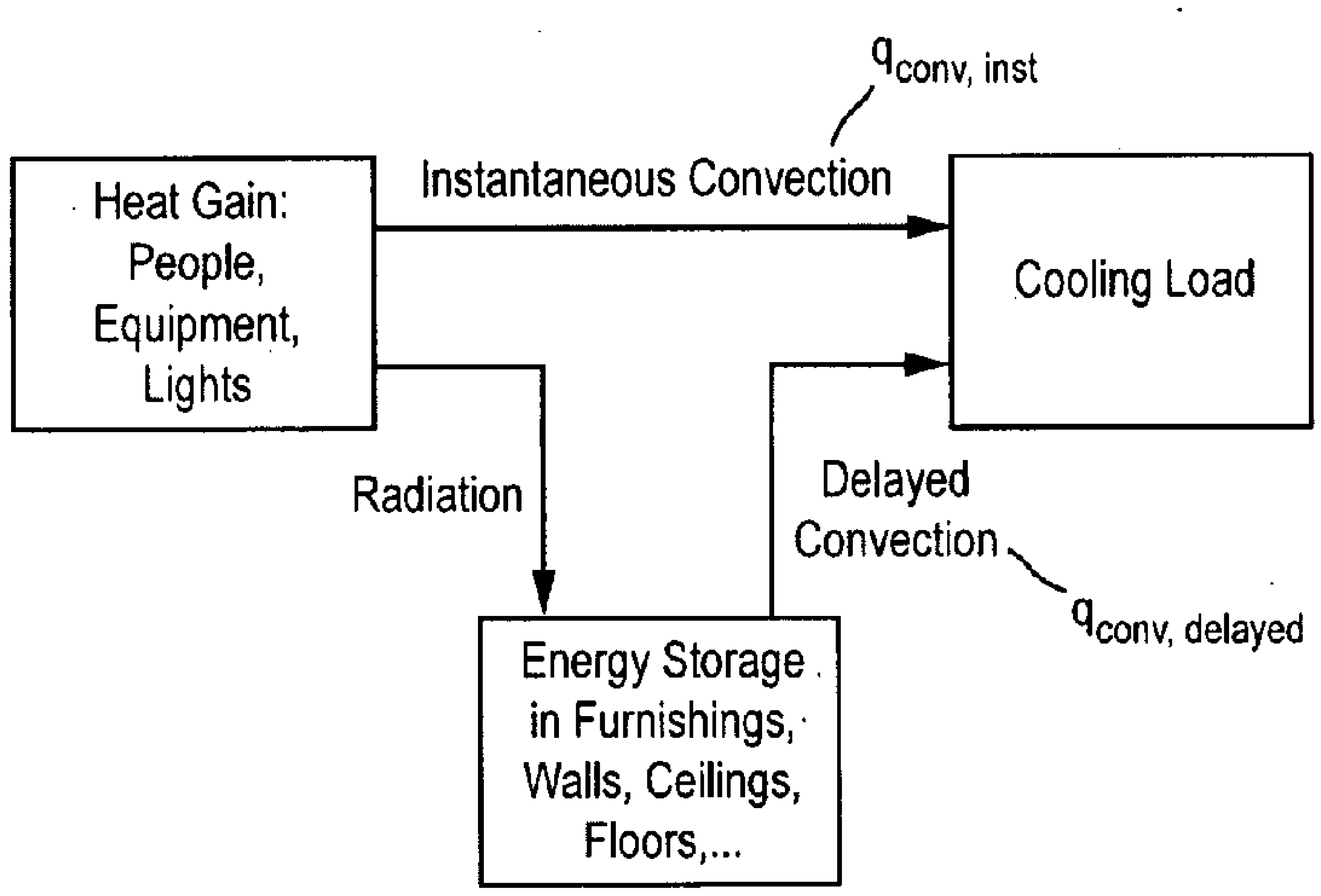

300
120
Sensor
502
Temperature Sensor
504
Temperature Setpoint Calculation
505
506
Setpoint Feedback Control
508
Feedforward Control
509
510
Summer
512
Ventilation Requirement
513
514
Limit Determinations
515
521
516
Feedback Control
518
Actuator
520
Flow Sensor

FIG. 5



$q_{rad, lights}$
$q_{rad, people}$
$q_{conv, equip}$
$q_{conv, people}$
$q_{conv, surface}$
$q_{rad, equip}$
$q_{conv, lights}$

FIG. 6A



$q_{conv, inst}$
Heat Gain: People, Equipment, Lights
Instantaneous Convection
Cooling Load
Radiation
Delayed Convection
$q_{conv, delayed}$
Energy Storage in Furnishings, Walls, Ceilings, Floors,...

FIG. 6B

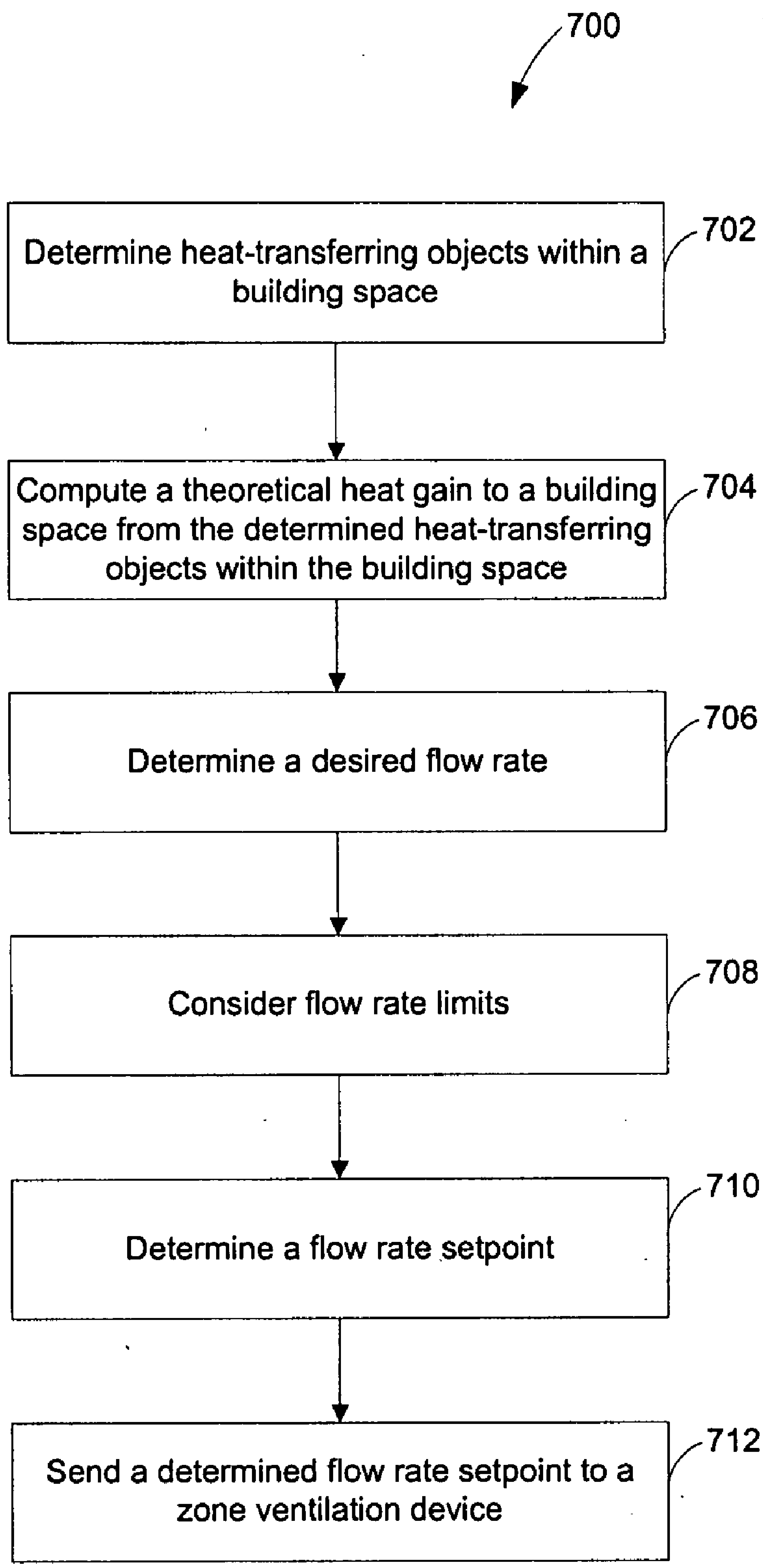

700
Determine heat-transferring objects within a building space
702
Compute a theoretical heat gain to a building space from the determined heat-transferring objects within the building space
704
Determine a desired flow rate
706
Consider flow rate limits
708
Determine a flow rate setpoint
710
Send a determined flow rate setpoint to a zone ventilation device
712

