Intelligent Air Source and Terminal Integration

Benefits of a Communicating VAV (Variable Air Volume) System

United Technologies
turn to the experts

Carrier Corporation
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TABLE OF CONTENTS

INTRODUCTION

The VAV (variable air volume) system consists of two interrelated sub-systems that function together to maintain building zone comfort conditions. The sub-systems that make up the VAV system are:

- An air source (packaged rooftop unit or air-handling unit)
- Zone air terminals

Although each of these sub-systems typically functions independently, they also can be linked together for optimum system performance. This paper will focus on the benefits of using an integrated and communicating system platform to link together the components of the two VAV sub-systems.

LINKAGE OF VAV SYSTEMS

An integrated VAV system platform digitally connects the building control zones to the central air source. Linkage of these systems provides a common communications platform between the air terminals and the air source where appropriate information may be exchanged in a continual real time manner. Based on information flowing from the air terminals (zones), the air source chooses the appropriate system operating mode at any point in time. The air source controller then executes the appropriate operating mode and communicates the operating mode to each zone controller. Thus, each system component can use the free flow of information to optimize its individual control function during each system operating mode and improve space comfort.

The communicating system provides the following benefits:

- Stable system operation
- Improved zone comfort conditions
- Improved building indoor air quality (IAQ)
- Reduced system energy consumption
- Reduced commissioning time

VAV SEQUENCE OVERVIEW

The VAV system varies the air volume and air temperature supplied to each control zone of the building to match the zone's cooling and heating space needs. A typical VAV system is shown in Figure 1. Note the air source and zone controller sub-systems.

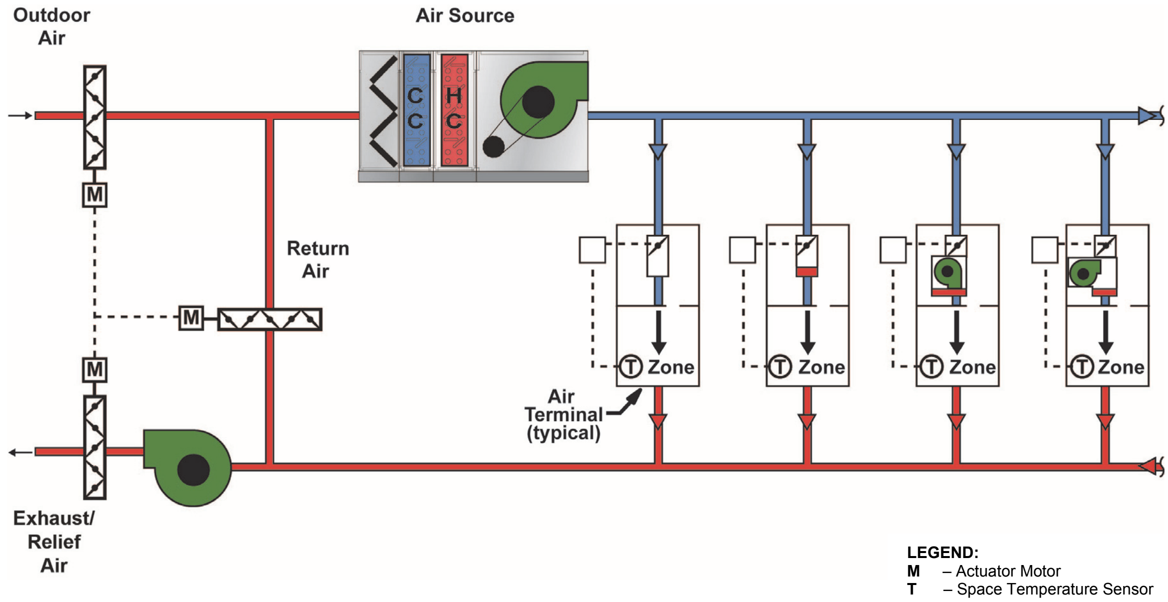


Fig. 1 – Typical VAV System

Packaged rooftop (RTU) and air-handling units (AHU) systems are available with factory-installed DDC control technology. The integrated DDC enables many functions that previously could not be served by VAV systems with simple electro-mechanical control systems. A typical VAV system with integrated DDC controls is shown in Figure 2. Zone DDC controllers are connected to the air source DDC controller by a communications bus.

