SYSTEM, APPARATUS AND HYBRID VAV DEVICE WITH MULTIPLE HEATING COILS

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CROSS REFERENCE TO RELATED APPLICATIONS

[0002] The application is related to and entitled to priority based on the subject matter disclosed in U.S. Provisional Patent Application S.N. 62/737,251 filed September 27, 2018 and U.S. Provisional Application S.N. 62/741,690 filed October 5, 2018 which are incorporated herein by reference in their entirety.

[0009] The prior art also includes numerous complete systems having remote controlled systems with computers and databases for saving energy such as Kuckuk, et al. U.S. Pub. 2017/0314796; Salsbury U.S. Patent 8,255,085; West U.S. Patent 6,296,193 and Barooah U.S. Patent 10,047,968. Some of the prior art controls a VAV and use multiple VAVs and control the temperatures based on setpoints, load and ventilation requirements. None of the prior art employs the novel hybrid VAV. Indeed West U.S. Patent 6,296,193 refers to the conventional VAV boxes of Ben-Aissa U.S. Patent 5,558,274.

[0010] Controlling temperature from a master room 29 is particularly a problem when a slave office 47 is a corner office as illustrated in Fig. 2A and especially where the corner office is exposed to the sun in the diurnal heating cycle. Office 47 may be too hot during one 24-hour period and too cold during another part of the 24-hour period. The typical solution to such situations is to add an additional VAV box or a separate space heater or space cooler which is not energy efficient and detracts value from the office space.

[0011] As heretofore discussed in the prior art the air flow once it leaves the VAV Box is distributed to multiple spaces (rooms) by adjusting manual balancing dampers to control temperature based on the HVAC output. Cooling temperature control is typically based on a single room temperature and air volume either increases or decreases to control all the spaces served by a VAV box. For exterior offices heating ability is added. In the event heat is required, the VAV box air volume is reduced and heat is injected into the air stream through either a hot water coil 25 or an electric heat element. For interior offices, typically the ability to heat is

not provided, heat is only achieved by not cooling (closing the air volume to its minimum setting and allowing the internal space temperature load and residual heating from exterior spaces to slowly heat the space. This traditional VAV system design while relatively inexpensive, has many drawbacks which are as follows:

[0012] 1. VAV boxes do not provide individual room control unless an individual VAV box is provided for each room served. This new design solves this design inefficiency by replacing the manual balancing damper with an automated space control damper. By using this design, a single hybrid VAV box with at least two air outlets can now provide individual room control without the expense of adding more VAV boxes. By adding more than one reheat coil to the hybrid VAV box and optionally a reheat coil for each outlet, each area served from the hybrid VAV box can have autonomous control from another served from the same VAV box.

[0013] 2. When a VAV box serves multiple offices and there is only one area occupied, the typical VAV has no ability to isolate (shut off) the unoccupied areas.

[0014] 3. Installation of each VAV box is expensive. This new design typically reduces the overall VAV count by 2/3. Using fewer, but larger VAV boxes with multiple outlets and re-heat coils served by a single set of balancing and isolation valves significantly reduces the cost of a building's mechanical infrastructure.

[0015] 4. VAV's use a physical thermostat to control temperature. The new design allows for each room to have either a physical or virtual thermostat (via a smartphone) which can be connected to the internet of things with many unique features that physical thermostats cannot provide.

[0016] 5. The new hybrid VAV allows for interior and exterior area's to be served by the same multi-coil VAV having a plurality of outlets. This makes for a more flexible overall system design, allowing easier and simpler floor alterations in the future.

[0017] 6. This new hybrid VAV also includes the unique ability to automatically calibrate minimum and maximum air flow settings for each area served. By closing all and only opening one control damper at a time, the air flow is read through the hybrid VAV box's velocity sensor. By modulating the control damper and reading the air flow sensor the system records when the proper minimum and maximum damper positions are achieved.

[0018] The new hybrid VAV in addition solves a number of problems in the prior art including poor temperature distribution and control by a prior art VAV serving a plurality of rooms controlled by a single thermostat in a single duct system. The novel hybrid design reduces the number of VAV's required to provide a more precise control of temperature in various zones for a given amount of space. The new hybrid VAV increases the efficiency of the use of energy and when coupled to a computer and a smart phone app and/or the internet of things allows energy to be conserved by using only the minimal amount of energy where needed and when needed.