FIG. 7

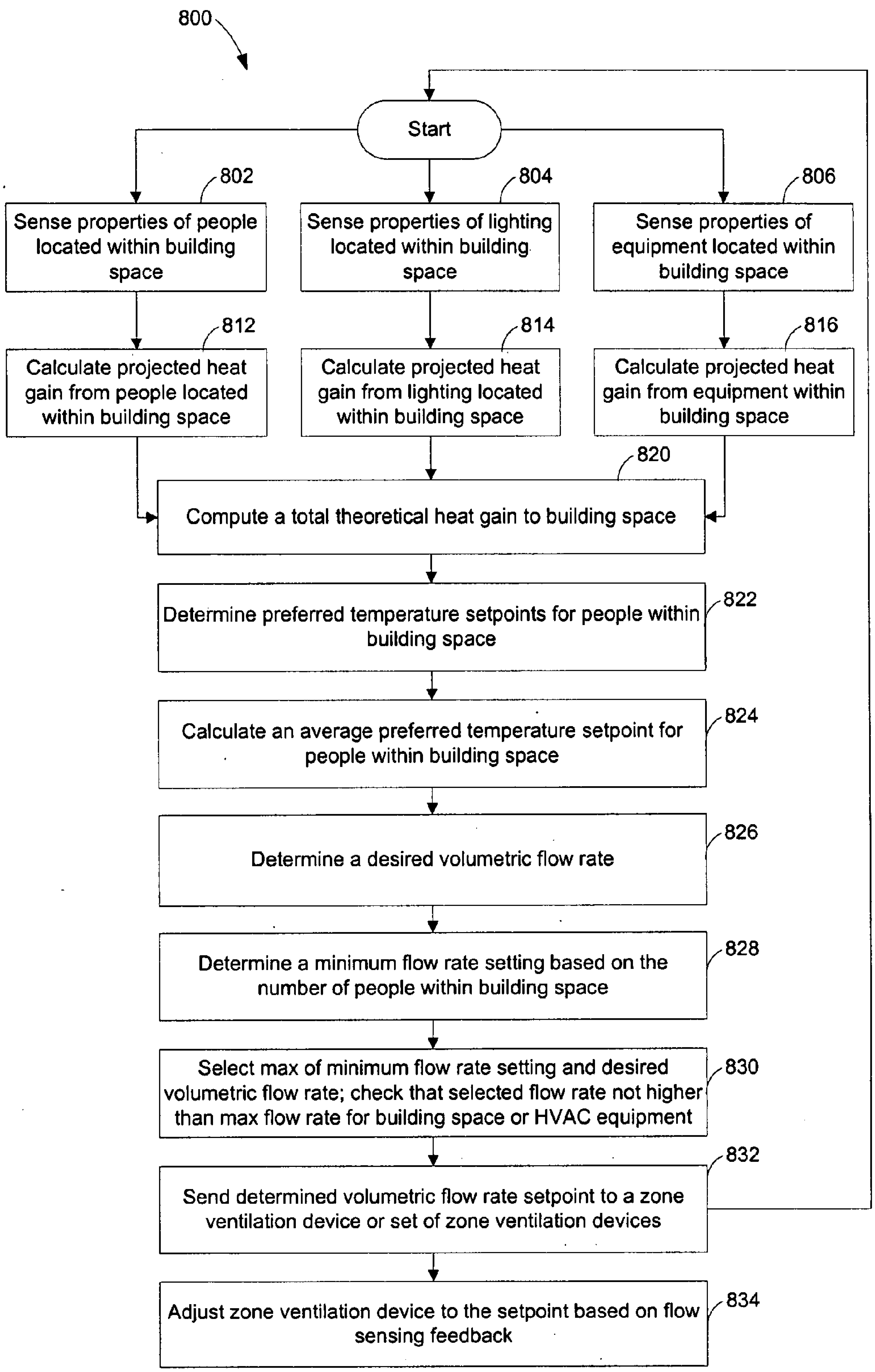

800
Start
802
Sense properties of people located within building space
804
Sense properties of lighting located within building space
806
Sense properties of equipment located within building space
812
Calculate projected heat gain from people located within building space
814
Calculate projected heat gain from lighting located within building space
816
Calculate projected heat gain from equipment within building space
820
Compute a total theoretical heat gain to building space
822
Determine preferred temperature setpoints for people within building space
824
Calculate an average preferred temperature setpoint for people within building space
826
Determine a desired volumetric flow rate
828
Determine a minimum flow rate setting based on the number of people within building space
830
Select max of minimum flow rate setting and desired volumetric flow rate; check that selected flow rate not higher than max flow rate for building space or HVAC equipment
832
Send determined volumetric flow rate setpoint to a zone ventilation device or set of zone ventilation devices
834
Adjust zone ventilation device to the setpoint based on flow sensing feedback

FIG. 8

HVAC CONTROL SYSTEM AND METHOD

BACKGROUND

[0001] The present application relates generally to the field of heating, ventilation, and air conditioning systems. More specifically, the present application relates to control systems and methods for heating, ventilation, and air conditioning systems.

[0002] Building services systems are often employed in office buildings, schools, manufacturing facilities, and the like, for controlling the internal environment of the facility. Building services systems may be employed to control temperature, air flow, humidity, lighting, energy, boilers, chillers, power, security, fluid flow, and similar building systems relating to the environment of the building. Some building services systems are specifically heating, ventilation, and/or air conditioning ("HVAC") systems. HVAC systems commonly seek to provide thermal comfort, acceptable air quality, ventilation, and controlled pressure relationships to building zones. HVAC systems typically include an HVAC control system and one or more ventilation devices such as air handling units, variable air volume boxes.

[0003] An air handling unit is a device typically at the root of commercial, industrial, and institutional HVAC systems. Air handling units typically include a blower, one or more heating and/or cooling elements, air filters, sound attenuators, and dampers. Air handling units typically connect to ductwork that distributes or supplies air throughout the building and returns the air back to the air handling unit. An air handling unit may be entirely enclosed by a single housing or frame, or it may be located in a dispersed fashion include a variety of components in contact with airflow. For example, an air handling unit may be considered a primary unit having a blower as well as a remote unit including a zone air handling unit and the unit's accompanying circuitry (e.g., fan, flow sensor, etc.). Air handling units may use one hundred percent outside air, one hundred percent recirculated air, or some mix of outside air and recirculated air. The blower of an air handling unit may operate at a single speed or operate at a variety of speeds to allow or control a variety of air flow rates. If an air handling unit is used to supply heat, the air handler may contain or be used with a fuel-burning heater, electrical heater, coils that are heated using circulated water or steam with the heat provided by a boiler, or any other heat creating apparatus. If an air handling unit is used for cooling, the unit may contain or be used with a refrigeration evaporator, water evaporator, coils cooled by chilled water provided by a chiller, or any other air cooling apparatus. Air handling units may include a variety of structures that may be used to filter the air, including pleated media, electrostatic filters, high efficiency particulate air filters, gas-phase units, ultraviolet air treatment units, or any other air filtering structure. Humidification of the air may be provided via the air handling unit and/or coupled humidifier units.

[0004] HVAC systems using air handling devices may also include any number of additional devices to supply controlled air flows to a building or building zone. While air flow may be varied using a single air handling unit capable of being controllably operated at variable speeds, variable air volume terminal units (i.e., variable air volume boxes, variable air volume units, etc.) are often used to control air flow rate at a building zone or building room level. Variable air volume units are typically connected to central HVAC control systems and/or local HVAC control systems. In many HVAC systems, the air flow rate is varied not only to control the distribution of air, but also to control temperature. For example, some systems use supply air of a relatively constant temperature, or cooled to a relatively constant temperature, (e.g., 50-60 degrees, etc.) and modify air flow rates provided to building zones to meet desired temperature setpoints. Variable air volume units may include a damper for regulating the amount of air flow provided to the building zone the variable air volume serves. A variable air volume unit damper may be coupled to an actuator which may position the damper so that appropriate air flow is provided to the building zone.

[0005] In modem systems, an HVAC control system may provide a variety of inputs to and accept a variety of outputs from variable air volume unit components (e.g., dampers, actuators, local VAV control circuits, flow sensors, temperature sensors, etc.). Using these inputs and outputs, an HVAC control system may control the heating, ventilation, and air conditioning provided to specific building zones. For example, an HVAC control system may receive inputs from sensors related to an air flow rate and temperature of a building zone and use a damper and its accompanying actuator to appropriately position the damper such that a desired air flow rate is provided to the building zone.