The DDC communicating control system coordinates the cooling or heating load requirements of each zone in the building while recognizing the current operating mode chosen by the air source. It would be impossible for the DDC system to orchestrate these system actions unless the system components were connected electronically through the DDC electronic connection called Linkage.

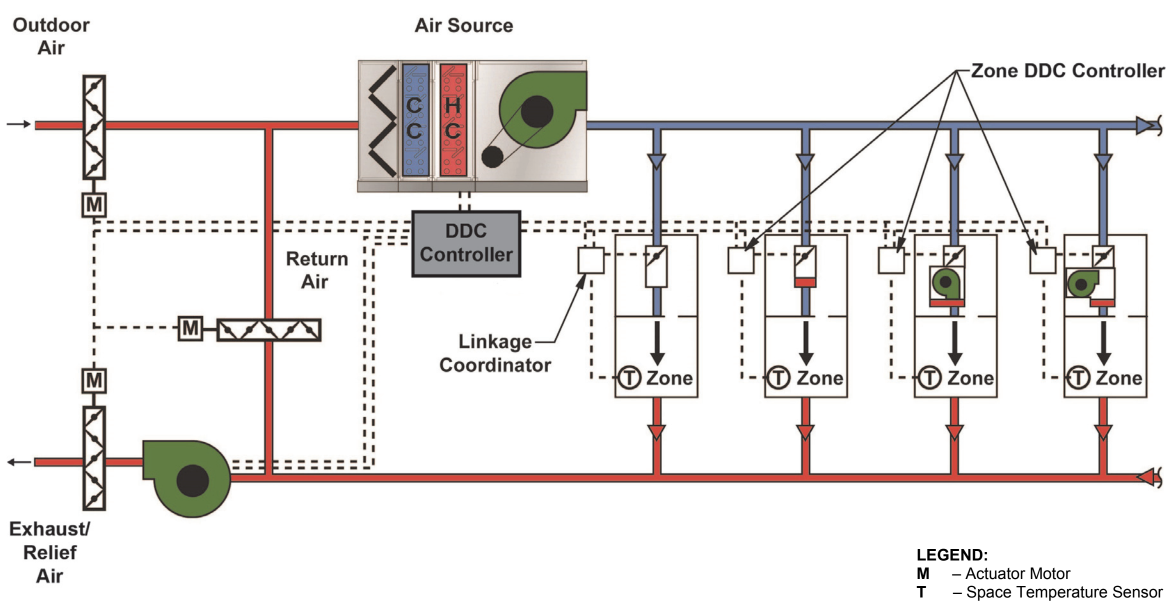


Fig. 2 – VAV System with Integrated DDC Controls

VAV COMPONENT OVERVIEW

As defined earlier, whether the VAV system is a communicating or non-communicating system, at a minimum the system will always include an air source and air terminals. In some instances, system components may also include a separate perimeter heating system.

Air Source

The air source is the system component that manages system airflow, supply air temperature, duct pressure, system humidity, and building ventilation air volume. These and other control functions are enabled by using an integrated DDC system to monitor vital building zone information, determine the appropriate function based on the analysis of the data, and initiate the appropriate function to meet the needs of the building. As shown in Figure 3, the air source may be an AHU or an RTU. A typical VAV system with an RTU with integrated DDC is shown in Figure 4.