[0019] As such, there is a need in the industry for a hybrid variable air volume terminal system with multiple heating coils that is compatible with a single duct system and enhances the temperature control and area coverage of the volume terminal boxes. The novel hybrid VAV increases the area coverage that a prior art VAV box can serve and reduces the number of VAV boxes installed in a building to reduce installation, operational and energy use. The novel method and system and its control applications and smart phone apps and connection to the internet of things provides versatility in office remodeling and changes in office layout as well as energy saving in application and operation.

SUMMARY

[0020] One implementation of the disclosed embodiments relates to the novel building management system which provides a virtual or a physical thermostat associated with each zone or room of a building served by a single duct that serves a plurality of zones or rooms. A communications interface is provided to communicate with a drop-down damper or preferably with an automated space control damper ASCD. The communications interface operates an electrically operated damper to increase or decrease air flow from a novel hybrid VAV. The building management system includes a controller and a database that implements commands from the tenant of the space, the building manager or a controller based either on sensed use and/or a history of past usage from the database to save energy.

[0021] The air handler (AH) that serves the building includes heaters, chillers, pumps and fans to provide heating, cooling, ventilation and other services to the building. In accordance with saving energy it has been recognized and appreciated that maintaining an unoccupied building or room of a building at about 68 to 70 °F or 20 to 25 °C is the most efficient use of energy for heating and cooling. It has also been recognized and appreciated that it is more energy efficient to heat air than to cool air.

[0022] In recognizing these energy saving parameters the energy saving implementation advantages involves running the cooling cycle of an AC of an AH at around 55 °F and transporting the cooled air to a novel hybrid VAV. The novel hybrid VAV provides heating elements in each outlet of the VAV minus one heating

building. This change in the novel hybrid VAV box makes the novel hybrid VAV box operate somewhat like a constant air volume box and somewhat like a variable air volume box hence it is referred to as a hybrid VAV. Control of temperature from the ASCD provides energy saving advantages in the operation of the entire system since heating and cooling can be diverted from zones not in use to zones that are in use.

[0025] One implementation of the energy savings advantages can be achieved by providing both a sensor link and/or a communications interface to the ASCD to heat or cool an area based on actual load sensed by an electronic occupancy sensor (EOS) or a room light switch so that when the light is on signifying the room is occupied the ASCD maintains the desired room temperature. When the room is unoccupied the space is either controlled to an OFF setting or to a more energy efficient setting. The ASCD, hybrid VAV and AH can also communicate with a database to heat and cool based on anticipated future load requirements. Actual load requirements can be provided by employing a building management system BMS that employs sensors and computer control with databases to track actual building use and occupancy. Anticipated future load requirements may be provided by smart device apps connected to a communications device to prepare for an unexpected meeting outside normal business hours.

[0026] Control of temperature by the ASCD and for the group of rooms also provide for a programmed or automatic recalibration of the entire group of rooms that previously required the work of an air balancer. After the installation or in operation of the prior art VAV the work of an air balancer to equalize air flow to each room or

the invention. The following detailed description including best mode is not to be taken in a limiting sense, since the scope of the invention is defined in the appended claims.

[0072] In certain embodiments of the invention, the novel hybrid variable air volume terminal system comprises one or more of the following components alone or in combination: (1) a hybrid VAV Box with or without a sub plenum; (2) Dual heating coils; (3) First air distribution duct or a plurality of distribution ducts; (4) Second air distribution duct; (5) Room control dampers for the first duct; and (6) Room control dampers and preferably automated space control dampers (ASCD) for the second duct.

[0073] Referring now to FIG. 4A a novel hybrid VAV 10 is illustrated having an inlet duct 12 and two outlet ducts 14 and 16. An air velocity flow sensor 18 is provided at the inlet along with an optional damper 20. The novel hybrid VAV 10 differs from prior art VAV box 11 (FIG. 1A) in having an optional damper 20 that is not adjusted to control temperature of air leaving hybrid VAV box 10. The temperature of the conditioned air leaving hybrid VAV box is determined not by damper 20 but instead by an automated space control damper ASCD 40 and heating coils 22. Heating coils 22A and 22B can be either water heating coils or electric heating coils with water the preferred implementation. A heating coil actuator with sensor 24, 26 is provided for each of the outlets, 14 and 16 of the novel VAV 10.