[0006] Typical HVAC control systems use a plurality of sensors to monitor HVAC variables to be controlled, such as temperature, humidity, or air flow rate. An HVAC control system may typically regulate these controlled variables by considering a feedback signal generated by a sensor disposed to monitor the controlled variable. For example, an HVAC control system may allow or generate more air flow into a building zone based on a sensed temperature level. If a sensed temperature level is at 85 degrees Fahrenheit, the HVAC control system may allow or generate more supply air flow into a building to reach a desired lower temperature target or setpoint. If a temperature setpoint is 72 degrees Fahrenheit, for example, the HVAC control system may determine that supply air flow rate should be near maximum to rapidly make up the thirteen degree difference. In a feedback-based system, the resulting changed temperature is periodically looped back into the HVAC control system via inputs from temperature sensors, and further adjustments may be made based on the changed data. This sort of process may be looped or repeated in a near infinite manner whereby the HVAC control system may constantly be adjusting variables of operation based on feedback from sensors.

[0007] HVAC systems have conventionally been primarily feedback-based systems. The majority of the HVAC setpoints are often rather static, often set manually, and typical HVAC control systems use feedback loops to maintain building zone variables such as temperature near the static setpoints of the system. These typical HVAC control systems may suffer from a number of challenges and lead to a number of building management issues such as inefficient HVAC operation, uncomfortable building zones, higher maintenance or operation costs, and shorter equipment lifespans. For example, some typical feedback-dominated systems may suffer from a condition known as "hunting" wherein an HVAC system may oscillate an output around a setpoint. This oscillation may happen when, for example, a number of people enter a building zone and have been in the room long enough to heat the room above the setpoint temperature range. In a feedback-dominated HVAC system, the HVAC controller will not command additional air flow to the building zone until the people have already heated the room beyond a certain setpoint range.

Once the HVAC system senses this temperature change, it may begin providing a greater cool air flow rate to the building zone than the system was previously providing. In some cases, if the building zone has heated relatively rapidly from the people, equipment, and lighting of the zone, the HVAC system may have to substantially increase the air flow rate. It is undesirable to substantially increase air flow rate and/or otherwise attempt to substantially change temperature of a building zone because these substantial changes may result in "overshoots" wherein the HVAC system misses a setpoint target and cools or heats the building zone too much, for example. When an overshoot occurs, an HVAC system may attempt to correct for the overshoot, which may result in a repeat effect, causing the condition of hunting or oscillation. During this process, the system may expend more energy than is desirable and may result in periods of discomfort for room occupants.

[0008] In addition to temperature control, HVAC control systems are used for building ventilation. Ventilation may be described as the movement of air to the inside of a building from the outside of a building. Ventilation air is important for providing acceptable indoor air quality to people. Ventilation air may dilute and/or remove airborne pollutants such as volatile organic compounds (VOCs) and respirable suspended particles (RSPs). The rate of ventilation air required is often expressed by volumetric flow rate of supply air (e.g., outside air) being introduced into a building zone.

[0009] It would be desirable to provide an HVAC control system and method that takes into account heat gains from people and/or electrical equipment. It would further be desirable to improve air quality by ensuring proper ventilation. It would further be desirable to enable users to reduce energy consumption by varying the minimum ventilation given the number of occupants in a zone. It would further be desirable to improve occupant comfort by reducing the size and number of temperature errors throughout the day. It would further be desirable to reduce occupant discomfort by calculating a setpoint temperature for a zone based on occupants' preferences. It would further be desirable to improve temperature control for a room because heat gains from people, equipment, and lights are compensated for at the time convective heat gains enter the zone.

[0010] It would be desirable to provide a system and/or method that satisfies one or more of these needs or provides other advantageous features. Other features and advantages will be made apparent from the present specification. The teachings disclosed extend to those embodiments that fall within the scope of the claims, regardless of whether they accomplish one or more of the aforementioned needs.

SUMMARY

[0011] One embodiment of the application relates to an HVAC control system configured to control the environment of a building zone. The HVAC control system includes a means for determining a number of people occupying the building zone and a means for determining properties of other heat transferring objects located within the building zone. The HVAC control system may also include a controller, the controller being configured to compute a projected heat gain in a building zone based on the determined number of people occupying the building zone and the determined properties of the other heat transferring objects located within the building zone. The controller may use the computed projected heat gain to determine a zone ventilation setpoint for the building zone.

[0012] Another embodiment of the application relates to a method of providing HVAC control to a zone using an HVAC control system, including determining a desired volumetric flow rate, selecting a volumetric flow rate setpoint, and sending the selected volumetric flow rate setpoint to a zone ventilation device. Determining a desired volumetric flow rate includes computing a projected convective heat gain to the zone from people and other heat transferring objects located within the building zone and considering at least one air property.

[0013] Yet another embodiment relates to a controller configured to control the environment of a building zone. The controller may include a data processor. The controller may also include a zone ventilation device interface communicably coupled to the data processor, the zone ventilation device interface being configured to route a control signal to a zone ventilation device. The controller may also include a sensor interface communicably coupled to the data processor, the sensor interface being configured to accept a signal from at least one sensor located within the building zone. The data processor may be configured to compute a projected convective heat gain to the building zone from people and other heat transferring objects located within the building zone based on a signal received from the sensor interface. The data processor may also be configured to send a control signal to the zone ventilation devices via the zone ventilation device interface based at least partially on the computed projected convective heat gain.

[0014] Alternative exemplary embodiments relate to other features and combinations of features as may be generally recited in the claims.

BRIEF DESCRIPTION OF THE FIGURES

[0015] The application will become more fully understood from the following detailed description, taken in conjunction with the accompanying drawings, wherein like reference numerals refer to like elements, in which:

[0016] FIG. **1** is a perspective view of an exemplary building that may include an HVAC control system;

[0017] FIG. **2** is a perspective view of a building zone that may be controlled by an HVAC control system of an exemplary embodiment;

[0018] FIG. **3** is a block diagram of an HVAC control system configured to sense preferred temperatures of people located within building zones, according to an exemplary embodiment;

[0019] FIG. **4** is a block diagram of an HVAC control system, according to an exemplary embodiment;

[0020] FIG. **5** is a logical block diagram of an HVAC control system, according to an exemplary embodiment;

[0021] FIG. **6**A is a diagram of a zone, the diagram illustrating various heat gain components from people, equipment, and lights;

[0022] FIG. **6**B is a block diagram that illustrates a relationship between instantaneous convection, radiated heat, delayed convection, and the cooling load of the room or zone due to people, equipment, and lights;

[0023] FIG. **7** is a flow chart of a method of providing HVAC control to a zone using an HVAC control system, according to an exemplary embodiment;

[0024] FIG. **8** is a detailed flow chart of a method of providing HVAC control to a zone using an HVAC control system, according to an exemplary embodiment.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS

[0025] Before turning to the figures which illustrate the exemplary embodiments in detail, it should be understood that the application is not limited to the details or methodology set forth in the following description or illustrated in the figures. It should also be understood that the phraseology and terminology employed herein is for the purpose of description only and should not be regarded as limiting.

[0026] In general, and referring generally to the FIGURES, an HVAC control system of any preferred embodiment may include at least one people sensor, at least one object sensor, a controller, and outputs to zone ventilation devices such as variable air volume units. The people and object sensors may be able to sense, via any number of different methods, the number and/or properties of people and other heat transferring objects, such as lights and equipment, located within a building zone. The controller, which may include a feedforward control, may be configured to compute a projected heat gain to the building zone based on the sensed heat transferring people and objects. The HVAC control system may then determine a desired volumetric flow rate of air into the building zone, based at least partially on the computed projected heat gain. The HVAC control system may then use the desired volumetric flow rate to determine dynamic setpoints and adaptively control the environment of the building zone with reduced reliance on temperature feedback and static setpoints.

[0027] Referring to FIG. **1**, a perspective view of an exemplary building **100** that may include an HVAC control system is illustrated. Building **100** may be a commercial building, an industrial building, an institutional building, a healthcare facility, a school, a manufacturing plant, an office building, a residential building, or any other building that makes use of HVAC systems. Building **100** may include one or more air handling units **102**, shown in FIG. **1** as a rooftop air handling unit, and one or more building zones **104**. As illustrated, building **100** may include more than one floor, more than one room, and may house any number of people, lights, and other equipment.