Fig. 3 – Air Sources for VAV Systems

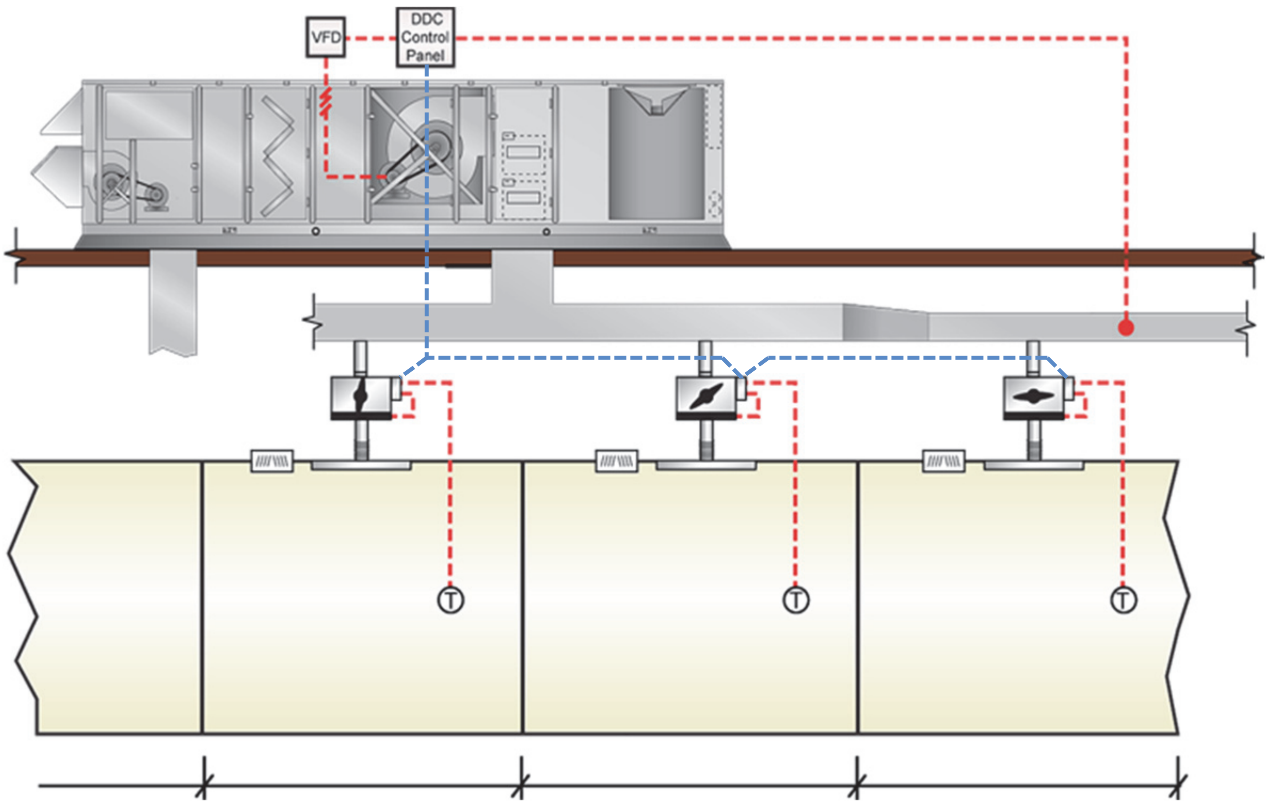


Fig. 4 – Integrated DDC Controls in a Typical VAV Rooftop Unit

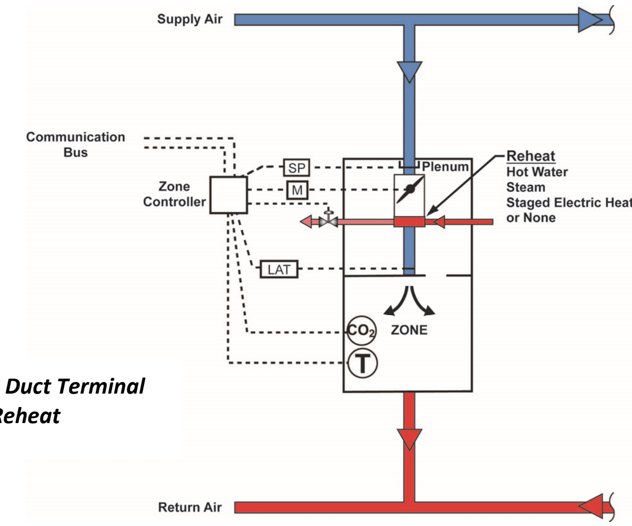
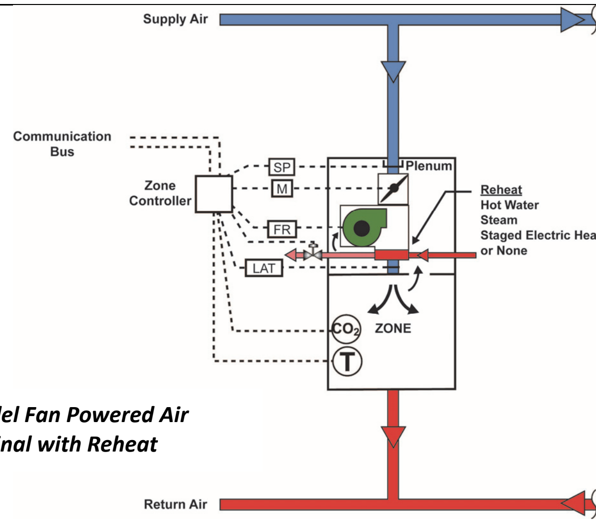
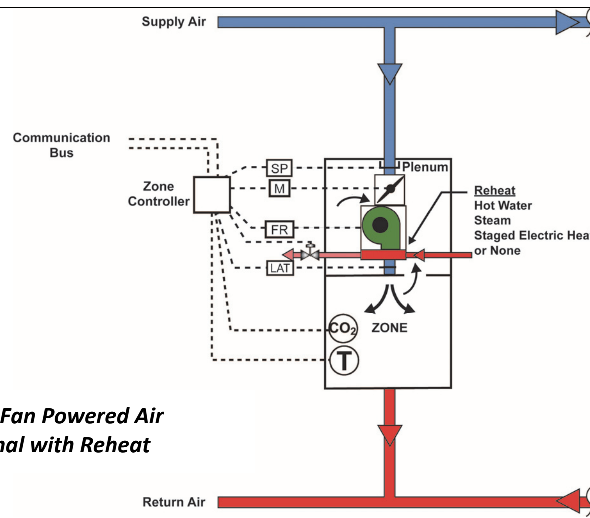
Air Terminals

The function of the VAV air terminals and their associated control is to maintain the building's zone comfort conditions. A zone controller mounted on each air terminal, with its associated sensors and actuators, varies the zone's supply air volume and temperature to meet the zone's cooling and heating needs. An integrated system coordinates the flow of information between the zone controllers and the central air source controller to facilitate the choice of a system operating mode required to satisfy the building's comfort and safety needs.

There are several different styles of air terminals available to best meet each zone's unique cooling and heating needs. The basic types of terminals are shown in Table 1.

Local zone heating for all terminal styles can be provided by hot water coils or steam coils or by an electric heater, depending on the design requirements of the building. Fan powered terminals can additionally utilize ceiling plenum heat for more efficient zone heating under light loads.

Table 1 – VAV Air Terminal Types

TYPE	APPLICATION	TYPICAL CONFIGURATION
SINGLE DUCT 	• Interior Zones (Cooling Only) • Exterior Zones (Cooling with Reheat in Mild Climates) • Low Cost Systems	 *Single Duct Terminal with Reheat*
PARALLEL FAN POWERED 	• Exterior Zones (Cooling with Reheat in Cold Climates) • Intermittent Fan Operation (Heating Only)	 *Parallel Fan Powered Air Terminal with Reheat*
SERIES FAN POWERED 	• Interior Zones (Cooling Only) • Exterior Zones (Cooling with Reheat) • High Airflow Turnover or High External Static • Sound Sensitive Applications • Energy Savings	 *Series Fan Powered Air Terminal with Reheat*