[0074] Hybrid VAV 10 includes a sub plenum 30 disposed between the plurality of outlets and a terminal wall 36 opposite inlet 12 to equalize air flow and reduce noise. The size of the sub plenum is approximately 10% to 20% of the interior space of the

novel hybrid VAV. Hybrid VAV 10 has at least two or more outlets 14 and 16 but may have one less heating element 22A or 22B than the total number of outlets. Where the novel hybrid VAV includes an outlet duct 14 and 16 each with a heating element 22A and 22B a single duct 32 and 34 connect the hybrid VAV 10 to a separate group of offices with each office having its own ASCD or automated space control damper 40A, 40B, 40C and 40D each of which control temperature in duct 32 which ASCD dampers 40E, 40F, 40G and 40H control temperature in duct 34 as illustrated in FIG. 5.

[0075] Referring now to FIG. 5 and 6A each office served by ASCD 40A, 40B, 40C, 40D, 40E, 40F, 40G and 40H each can have their separate thermostat to individually set the temperature in their office by opening and closing the damper in the ASCD in their individual office using a wired thermostat or a wireless thermostat that can be accessed through a smart device such as cellphone 50.

[0076] Comparing now prior art FIG. 1A and FIG. 2A with FIG. 5 and 6A it will become apparent that unlike the prior art, temperature of each individual office is not controlled by damper 19 but instead dampers in each ASCD 40A, 40B, 40C, 40D, 40E, 40F and 40G in each individual office 52, 54, 56, 58, 60 and 62. This change in control converts a VAV variable air volume device into the novel hybrid VAV which operates somewhat like a constant air volume device and somewhat like a variable volume device. A further observation is that room 52 can be later remodeled or subdivided into two rooms each of which have their own thermostat and temperature control. A further observation is the master slave arrangement between offices has been eliminated.

[0077] The novel hybrid VAV box can be configured in a number of different ways as illustrated in FIGs. 4B, 4C, 4D and 4E. The hybrid VAV 10 can be rectangular as illustrated in FIGs. 4B and 4C or be polygonal as illustrated in FIG. 4D or even round as illustrated in FIG. 4E. The hybrid VAV preferably has a single inlet with 2 to 6 or more outlets with each outlet having a heating coil 22 or one or more outlets not having a heating coil to transfer unheated air to other portions of the building or to another hybrid VAV box.

[0078] In one embodiment, a single hybrid VAV box 10 feeds two or more ducts 14, 16. Each duct can have a heating coil 22 operably connected thereto. Conditioned air is then delivered to individual temperature controlled rooms by ASCD control dampers 40A-H. This assembly can be installed as many times as needed throughout the building. The hybrid VAV box air flow is controlled to maintain a static duct pressure setpoint FIG. 5 using feedback from a duct static pressure sensor P (FIG. 5). If the total airflow exceeds the maximum CFM setpoint, then the control is switched to maintain the maximum CFM flow setting using the velocity pressure sensor 18 within the hybrid VAV box. For each duct 32, 34 , the heating coil opens if more than half of the served rooms 52, 54, 56, 58, 60 and 62 (FIG. 6A) require heat. If more than half the rooms need heat, then the ASCD room damper control action is reversed (open heat), otherwise the room control action is (open cool). Each room control damper ASCD opens and closes to maintain individual space temperature based on each temperature sensor.

[0079] Referring now to prior art FIG. 2 a typical floor office layout for heating and cooling is illustrated. VAV boxes are expensive and as a result each VAV box 11

serves a plurality of offices 27, 29, 31, 33 and 47 resulting in a lot of interior areas such as areas 51 and 53 having no interior heat and limited ventilation. These interior spaces 51 and 53 generally become wasted office space or storage areas.

[0080] Referring now to FIG. 6 and prior art Fig. 3 the problem of ventilation, comfort control and cost was solved by the novel hybrid VAV box 10 and ASCD 40. In FIG. 6 only 11 hybrid VAV boxes 10 coupled with 85 ASCD's 40 provide 85 controlled areas. Only 6 novel hybrid VAV's are required to heat all the exterior offices and only 5 novel hybrid VAV's are required to provide heat and ventilation to all the interior spaces. Comparison prior art Fig. 3 shows that to provide the same heating and ventilation 32 prior art VAV boxes are required with 17 prior art VAV boxes required to heat the exterior offices and 15 VAV boxes are required for the interior offices. The comparison between prior art Fig. 3 and Fig. 6 illustrates the novel hybrid VAV boxes reduce the number of boxes by 2/3rd and results in more granular heating control with the elimination of the master slave system and an 18% lower cost than a conventional system. The advantages are further broken down in FIG. 9 and presented graphically in a project cost comparison. One of the items in the cost comparison in FIG. 9 is the cost of a manual labor cost for air balance by utilizing an air balance provided by the combination of the novel hybrid VAV 10 and the automated space control damper ASCD 40.