[0028] Building **100** and its HVAC system may include any type or number of air handling units (e.g., a makeup air unit, a rooftop air unit, a fan coil unit, a constant air volume air handling unit, a variable air volume air handling unit, etc.). Building **100** may also include any type or number of HVAC subsystems and/or HVAC zones. For example, building zone **104** may be an HVAC zone comprising a single room or multiple rooms. In other buildings or systems, each floor of a building may be a separate building zone or HVAC zone controlled by a separate HVAC system or HVAC subsystem. Any number of individual heating, cooling, or air control devices may be disposed around the building and/or each building zone. For example, variable air volume units may be installed throughout building **100**. The variable air volume unit or set of variable air volume units may be used by an HVAC control system to regulate the air flow rate and other variables (e.g., heat, humidity, outside air, etc.) provided to the building zone by the HVAC system. Each variable air volume unit may be of any type or design and may include a damper, an actuator, and an actuator control circuit. Variable air volume units may generally be referred to as a type of zone ventilation device. A zone ventilation device may be considered any device or devices configured to provide controlled ventilation (heated, cooled, filtered, or otherwise) to a building zone. For example, a zone ventilation device may be a terminal variable air volume unit, an intermediate variable air volume unit, a fan, an air conditioner, an evaporative -cooler, an zone-specific air handling unit, etc.

[0029] Referring to FIG. **2**, a close-up perspective view of a building zone **104** is shown, according to an exemplary embodiment. Building zone **104** may include an HVAC vent **108** coupled to ductwork **106**. Supply air flow or ventilation may be provided to zone **104** via vent **108**. Building zone **104** may also include lights **110**, equipment **112** (shown as a computer workstation), laptops **114**, people **116**, **118**, and one or more sensors **120**. Building zone **104** may include any number of additional or alternative objects, equipment, structures, surfaces, people, and/or lights.

[0030] Sensors **120** may be disposed within and/or around building zone **104** and may be configured to sense HVAC-related conditions or variables of building zone **104**. For example, sensors **120** may be temperature sensors, humidity sensors, air quality sensors, equipment sensors, person sensors, lighting sensors, heat transferring object sensors, infrared sensors, RFID transceivers, and/or any other type of sensor that may be configured to sense an HVAC related condition, property, number of people, property of other heat transferring objects located within the building zone, or any other related variable of building zone **104**. Sensors **120** are shown disposed on the walls of building zone **104**, but may be located, positioned, or disposed in any manner or location within building zone **104**. Sensors **120** may also have any number of user interface and/or communications features configured to facilitate their operation with an HVAC control system. Sensors **120** may be wireless or wired sensors configured to operate on a mesh network or to operate on or with any other network topology.

[0031] Objects **112** through **118** are examples of heat transferring people or objects that may transfer (via radiation and/or convection) heat to building zone **104**. For example, heat may be transferred from people **116**, **118**, equipment **112**, **114**, and lighting **110** to building zone **104**. One or more sensors **120** may be configured to determine the number and properties of people located within building zone **104**. One or more sensors **120** may also be configured to determine the number, type, and/or properties of other heat transferring objects located within building zone **104**.

[0032] According to an exemplary embodiment, a variety of sets or different types of sensors **120** may exist within building zone **104**. For example, a first set of sensors **120** may be configured to sense ambient temperature of the zone, a second set of sensors **120** may be configured to determine heat transferring properties (e.g., number of people, average heat generation per person, preferred temperature settings, etc.) of people in the building zone, and a third set of sensors may be configured to determine heat transferring properties of non-human objects within the zone (e.g., number of lights, number of computers, heat of the lights, power used by the lights, efficiency of the equipment and lights, etc.).

[0033] According to an exemplary embodiment, some sensors **120** may be thermographic imaging sensors capable of using a thermal imager to detect, display and record thermal patterns and temperatures across the surface of an object. For example, a sensor **120** configured to use infrared thermography to detect heat transferring objects within a building zone may be able to compare the ambient or average temperature of objects within the zone to areas of the zone that exceed some threshold. Using this information, for example, a thermographic sensor may be able to determine that there are six heat radiating lights within building zone **104** by determining that the surface temperatures of the lights are greater than thirty degrees hotter than the average temperature of the building zone. Using thermographic sensors, an HVAC control system may be able to detect different heat signatures, (e.g., for people, equipment, and lights, etc.) and count the number of each located in the building zone. Some thermographic sensors or a sets of thermographic sensors may be able to calculate a projected heat gain to the space without specifically identifying the objects located within the building zone based on the difference between the known ambient air temperature and the thermographically sensed surfaces of heat transferring objects and/or people dispersed in the zone.

[0034] According to another exemplary embodiment, various circuits such as a resistor-capacitor circuit may be used as sensors to determine heat transferring properties of the lights or other power-using objects located within the building zone. Heat transferring properties of lights may be the number of activated lights located within a building zone, the power used by the lights located within the building zone, the current flow through a lighting circuit, or any other property of lights that may be used to estimate heat transfer to a building zone. These properties may be determined and reported to the HVAC control system for further processing.

[0035] According to another exemplary embodiment, some properties of heat transferring people and objects located within a building zone may be obtained by a database and accompanying processing components. For example, a database of network connections and/or login information for a building zone may be maintained and this information provided to the HVAC control system. Using this network connection or login information, an HVAC control system may be able to both determine the number of active workstations (and accompanying equipment such as lights and computers) and/or the number of active people located within the zone. In a building zone having a number of single-user cubicles, each cubicle having a similar desktop computer and lighting configuration, information regarding the number of people located within the building zone, the number of active lights located within the zone, and the number of active desktop computers located within the zone may be estimated relatively accurately using login information of a building zone. Similarly, people, equipment and lights may be estimated using schedule and meeting information related to a building zone. For example, if a meeting zone such as a conference room is reserved and/or otherwise scheduled, a database system may access attendee information to estimate the number of people located within the zone at any given time. Additionally, the system may be programmed to assume that the lights of the building zone may be turned on prior to the meeting and that the lights will begin transferring heat to the building zone at that time. According to various other exemplary embodiments, information regarding schedules and/or network connection information may be used to activate certain wireless sensors located within the building zone in an attempt to conserve energy of those wireless sensors. For example, an HVAC control system may be able to predict people, equipment, and lighting heat loads based on scheduled or occupancy information from the building occupants' primary or office-wide scheduling systems such as LOTUS NOTES®, LOTUS CALENDAR®, MICROSOFT OUTLOOK CALENDAR®, MICROSOFT EXCHANGE®, phone system vacation settings, vacation schedules of human resources software, and/or any other software that may be available that the HVAC control system may draw upon to predict occupancy and/or activity information.

[0036] Referring to FIG. **3**, according to an exemplary embodiment, sensors **120** configured to determine the number of people in a building zone may be radio frequency identification ("RFID") sensors. Each person **116**, **118** in a building zone may normally carry an RFID tag or transponder **306**. RFID tag or transponder **306** may be embedded or included with a person's identification badge, nametag, cellphone, PDA, uniform, key fob, or any other object a person may frequently carry with him or her. Each person may be able to login or access a personal setting interface **302** via an employee intranet, internet, or standalone application. Interface **302** may allow an employee to specify a number of personal comfort settings, such as preferred temperature, that may be associated with each worker's RFID transponder **306**. Interface **302** may access information from and store information to database **304**. Database **304** may be communicably coupled to HVAC control system **300** (e.g., METASYS® building control system sold by Johnson Controls, Inc. or other available building control systems, etc.). Database **304** may be external HVAC control system **300** or may be integral or embedded into HVAC control system **300**. Whenever a person enters a building zone having RFID-capable sensors configured to sense and/or read RFID transponders, the sensors may communicate with database **304** and/or HVAC control system **300** to lookup information associated with the sensed ID badge. The HVAC control system may then used this looked-up information (e.g., preferred temperature, etc.) as an input when determining a desired flow rate or setpoint of various HVAC components relating to the building zone. Using such a system, for example, a person who is more comfortable in a cooler room might be able to automatically cause an increase in room ventilation when he or she enters the room. When more than one person is located in the same room or building zone, the HVAC control system **300** may be configured to use the preferred temperatures of a plurality of people in the building zone to arrive at an average preferred temperature, median preferred temperature, or some other group temperature or comfort-related determination.

[0037] In addition to using RFID technology to identify people within a building zone, other technologies and/or methods may be used to identify the numbers of people in a zone and/or the preferences of people in the zone. For example, wireless data communication technologies or protocols such as **802**.xx protocols may be used, BLUETOOTH protocols, or any other wireless protocol may be used to identify devices or tags **306** workers may normally carry. Workplaces where PDA or Smartphone use is popular might, for example, use sensed Bluetooth-enabled PDA's, Smartphones, and/or mobile phones located within a building zone to provide identifying information to a receiver or sensor **120** and eventually to a HVAC control system.

[0038] According to one alternative embodiment, a sensor system may be configured to determine or estimate the number of people in a zone based on a sensed carbon dioxide generation rate. One such possible sensor system configured to determine the number of people in a building zone based on carbon dioxide is described in U.S. Pat. No. 5,550,752, to Federspiel et al.

[0039] According to other various exemplary embodiments, the HVAC control system is further configured to learn the heating characteristics of the zone. The HVAC control system may use the learned heating characteristics of the zone and the sensed people to compute the projected heat gain to the zone based on people and objects. For example, HVAC control system may learn that when a building zone is occupied by a person, the person, lights, and equipment of the zone will experience a certain average convective heat gain relative to an unoccupied zone.