LEGEND:

CO_2	– Carbon Dioxide Sensor	**FR**	– Fan Relay
FR	– Fan Relay	**SP**	– Static Pressure Sensor
LAT	– Leaving Air Temperature Sensor	**T**	– Space Temperature Sensor

Comparison of Communicating and Non-Communicating VAV System Functions

The communicating VAV systems can operate like a traditional VAV system, with cooling provided year-round by the air source during normal occupied operation, and heating provided by terminal reheat at the zone level. However, one important advantage that can be realized immediately with a communicating VAV system is that central air source occupied heating is possible.

Due to the communication between the zone controllers and the air source controller, more control functions are available in this system than are possible with a non-communicating VAV system. In addition, the control response during each system control function is much more sophisticated and can provide quicker reactions to building conditions.

Table 2 explains the actions taken at the zone air terminals and the central RTU air source for each control function in a communicating VAV system.

The responses, in most cases, are different from those in a non-communicating VAV system; some of these differences in the responses are shown in the last column in Table 2.

In addition, the following control functions are streamlined by the use of an integrated system.

Demand Controlled Ventilation (DCV) – This function changes the way ventilation air is provided for a commercial building. Figure 5 illustrates the difference between conventional building ventilation control and that accomplished by DCV. Demand controlled ventilation uses zone CO_2 sensors as "people counters." Through communication with the central air source, the system can utilize a staged methodology to provide optimized ventilation while saving energy. The zone controller will utilize excess ventilation already within the building but returned from other zones through the return air plenum. This is done by first increasing airflow at a particular VAV zone rather than increasing the outdoor air percentage at the air source. If this alone cannot meet the zone requirements, then the air source increases the amount of outdoor air as a percentage of the total supply air and positions the outside damper to match actual building ventilation requirement in real time. This integrated system reduces the treatment of excessive amounts of outdoor air, which can result in tremendous energy savings.

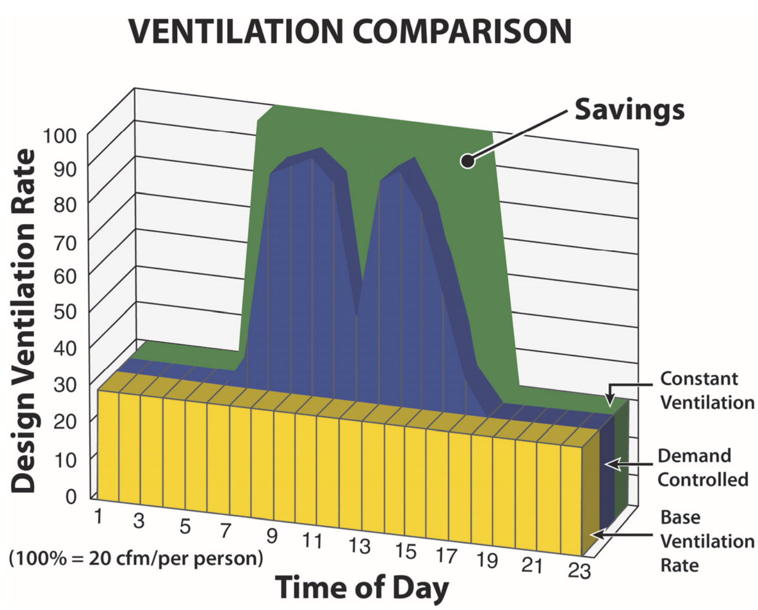


Fig. 5 – Demand Controlled Ventilation

Static Pressure Reset – This energy-saving routine optimizes fan speeds during partial load conditions where full load design static pressure is not needed. Zone damper positions are monitored to ensure that they are receiving sufficient air and the system can dynamically decide when the supply duct airflow can be reduced while still maintaining sufficient system pressure. This reduction in duct static pressure lowers the power draw for the air source's indoor fan motor, thereby saving energy.