[0081] In certain embodiments and a preferred application, the hybrid variable air volume terminal system comprises an automated air balance system and demand response control system to control and/or vary the amount of air flow into the plurality of rooms in the building by the ASCD. In the prior art once the system is

installed the air balance remains the same until a technician comes out and rebalances the system. As a result seasonal and even diurnal changes can make a static air balanced system feel uncomfortable particularly prior art master slave air balanced systems. The dynamic air balance system provided by the novel VAV 10 and ASCD 40.

[0082] Referring now to FIG. 8 the dynamic air balance provided by the novel hybrid VAV and ASCD is achieved by sequentially opening one of the ASCD dampers 40A and closing the others 40B to 40H and then using the novel hybrid VAV as a flow hood and preparing a sequence log of damper settings for minimum and maximum and also log flow versus damper position. The heating control actuator with sensor 24 or 26 FIG. 4A is used to log flow for each ASCD 40A to 40H. Once damper 40A is complete damper 40A is closed and damper 40B is opened until all the ASCD 40 dampers are completed and logged the dampers are set in a balanced position or default position with respect to each other. The advantages of this embodiment is not only provided for periodic rebalancing when an ASCD controller 100 includes a database 102 (FIG. 19).

[0083] In the dynamic air balancing embodiment, the hybrid variable air volume terminal system comprises an automated air balance system due to its ability to isolate individual rooms. In certain embodiments, the automated air balance system comprises one or more of the following: (1) Minimum CFM drop damper position (based on measured airflow); (2) Maximum CFM drop damper position (based on measured airflow); (3) Maximum noise CFM drop damper position (based on setting or diffuser design); (4) Drop damper position / CFM calculation (created during

office upon registering entry of a tenant as illustrated in FIG. 11. In addition motion sensors may be employed to cut back service if there is no motion or activate service when motion is detected. Similarly upon exiting the office everything can be turned OFF as illustrated in FIG. 11. The system can be activated remotely by a smart device remotely to prepare for meetings or work on weekends as illustrated in FIG. 12.

[0087] In a further energy saving embodiment, a demand response control system may be added to permit the following stages of the system: (1) First stage: Turn off all air in rooms that are not occupied and are being controlled using temperature setback; (2) Second stage: Raise room temperature setpoints in non-critical common areas (i.e. kitchens, break rooms, storage areas, etc.); and (3) Third stage: Raise room temperature setpoints in occupied offices.

[0088] In certain embodiments, the variable air volume terminal system comprises a virtual office thermostat configured to operate with or without the VAV box described in certain embodiments. The virtual office thermostat provides a web service that allows the office occupant of a building or building personnel using a smartphone, tablet, or desktop computer to view and control their own individual office space. Virtual thermostats are connected/interfaced into the building BMS system via a web or their client application.

[0089] In certain embodiments, the office occupant, building personnel or other user can access and/or control any one of the following using the virtual office thermostat: (1) Room temperature setpoint (includes single and dual set points); (2) Lighting level setpoint; (3) Arrival and departure times; (4) Request after-hour

terminal system provides an enhanced building personnel experience with the following characteristics: (1) Granular control provides for superior remote trouble shooting capability; (2) 3D control graphics are intuitive and easy to use; and (3) Comfort Control software application provides complete control and setup functionality.

[0092] In certain embodiments, the variable air volume terminal system provides enhanced system functionality with the following characteristics: (1) Intelligent Controlled Cool Down / Warmup is based on past room occupancy as illustrated in FIG. 11 and 12; (2) Priority Based Floor Recovery Mode (Cool important areas first); (3) Enhanced Demand Response Control (shut off setback areas); and (4) Integrate-able to Access Expert (control office enabled based upon entry and exit).

[0093] It shall be appreciated that the variable air volume terminal system allows one novel hybrid VAV box to perform the work of multiple prior art VAV boxes. This system combined with automated air balance, downstream controlled room dampers, virtual thermostats and enhanced sequences reduces the overall cost and increases the overall effectiveness of the temperature control.

[0094] The variable air volume terminal system comprises the following advantages: (1) Reduces the cost of air distribution systems while providing better control for commercial buildings; (2) System provides tenants with an intuitive interface (looks like a thermostat) to interact with the building's mechanical system; (3) System provides building personnel with a convenient tool to setup and control the building; and (4) Superior energy savings can be achieved due to the system's design.