[0040] Sensors **120** may have various communications hardware and/or software for communicating with components of an HVAC control system. For example, sensors **120** may be of any wired or wireless technology capable of communicating sensed information back to an HVAC control system. According to one exemplary embodiment, sensors **120** are wireless-capable sensors configured to operate with IEEE 802.15 standards and protocols (e.g., ZigBee compatible wireless-capable sensors, etc.).

[0041] Referring to FIG. **4**, a block diagram of an HVAC control system **300** is shown, according to an exemplary embodiment. An HVAC control system **300** may include a controller **400**, a plurality of sensors, a graphical user interface display **438**, and a control array **436**. HVAC control system **300** may be an HVAC control system capable of controlling a plurality of building zones, an entire building, or a single zone. While the various components of HVAC control system **300** and controller **400** are shown integrated into a single unit, it should be appreciated that distributed HVAC systems, such as the METASYS® building control system sold by Johnson Controls, Inc., may include one or more network automation engines, one or more application data servers, one or more communications networks, one or more field controllers connected to the network automation engines or application data server via the communications network, the field controller being capable of driving any number of other field controllers or devices. According to other alternative embodiments, controller **400** may have fewer components and may be integrated into an actuator for a single damper that controls ventilation to a relatively small (e.g., single room) zone. According to yet other alternative embodiments, controller **400** may be installed in the residential context in a home air handler, air conditioner, fan unit, or furnace.

[0042] Controller **400** may include a primary data processor **402**, a secondary microcontroller **404**, a memory **406**, a sensor interface and controller **412**, a zone ventilation device interface and controller **414**, a network communications device **416**, a wireless communications device **418**, a display output controller, and a control input controller **422**. The components of controller **400** may be contained in a single housing or distributed around the various spaces or building zones of a building.

[0043] Primary data processor **402** may be communicably coupled to the various other components of the HVAC control system and is generally configured to control each function of controller **400**. Primary data processor **402** may include digital or analog processing components and/or be of any past, present, or future design that facilitates control or features of HVAC control system **300**. Primary data processor **402** may be a single data processing device or multiple data processing devices. Primary data processor **402** may include any combination of program software and hardware capable of providing control, display, communications, input and output features to an HVAC control system. For example, primary data processor **402** may include any number of additional hardware modules, software modules, or processing devices (e.g., additional graphics processors, communications processors, etc.). Primary data processor **402** and/or secondary microcontroller **404** may coordinate the various devices, components and features of the HVAC control system (e.g., memory **406**, sensor interface and controller **412**, zone ventilation interface and controller **414**, etc).

[0044] Memory **406** is configured to store data accessed by HVAC control system **300** or controller **400**. For example, memory **406** may store data input from zone sensors and actuators, data created by primary data processor **402** that may be used later, intermediate data of use in a current calculation or process, or any other data of use by HVAC control system **300**. Memory **406** may include both a volatile memory **410** and a non-volatile memory **408**. Volatile memory **410** may be configured so that the contents stored therein may be erased during each power cycle of the controller **400**. Non-volatile memory **408** may be configured so that the contents stored therein may be retained across power cycles, such that upon controller **400** power-up or reset, data from previous system use remains available to the controller or user. According to an exemplary embodiments non-volatile memory **410** may store any number of databases, tables, or profiles for use with the various zones or functions of the HVAC control system **300**. According to other various exemplary embodiments, controller **400** may access remote data stores or servers via wired or wireless networks.

[0045] Sensor interface and controller **412** may be a device or set of devices configured to facilitate signal connections between a set of building zone sensors **432** and controller **400**. Sensor interface **412** may use any number of hardware technologies and/or software protocols to accomplish necessary connections and or communications with sensors such as environment sensors **424**, people sensors **426**, RFID sensors **428**, lighting sensors **430**, zone temperature sensors **434**, and any number of additional sensors or devices (e.g., security devices, smoke alarms, etc.). Sensor interface and controller **412** may also be wired or connected to wireless receivers distributed around a building zone. For example, sensor interface and controller **412** may be coupled to a wireless RFID transceiver or receiver configured to identify people occupying a building zone.

[0046] Zone ventilation device interface and controller **414** may be a device or set of devices configured to facilitate signal connections between a set of zone ventilation devices (e.g., wired zone ventilation devices **415**, wireless zone ventilation devices **452**, etc.) and controller **400**. Zone ventilation device interface and controller **414** may use any number of hardware technologies and/or software protocols to accomplish necessary connections and or communications with zone ventilation devices. Zone ventilation device interface **414** may also use wireless technology and/or may be communicably connected to wireless communications device **418** to accomplish communications with wireless zone ventilation devices **452**. It is important to note that zone ventilation devices **452**, **415** may include any number of local control circuits, sensors, and/or actuators that may be used to facilitate local or device level control of the various zone ventilation devices of the HVAC control system.

[0047] Wireless communications device **418** is generally configured to establish communication links with wireless sensors and actuators of HVAC control system **300**. Wireless communications device **418** may be configured to use any variety of wireless communications technologies or topologies (e.g., mesh topology, star, etc.). According to an exemplary embodiment, building zones may be partially wireless and partially wired. Wireless communications device **418** may connect to any number of various zones sensor sets **448** that may include sensors such as wireless environment sensors **440**, wireless people sensors **442**, wireless RFID sensors **444**, wireless lighting sensors **446**. Wireless communications device **418** may also connect to any other wireless sensor such as wireless zone temperature sensors **450**, wireless zone ventilation devices **452**, and/or any other type of wireless device including intermediate wireless access points, coordinators, routers, and/or gateways.

[0048] Network communications device **416** is generally configured to provide a connection to a data communications network such as an Ethernet-based LAN or WAN. According to other various embodiments, network communications device **416** is a wireless network communications device. Users of the HVAC control system **300** may use network communications device **416** to perform remote control functions and/or to connect distributed components of controller **400** or HVAC control system **300**. Network communications device **416** and/or wireless communications device **418** may also be connected to a building-wide or multiple-zone HVAC system, network, network automation engine, and/or application data server. These components may be a part of the METASYS® building control system sold by Johnson Controls, Inc. or other available building control systems, etc.

[0049] Controller **400** may also include any number of secondary microcontrollers **404** that may be configured to compute or process various functions of the HVAC control system **300**. Controller **400** may also include control input controllers **422** and display output controllers **420** that may be communicably connected to control arrays **436** and/or graphical user interface displays **438**. Using these devices, controller **400** may be able to serve as a standalone device, not requiring the use of a separate networked workstation or browser to control various features of controller **400**.

[0050] Referring to FIG. **5**, a logical block diagram of an HVAC control system with a control strategy for zone ventilation devices is illustrated, according to an exemplary embodiment. Sensors **120**, and any accompanying processing components, wireless receivers, and other devices used with sensors, may be installed within a building zone and configured to provide a variety of inputs to HVAC control system **300**. Sensors **120** may provide input in the form of the number of people, power use by lighting, power use by equipment, RFID numbers sensed, and any other information or properties of people, lighting, and equipment of the building zone that may be used by feedforward control **508** to determine convective heat gain to a building zone from people, equipment, and lights.

[0051] Preferred temperature setpoint calculator **504** takes input from sensors **120**. The input provided to preferred setpoint calculator **504** from sensors **120** may be in the form of a number of people, people identifiers, and/or a preferred temperature for each person occupying the zone. According to an exemplary embodiment, preferred setpoint calculator **504** may use person identification information obtained by sensors **120** to poll preferred temperature database **505** for a preferred temperature of each person occupying the relevant building zone. Preferred temperature setpoint calculator **504** may use any number of different calculations to calculate a room temperature setpoint from the preferred temperature for each person in the room. According to one exemplary embodiment, preferred temperature setpoint calculator **504** may use the following equation to determine the preferred temperature setpoint:

$$T_{set} = \frac{T_{set,1} + T_{set,2} + \ldots + T_{set,n}}{n}$$

$T_{set,n}$ is the preferred temperature for the nth person in a building zone and n is the number of people currently located in the building zone. Preferred temperature setpoint calculator **504** may provide an input to preferred temperature setpoint feedback control **506**. It is important to note that preferred temperature setpoint calculator **504** may make any additional calculations or substitute calculations to arrive at a preferred temperature setpoint (T_{set}). For example, preferred temperature setpoint calculator **504** may perform various weighing calculations to assign a higher priority to a first person compared to a second person. Temperature setpoint calculator **504** may also access database **505** to read or write preferred temperature information.