Fire Shutdown – A smoke detector can be wired to stop the air source and send a message to a remote alarm system while also re-positioning the zone dampers and immediately stopping any zone terminal fans with a quick and simple digital command that is best for the building's condition.

Smoke Purge, Zone Pressurization, and Smoke Evacuation – Smoke Purge and Zone Pressurization coordinate the outside air intake capabilities of the air source with zone damper positioning to pressurize the affected zones with outside air in order to rid them of smoke or other contaminants. Zone dampers are opened to their Cool Max position during a Purge or Pressurization event. Pressurization is most commonly used in multi-story buildings where floors above and floors below an area with a smoke event are pressurized to help contain the smoke.

Smoke Evacuation coordinates either building exhaust fan(s) or a return fan/exhaust damper combination in the air source to draw smoke out of the building. Zone dampers are fully closed during Smoke Evacuation.

These routines can be manually initiated (typically though a fireman's smoke control panel) or automatically by smoke detectors or a signal from the life safety control system. Note that some VAV systems may not have the necessary equipment to perform these functions, and those that do may be prevented from automatic initiation based on local fire codes.

Table 2 – Control Sequence at the Zone Air Terminals and RTU Sub-Systems

CONTROL FUNCTION	COMMUNICATING VAV SYSTEM RESPONSE		NON-COMMUNICATING VAV SYSTEM RESPONSE
	Zone Response	RTU Air Source Response	
SYSTEM START/STOP			
System Start	Occupancy scheduling at each zone establishes system start. First zone to go occupied starts the system.	Through digital communication, RTU responds to zone occupancy scheduling and starts accordingly.	Zone responds to RTU; RTU responds to a time clock.
Timed Override	When unoccupied, a zone sensor push button can start the system in the occupied mode for a fixed number of hours.	Through digital communication, RTU responds to zone sensor button push and starts in occupied mode. RTU stays occupied for fixed number of hours, then goes unoccupied.	Terminal responds to timed override request, RTU then responds to impact on supply air temperature and supply duct pressure.
System Stop	Occupancy scheduling at each zone establishes system stop. Last zone to go unoccupied stops the system.	Through digital communication, RTU stops when last zone goes unoccupied.	Zone responds to RTU; RTU responds to a time clock.
HEATING/COOLING			
Occupied Cooling	Zones send temperature and set point information to enable the RTU to determine the most efficient way to meet the current load requirements. The RTU tells zones it is in a cooling mode and the zone dampers modulate between the minimum occupied and maximum cooling airflow (cfm) limits to meet zone's occupied cooling set point. Cooling setting is used to satisfy any zone needing heat.	Through digital communication, RTU determines the need for cooling to satisfy weighted average of any occupied zone's cooling needs. Because actual temperature and set point data is available at the air source, the air source can determine if the economizer or outdoor air damper can more efficiently satisfy the cooling requirement.	Similar to non-communicating VAV system. Utilizes a return air temperature sensor and preconfigured set point to start and end cooling cycle which may or may not match the occupants' needs and the VAV terminals' set points.
Occupied Heating	Zones send temperature and set point information to enable the RTU to determine when the heating load has increased above the cooling load. The RTU tells zones it is in a heating mode and any zone needing heat will modulate its damper between the minimum occupied and maximum heating airflow (cfm) limits to meet the zone's occupied heating set point. Terminal reheat may operate to supplement RTU heat as necessary.	If, through digital communication, the average zone data indicates the need for heat, the RTU can be configured to switch into the occupied heating mode, and central heat is used to heat the building. This may be more cost effective than operating local zone electric heaters at each VAV terminal unit.	RTU stays in cooling while the building is occupied. Any local heating must be accomplished using VAV terminal reheat.

LEGEND:
DCV – Demand Controlled Ventilation
IAQ – Indoor Air Quality
RTU – Rooftop Unit
VAV – Variable Air Volume

Table 2 – Control Sequence at the Zone Air Terminals and RTU Sub-Systems (cont)

CONTROL FUNCTION	COMMUNICATING VAV SYSTEM RESPONSE		NON-COMMUNICATING VAV SYSTEM RESPONSE
	Zone Response	RTU Air Source Response	
HEATING/COOLING (cont)			
Unoccupied Cooling	Zones send temperature and set point information to enable the RTU to determine the most efficient way to meet the current load requirements. The RTU tells zones it is in a cooling mode and the zone dampers modulate between the minimum unoccupied and maximum cooling airflow (cfm) limits to meet zone's unoccupied cooling set point.	If, through digital communication, the average zone data indicates the need for cooling, RTU will start and the outside dampers will remain closed unless the outside air is suitable to meet the cooling requirements. The RTU will select the suitable cooling source, whether economizer, mechanical or a combination of both to satisfy the weighted average of zone's cooling needs in the most efficient manner when unoccupied. Through communications, the RTU will relay the appropriate cooling mode to all VAV terminals.	Zone responds to RTU; RTU responds to any commissioned unoccupied cooling set-points within RTU. Commonly not utilized.
Unoccupied Heating	Zones send temperature and set point information to enable the RTU to determine when heating is required. The RTU tells zones it is in a heating mode, and the zone dampers modulate between the minimum unoccupied and maximum heating airflow (cfm) limits to meet zone's unoccupied heating set point.	If, through digital communication, the average zone data indicates the need for heating, RTU will start and provide heating to satisfy weighted average of zone's heating needs when unoccupied. The outside dampers remain fully closed,	RTU remains in the OFF position.
Supply Air Tempering	RTU is in a fan only mode, and zone dampers modulate between minimum and maximum cooling airflow (cfm) limits to meet zone's occupied cooling set point. Terminal reheat with damper in minimum cooling setting is used to satisfy any zone needing heat.	When only the economizer is operating to maintain the minimum ventilation requirements with very cold outdoor air, the RTU heat is used to maintain an adjustable supply air temperature set point.	Zone responds to RTU; RTU responds to any commissioned unoccupied heating set points within RTU. Commonly not utilized.

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Table 2 – Control Sequence at the Zone Air Terminals and RTU Sub-Systems (cont)

CONTROL FUNCTION	COMMUNICATING VAV SYSTEM RESPONSE		NON-COMMUNICATING VAV SYSTEM RESPONSE
	Zone Response	RTU Air Source Response	
HEATING/COOLING (cont)			
Morning Warm-up	RTU receives real time temperature and set point information from each VAV zone and determines the optimal time when heating is required. The RTU tells zones it is in morning warm-up mode and the zone dampers modulate between minimum and maximum heating airflow (cfm) limits to warm the zone to the midpoint between the occupied heating and occupied cooling set points. Terminal heat supplements RTU heat as needed.	Dynamic daily start time predicted by optimum start routine based on difference between existing temperature and occupied space temperature set point. Outside air dampers are closed. RTU heat used to warm the building prior to occupancy.	RTU uses time clock channel to start.
Morning Cool-down	RTU receives real time temperature and set point information from each VAV zone and determines the optimal time when cooling is required. The RTU tells zones it is in a cooling mode and the zone dampers modulate between minimum and maximum cooling airflow (cfm) limits to cool the zone to the occupied cooling set point.	Dynamic daily start time predicted by optimum start routine based on difference between existing temperature and occupied space temperature set point. Outside air dampers are closed unless the outdoor air is suitable for cooling. RTU mechanical cooling used to cool the building prior to occupancy.	RTU uses time clock channel to start.
Supply Air Temperature Control	Zone dampers modulate between min and max settings based on the operating mode of the RTU (cooling or heating). Two minimum zone airflow settings are provided and are selected by the VAV zone controller based on the zone's occupancy.	RTU maintains typical supply air temperature set points of 53 F to 55 F during cooling; optionally, supply air reset may be used to increase the supply air set point and prevent unnecessary zone reheat when the cooling load decreases, increasing efficiency. During heating, the supply air typically is warmed to 105 F.	RTU maintains a fixed supply air temperature, typically 55 F. Zone dampers modulate based on zone set point.
Static Pressure Control	No zone response.	Duct pressure maintained at the required set point design value. Pressure sensor is located 1/2 to 2/3 of the way down main trunk duct.	Zones respond to space demands, RTU reacts to impacted supply duct pressure.