[0052] Feedback control **506** also accepts an input from one or more temperature sensors **502** located in the building zone. Using the sensed temperature, feedback control **506** determines a volumetric flow setpoint (V_{FB}) necessary to maintain the preferred temperature setpoint (T_{set}) determined by preferred temperature setpoint calculator **504**.

[0053] Feedforward control **508** may determine a desired volumetric flow rate (V_{FF}). HVAC control system **300** may use the desired volumetric flow rate to improve HVAC performance and building zone comfort by adjusting the supply airflow provided to the building zone to balance heat gains from people, equipment, and lights. This determination may allow HVAC control system **300** to maintain a building zone temperature or ventilation level closer to desired setpoints than would be possible with conventional control strategies. Feedforward control **508** may compute a projected or predicted convective heat gain (Q_{CONV}) to a building zone based on properties of people, equipment, and lights. According to one exemplary embodiment, feedforward control **508** may use the following equation to determine a desired volumetric flow rate (V_{FF}), where (ρ) is the density of air, ($\dot{c}_p$) is the specific heat of supply air, (T_{ZONE}) is the building zone temperature, and (T_{SUPPLY}) is the supply air temperature:

$$V_{FF} = \frac{Q_{CONV}}{\rho c_P (T_{ZONE} - T_{SUPPLY})}$$

[0054] Q_{CONV} may be computed in a variety of ways. For example, among other ways Q_{CONV} may be computed, Q_{CONV} may be computed using the instantaneous convection of the people, lighting and equipment sensed in the zone, or the sum of instantaneous convection and delayed convection. Instantaneous convection refers to heat transferred to the zone air via convection from people, equipment, lights and other objects. Delayed convection refers to convection from the interior surfaces (e.g., walls, furnishings, etc.) of the room to the zone air that exists because radiated heat from people, equipment, lights and other objects are absorbed by those interior surfaces and transferred back to the room air via convection.

[0055] Referring to FIG. **6**A, a block diagram of a zone is shown that illustrates sensible heat gain components from people, equipment, and lights. Heat gains from people, equipment, and lights may be split into two components: radiation heat that is absorbed by other surfaces in the room; and convection heat that is transferred to the air of the room. For example, people create some amount of instantaneous convective heat gain in the zone ($Q_{CONV,PEOPLE}$); equipment create instantaneous convective heat gain ($Q_{CONV,EQUIP}$); and lights create instantaneous convective heat gain ($Q_{CONV,LIGHTS}$) People may also radiate some amount of radiated heat ($Q_{RAD,PEOPLE}$) to the interior surfaces of the zone; equipment radiate ($Q_{RAD,EQUIP}$); and lights **68** radiate $Q_{RAD,LIGHTS}$. Some radiated heat may be absorbed by the interior surfaces (e.g., furnishings, walls, ceilings, floors, etc.) of the room or zone and the temperatures of those surfaces will increase because of the absorbed radiation. If a surface temperature is greater than the room temperature, then some or all of the radiation absorbed by the surface will be transferred back to the air of the room or zone from the surfaces ($Q_{CONV,SURFACE}$). FIG. **6**B is a block diagram that further illustrates the relationship between instantaneous convection ($Q_{CONV,INST}$), radiated heat, delayed convection ($Q_{CONV,DELAY}$), and the cooling load of the room or zone due to people, equipment, and lights.

[0056] Instantaneous convection may be determined using the following equation:

$$Q_{CONV,INST}=\Sigma(Q_{CONV,PEOPLE}+Q_{CONV,LIGHTS}+Q_{CONV,EQUIP})$$

The delayed convection equals the energy that is absorbed by interior surfaces and then transferred back to the room at a later time by convection. In other words, $Q_{CONV,DELAY}$ may be set to equal $Q_{CONV,SURFACE}$.

[0057] Depending on the processing power available to the HVAC control system or the zone controller, convective heat gain (Q_{CONV}) computed or input to feedforward control **508** of FIG. **5** may be computed or predicted using detail beyond raw counts of occupants, preferred temperatures, lights, and computers. For example, tables provided by the handbook "2005 *ASHRAE Handbook Fundamentals, SI Edition*" may be used to determine the heat created by person located within the zone and the percentage of that heat that is convective. Two exemplary entries of such a table may include the following:

Degree of Activity	Application	Heat	Heat that is Convective (Low Air Velocity)	Heat that is Convective (High Air Velocity)
Seated, light work	Office	70	40%	73%
Moderately Active	Office	75	42%	62%

To determine the convective heat gain per person based on the table, for example, heat for a certain activity may be multiplied by the percentage of heat for that activity level that is convective. The convective heat gain of each person in the zone may be added to provide $Q_{CONV,PEOPLE}$.

[0058] According to an exemplary embodiment, RFID tag or transponder **306** and RFID compatible sensors **120** of FIG. **3** and other various FIGS. of this application may use RFID data to determine the degree of activity of the people in a zone in addition to the number of people in the zone. For example, in a room where people are frequently coming and going, the average number of people in the zone may be relatively low, but it may be determined that the activity level of the room is high because of the short amount of time each RFID tag stays within the zone. According to another exemplary embodiment, a zone with a relatively large number of low power RFID sensors may be used to sense activity by determining how often an RFID tag moves from sensor to sensor in a zone. According to yet further exemplary embodiments, RFID tags **306** (or a database drawing upon the tags) may store vital statistics for the people in the zone such that heat may be more accurately predicted for any given person (e.g., a 2501b man may generally do more work to stand up and move and may therefore create more heat than a **1501**b man standing and moving the same distance).

[0059] Referring still to FIGS. **5**-**6**B, $Q_{CONV,LIGHTS}$ may be obtained by based on the heat gain from electric lighting used in the room. While the heat gain from electrical lighting may be provided by a variety of methods and/or equations, one such equation provided by the handbook "2005 *ASHRAE Handbook Fundamentals, SI Edition*" is: $Q_{light}=WF_{ul}F_{sa}$; where W is the total light wattage, F_{ul} is a lighting use factor that equals the ratio of wattage in use to total installed or potential wattage, and F_{sa} is the lighting special allowance factor that accounts for different fixture or lighting types (e.g., fluorescent, high-pressure sodium, metal halide, mercury vapor, etc.) and/or fixtures that are ventilated or installed so that only part of the heat gain enters the room. Tables of use factors and special allowance factors may be found in the handbook "2005 *ASHRAE Handbook Fundamentals, SI Edition*". The instantaneous convective heat gain from lights ($Q_{CONV,LIGHT}$) may be determined by multiplying the total heat gain from lights (Q_{light}) by the fraction of energy that is convective. According to various sources such as "*Heating, Ventilating, and Air Conditioning Analysis and Design*," by McQuiston, et al., 2005, the heat gain for fluorescent fixtures used in office zones is often assumed to be around 59 percent radiative and 41 percent convective. The same source estimates that incandescent fixtures provide a heat gain mixture of approximately **80** percent radiative heat and **20** percent convective heat.

[0060] Convective heat gain from equipment ($Q_{CONV,EQUIP}$) may include heat from electric motors, appliances, laboratory equipment, medical equipment, office equipment, amplifiers, power supplies, commercial cooking appliances, medical equipment, computer equipment, laser printers and copiers, vending machines, mail-processing equipment, and any number of other different types of equipment. Sources such as the handbook "2005 *ASHRAE Handbook Fundamentals, SI Edition*" may contain tables of heat gains and summaries of radiant/convective heat percentages for many various types of equipment. The convective portion for many types of office equipment, for example, is typically between about 60 and 90 percent.

[0061] While delayed convection ($Q_{CONV,DELAY}$) may be computed by the controller and accounted for using feedforward control **508** if adequate processing power is available, using only instantaneous convection as the convective heat gain (e.g., $Q_{CONV}=Q_{CONV,INST}$) may result in a less processor intensive control strategy. Remaining load disturbances caused by convection delay may largely and eventually be removed by room temperature feedback control **506** of FIG. **5**. Feedback control **506** may also remove disturbances caused by sensor and modeling errors used to compute the instantaneous convective gains, solar gain, and other heat gains throughout the exterior walls, floors, and ceilings.

[0062] Referring again to FIG. **5**, feedforward control **508** may be communicably coupled to database **509** that may contain various lookup tables relating to computing variables or components such as Q_{CONV}, $Q_{CONV,INST}$, $Q_{CONV,DELAY}$, $Q_{CONV,PEOPLE}$, $Q_{CONV,LIGHTS}$, $Q_{CONV,EQUIP}$, etc. For example, database **509** may be a relational database capable of relating a zone's characteristics, expected people activity levels, lights, and equipment to table entries such as the tables of the sources mentioned above that provide estimated total heat amounts and convective heat/radiant heat percentages. Feedforward control **508** may use the results of queries drawing upon database **509** to compute Q_{CONV} for use in the equation used by feedforward control **508** to determine a desired volumetric flow rate. According to various alternative embodiments, feedforward control **508** or other components of the controller or HVAC control system may use any number of lookup tables, databases, memories, and/or analog or digital circuits to determine Q_{CONV}.

[0063] Referring still to FIG. **5**, summer **510** receives input from feedforward control **508** and feedback control **506** to provide a control signal to limit determinations block **514**. Summer **510** may help control system **300** account for both the preferred temperature setpoints of people located within the building zone and for projected changes in room temperature due to the sensed or determined people, lights, and equipment of the zone.

[0064] Ventilation requirement block **512** may determine or adjust a lower limit of supply airflow. Using the sensed number of people located within a building zone, ventilation requirement block **512** may lower energy consumption and improve the comfort and health of occupants by adjusting a lower limit of supply airflow. Ventilation requirement block may use any number of lookup tables and/or equations to determine a lower limit of supply airflow based on a sensed number of people located within a building zone. For example, ventilation requirement block **512** may use any number of equations recommended, suggested, and/or required by standards or building codes such as the standards published by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) or the American National Standards Institute (ANSI). For example, ventilation requirement block **512** may use equations based on ANSI/ASHRAE Standard 62.1-2004 "Ventilation for Acceptable Air Quality" to determine the building zone outdoor airflow rate (V_{OT}). One possible example is:

$$V_{OT} = \frac{R_P n + R_A A_Z}{E_Z}$$

(R_P) is the desired outdoor airflow rate required per person as determined from a lookup table (e.g., Table 6-1 of ANSI/ASHRAE Standard 62.1-2004) or equation. (n) is the number of sensed people in a building zone. (R_A) is the outdoor airflow rate required per unit area as determined from a lookup table (e.g., Table 6-1 of ANSI/ASHRAE Standard 62.1-2004) or equation. (A_Z) is the net occupiable floor area of the room. (E_Z) is the building zone distribution effectiveness as determined from a lookup table (e.g., Table 6-1 of ANSI/ASHRAE Standard 62.1-2004, etc.) or equation. Ventilation requirement block **512** may access database **513** to retrieve information from a variety of lookup tables. A determined lower limit of the supply airflow setpoint (V_{min}) may be determined based on any number of lookup tables and/or equations. For example, a determined lower limit of the supply airflow setpoint (V_{min})may be determined from equation:

$$V_{MIN} = \frac{V_{OT}}{f_{OA}}$$

where (f_{OA}) is the fraction of outdoor air in the supply air.

[0065] Limit determinations block **514** may determine the final volumetric flow rate setpoint, according to an exemplary embodiment. Limit determinations block **514**, may, for example, determine whether to use a setpoint based on (V_{MAX}), the maximum flow rate for the building zone based on design and/or equipment conditions, or to use a setpoint based on the desired volumetric flow rate (V_{FF}). Limit determinations block **514**, may also, for example, determine whether to use the minimum volumetric flow rate (V_{min}), based on the number of sensed people in the zone, instead of the desired volumetric flow rate (V_{FF}) and feedback-based volumetric flow setpoint (V_{FB}). According to one exemplary embodiment, the setpoint for volumetric flow rate (V_{SET}) may be determined from:

$$V_{SET}=\min\{V_{max}, \max\,[V_{min}, (V_{FF}+V_{FB})]\}$$

where the maximum of (V_{min}) and ($V_{FF}+V_{FB}$) is first determined to ensure a setpoint that accounts at least for current ventilation flow and the ventilation flow setpoint or some predetermined minimum flow rate. The system then selects the minimum of that predetermined number and the maximum flow rate (V_{MAX}).

[0066] According to various other exemplary embodiments, any number of limit or filter computations or determinations may be made by limit determination block **514**. For example, limit determination block **514** may consult a database or lookup table **515** to determine a minimum volumetric airflow based on the size of the building zone in addition to the number of people, ensuring that even if the sensed number of people is incorrect, some minimum airflow for the zone will be met. According to various other exemplary embodiments, limit determination block **514** only checks to ensure that a threshold maximum volumetric flow rate is not exceeded. In some systems, limit determination block **514** may not exist at all or may exist embedded within other calculations or blocks of HVAC control system **300**. Limit determinations block may access database **515** to lookup data related to any number of relevant variables.

[0067] Once a volumetric flow point setpoint has been determined by one or more of the various components or blocks of HVAC control system **300**, the setpoint may be output from a controller to a zone ventilation device **521**. Zone ventilation device **521** may include a local feedback controller **516** that modulates a flow-affecting actuator **518** of a damper. Feedback controller **516** may obtain input from one or more flow sensors that assist in accurately achieving the volumetric flow rate setpoint.

[0068] It is important to note that while FIG. **5** displays an HVAC control system controlling a zone ventilation device including a damper, the HVAC control system illustrated in FIG. **5** may be adapted for use with a variety of different zone ventilation devices. For example, flow rate to various building zones may be controlled using a HVAC control system having variable frequency blowers or a combination of variable frequency blowers and other zone ventilation devices. According to other various embodiments, zone ventilation devices or heating or cooling devices may experience "on/off" control cycles and/or other variable control based on input received from a controller having people, lighting, and equipment sensing features described herein. For example, a flow rate of chilled or heated water in chilled ceiling or floor tiles or zones could be controlled using a modified version of the logical block diagram shown in FIG. **5**.

[0069] The components or blocks of FIG. **5** may be configured to refresh, re-sense, or update on any variety of intervals. For example, feedback control **516** may update or refresh at a faster rate than feedforward control **508** and/or feedback control **506**. By way of further example, some low-power wireless sensors **120** may refresh relatively infrequently so that sensors **120** do not frequently interfere with other RF-based devices located around the building zone or building. According to other exemplary embodiments, people sensors or other blocks of HVAC control system **300** update or refresh at a relatively much faster rate than other components in an attempt to begin adjusting system variables as soon as the sensed properties of people, equipment, or lighting within the room change.

[0070] It is also important to note that the logical block diagram of the HVAC control system shown in FIG. **5** may be implemented in hardware and/or software in a variety of ways. For example, the HVAC control system may be implemented in a largely computer software-based system having a variety of sensing inputs and actuator control outputs. According to other various embodiments, the HVAC control system may be implemented using a mix of hardware and/or software modules.

[0071] Referring to FIG. **7**, a process **700** of providing HVAC control to a zone using an HVAC control system is illustrated, according to an exemplary embodiment. The number of heat transferring people or objects located within a zone and/or any number of other properties of heat transferring objects occupying a building zone may be determined (step **702**). Once heat transferring objects (and any relevant properties) within a building zone have been determined, an HVAC control system may compute a theoretical or projected heat gain (step **704**) to a building zone from the determined heat transferring people or objects located within the zone. Using the heat gain projected in step **704**, the HVAC control system may then determine a desired flow rate (step **706**). The HVAC control system may consider certain flow rate limits (step **708**) when considering the various system computations or variables. An HVAC control system may use any number of further steps or processes to determine a flow rate setpoint (step **710**) and may eventually send the determined flow rate setpoint to a zone ventilation device (step **712**) such as a damper (and/or a damper's corresponding local control system).

[0072] Referring further to FIG. **7**, the step of determining heat transferring objects within a building zone (step **702**) may make any number of determinations related to heat transferring objects. For example, the step of determining heat transferring objects within a building zone may include collecting a variety of variables such as the number of heat transferring objects sensed, the rate of heat transferred to a volume of air per unit time, a preferred temperature setpoint, a unit of power used, and/or any other property or variable that may allow the HVAC control system to make decisions based on the heat transferring objects located within a building zone. These determinations may also include a number of sub-steps and/or sub-calculations to derive variables to be used in computing a theoretical heat gain to a building zone.

[0073] Referring now to FIG. **8**, a detailed flow chart of a process **800** of optimizing a volumetric flow rate setpoint using an HVAC control system is illustrated, according to an exemplary embodiment. Any number of devices or processes may be utilized by an HVAC control system to sense properties of people located within the building zone (step **802**). Any number of devices or processes may also be utilized by an HVAC control system to sense properties of lighting (step **804**) and equipment (step **806**) located within a building zone. An HVAC control system may then calculate a projected heat gain from the people located within the building zone (step **812**), lighting located within the building zone (step **814**), and equipment located within the building zone (step **816**). An HVAC control system may then compute a total theoretical heat gain to a building zone (step **820**) using the sensed properties and/or the calculated projected heat gains for the people, lighting, and equipment located within the building zone. In addition to considering the theoretical heat gain, an HVAC control system may determine preferred temperature setpoints for the people located within the building zone (step **822**). Using the determined preferred temperature setpoints, the HVAC control system may calculate an average preferred temperature setpoint (step **824**) for the people located within the building zone. Summing or otherwise considering both the preferred temperature(s) and the total projected theoretical heat gain, the HVAC control system may determine a desired volumetric flow rate (step **826**). Before using the desired volumetric flow rate determined in step **826**, an HVAC control system may determine a minimum flow rate setting based on the number of people located within the building zone (step **828**). An HVAC control system may make any number of limit determinations during process **800**. For example, an HVAC control system may select a maximum (step **830**) of the minimum flow rate setting determined in step **828** and the desired volumetric flow rate determined in step **826**. Step **830** may also check to ensure that the selected or desired flow rate is not higher than the maximum flow rate for the building zone or HVAC equipment. An HVAC control system may make any number of setpoint adjustments based on limits or other minimum/maximum checks. Once calculations, limits, and other checks have been completed, an HVAC control system may send the determined volumetric flow rate setpoint to a zone ventilation device (e.g., a damper and/or the damper's local control systems, an air flow control device, etc.) (step **832**). The zone ventilation device and/or the HVAC control system may further adjust the components of the zone ventilation device to the determined setpoint based on flow-sensing feedback (step **834**). At any point during process **800**, process **800** may refresh or loop back to start (or other step) to begin further sensing and calculating operations and/or to determine whether building conditions have changed.

[0074] While the exemplary embodiments illustrated in the figures and described above are presently preferred, it should be understood that these embodiments are offered by way of example only. Accordingly, the present invention is not limited to a particular embodiment, but extends to various modifications that nevertheless fall within the scope of the appended claims. The order or sequence of any processes or method steps may be varied or re-sequenced according to alternative embodiments.

[0075] The present invention contemplates methods, systems and program products on any machine-readable media for accomplishing its operations. The embodiments may be implemented using an existing computer processors, or by a special purpose computer processor for an appropriate HVAC system, incorporated for this or another purpose or by a hardwired system.

[0076] It is important to note that the construction and arrangement of the HVAC control system as shown in the various exemplary embodiments is illustrative only. Although only a few embodiments have been described in detail in this disclosure, those skilled in the art who review this disclosure will readily appreciate that 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.) without materially departing from the novel teachings and advantages of the subject matter recited in the claims. For example, elements shown as integrally formed may be constructed of multiple parts or elements (e.g., multiple processors, circuits, controllers, control interfaces, sensors, etc.), the position of elements may be reversed or otherwise varied (e.g., feedforward control, summer, temperature setpoint calculation, limit determinations, ventilation requirements, etc.), and the nature or number of discrete elements or positions may be altered or varied (e.g., sensors, communications devices, microcontrollers, etc.). Accordingly, all such modifications are intended to be included within the scope of the present invention as defined in the appended claims. The order or sequence of any process or method steps may be varied or re-sequenced according to alternative embodiments. In the claims, any means-plus-function clause is intended to cover the structures described herein as performing the recited function and not only structural equivalents but also equivalent structures. 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 inventions as expressed in the appended claims.

[0077] As noted above, embodiments within the scope of the present invention 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 which 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. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a machine, the machine properly views the connection as a machine-readable medium. Thus, any such connection is properly termed a machine-readable medium. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions comprise, 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.

[0078] It should be noted that although the diagrams herein may show a specific order of method steps, it is understood that the order of these 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. It is understood that all such variations are within the scope of the invention. Likewise, software implementations of the present invention 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. An HVAC control system configured to control the environment of a building zone, comprising:

means for determining a number of people occupying the building zone;

means for determining properties of other heat transferring objects located within the building zone; and

a controller, the controller being configured to compute a projected heat gain in a building zone based on the determined number of people occupying the building zone and the determined properties of the other heat transferring objects located within the building zone;

wherein the controller uses the computed projected heat gain to determine a zone ventilation setpoint for the building zone.

2. The system of claim **1**, wherein the zone ventilation setpoint is a volumetric flow rate of air, and wherein the zone ventilation setpoint is used to adjust at least one zone ventilation device capable of affecting the volumetric flow rate of air provided to a building zone.

3. The system of claim **1**, wherein the controller includes a feedforward control having inputs of the determined number of people and the determined properties of other heat transferring objects.

4. The system of claim **1**, wherein the projected heat gain is a projected convective heat gain to the building zone.

5. The system of claim **1**, wherein the means for determining the number of people occupying the building zone includes a radio frequency receiver.

6. The system of claim **1**, wherein the means for determining properties of other heat transferring objects located within the building zone includes a wireless sensor.

7. The system of claim **1**, wherein the other heat transferring objects of the building zone include heat transferring lights of the building zone.

8. The system of claim **7**, wherein the means for determining properties of other heat transferring objects located within the building zone includes a circuit configured to determine a lighting property of the zone.

9. The system of claim **1**, wherein the controller is further configured to learn the heating characteristics of the zone; and wherein the HVAC control system uses the learned heating characteristics of the zone and the determined number of people to compute the projected heat gain to the zone based on people and objects.

10. The system of claim **1**, wherein the controller is configured to compute the projected heat gains of a zone based on determined properties of people, computers, and lights of the zone.

11. The system of claim **1**, wherein the controller is configured to identify at least one person within the zone, and wherein the controller determines a preferred temperature for the identified at least one person within the zone.

12. The system of claim **11**, wherein the controller is further configured to identify at least two people located within the building zone in order to determine the zone ventilation setpoint for the building zone using the preferred temperature of the at least two people.

13. The system of claim **12**, wherein the ventilation setpoint is determined by averaging the determined preferred temperature of the at least two people in the zone.

14. The system of claim **12**, wherein the means for determining a number of people occupying the building zone includes an RFID sensor configured to identify RFID devices carried by people.

15. The system of claim **14**, wherein the controller retrieves an identified person's preferred temperature from a database of preferred temperatures communicably coupled to the controller, and wherein the person's preferred temperature may be set via a web-based interface.

16. A method of providing HVAC control to a zone using an HVAC control system, comprising:

determining a desired volumetric flow rate, comprising:

computing a projected convective heat gain to the zone from people and other heat transferring objects located within the building zone, and considering at least one air property;

selecting a volumetric flow rate setpoint;

sending the selected volumetric flow rate setpoint to a zone ventilation device.

17. The method of claim **16**, further comprising determining the number of people occupying the zone; and

determining a lower limit of supply airflow based on the number of people occupying the zone.

18. The method of claim **16**, further comprising:

identifying at least one person occupying the zone;

determining a preferred temperature for the identified at least one person occupying the zone; and

using the determined preferred temperature of the at least one person occupying the zone to partially determine the zone ventilation setpoint for the building zone.

19. The method of claim **16**, further comprising:

identifying at least two people occupying the building zone using RFID sensors configured to identify RFID devices carried by people;

determining the preferred temperature for the at least two identified people occupying the building zone and using a database of preferred temperatures associated with people;

averaging the determined preferred temperatures of the at least two people; and

using the average to compute a zone ventilation setpoint.

20. The method of claim **16**, further comprising determining the number of people occupying the zone using a wireless RFID sensor configured to identify RFID devices carried by people.

21. The method of claim **20**, further comprising determining the activity level of the people occupying the zone using the wireless RFID sensor; and

using the determined activity level to compute the projected convective heat gain to the zone from people.

22. The method of claim **16**, further comprising:

predicting the convective heat gain to the zone from people and other heat transferring objects located within the building zone based upon schedule information of a scheduling database; and

adjusting a volumetric flow rate setpoint prior to a scheduled meeting time.

23. A controller configured to control the environment of a building zone, comprising:

a data processor;

a zone ventilation device interface communicably coupled to the data processor, the zone ventilation device interface being configured to route a control signal to a zone ventilation device; and

a sensor interface communicably coupled to the data processor, the sensor interface being configured to accept a signal from at least one sensor located within the building zone;

wherein the data processor is configured to compute a projected convective heat gain to the building zone from people and other heat transferring objects located within the building zone based on a signal received from the sensor interface; and wherein the data processor is configured to send a control signal to the zone ventilation devices via the zone ventilation device interface based at least partially on the computed projected convective heat gain.

24. The controller of claim **23**, further comprising a means for determining a preferred temperature based on the people occupying the building zone, wherein the determined preferred temperature is considered by the processing means to determine the environment setpoint.

25. The controller of claim **23**, further comprising a communications device configured to receive scheduling information from a scheduling database, wherein the data processor is configured to predict convective heat gain to the building zone based upon the received scheduling information and to send a control signal to the zone ventilation devices via the zone ventilation device interface based on the predicted convective heat gain to the building zone.

26. The controller of claim **25**, wherein the controller causes the zone ventilation devices to provide an increased level of ventilation to the zone prior to a scheduled time of the scheduling database.

27. The controller of claim **25**, wherein the scheduling database is the primary scheduling database used by the occupants of the building zone and wherein the scheduling information is meeting information.

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