Table 2 – Control Sequence at the Zone Air Terminals and RTU Sub-Systems (cont)

CONTROL FUNCTION	COMMUNICATING VAV SYSTEM RESPONSE		NON-COMMUNICATING VAV SYSTEM RESPONSE
	Zone Response	RTU Air Source Response	
OUTDOOR AIR			
Economizer	Zones send temperature and set point information to the RTU. The zones receive indication of a cooling mode, and the zone dampers modulate between minimum and maximum cooling airflow (cfm) limits to meet zone's occupied cooling set point. Terminal reheat may be used to satisfy any zone needing heat.	When outdoor air is suitable, RTU enables economizer operation with mechanical cooling added as necessary. During integrated cooling operation, the outdoor damper remains 100% open. The outdoor damper is modulated to maintain the fixed minimum ventilation airflow (cfm) as the total fan airflow varies. If DCV is utilized, the outdoor air damper will modulate open from the minimum ventilation position as necessary to meet the building's ventilation requirement.	RTU responds to outdoor air temperature and determines if free cooling available. Zones respond "as normal" and not uniquely to economizer operation.
Unoccupied Free Cooling	RTU receives real time temperature and set point information from each VAV zone. Zone dampers modulate between the minimum unoccupied and maximum cooling CFM limits to meet each zone's set point – halfway between occupied cooling and heating set points.	Active during any unoccupied period but typically between 3 a.m. and 7 a.m., the RTU initiates this routine if the outdoor air is suitable to precool the space (cold enough compared to indoor air temperature). The RTU starts the indoor fan and then opens the outdoor air dampers to maintain the desired supply air set point. Mechanical cooling is not used.	Zone responds to RTU; RTU responds to any commissioned unoccupied cooling set points within RTU. Commonly not utilized.
ENERGY SAVING			
Supply Air Temperature Reset	Zone dampers modulate between minimum and maximum cooling airflow set points.	Digital communication is used to dynamically adjust the supply air temperature set point in real time to match that needed to meet the average zone's comfort needs.	Zone dampers modulate based on zone set point, RTU uses fixed reset schedule.
Static Pressure Reset	Digital communication from each zone provides all zone damper positions to the air source.	To improve system operation and reduce energy usage and damper airflow noise, digital communication allows a dynamic reset in real time of the air source static pressure set point based on zone damper positions. The pressure is reset to maintain the position of the most open damper in the system.	Unable to accomplish this properly as a stand-alone function. Requires extensive networking between RTU and terminals for proper reaction.

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Table 2 – Control Sequence at the Zone Air Terminals and RTU Sub-Systems (cont)

CONTROL FUNCTION	COMMUNICATING VAV SYSTEM RESPONSE		NON-COMMUNICATING VAV SYSTEM RESPONSE
	Zone Response	RTU Air Source Response	
ENERGY SAVING (cont)			
Demand Controlled Ventilation (DCV)	Zones use CO_2 sensors and a zone IAQ set point in ppm to override zone temperature control and increase zone supply airflow and zone ventilation. If zone becomes overcooled, terminal reheat is enabled to maintain zone temperature halfway between occupied cooling and heating set points.	Through digital communication, RTU can respond by opening the outside air dampers when and if additional outdoor air is required to meet the ventilation needs after the terminal airflow has already increased. (This requirement is determined by zone CO_2 measurements.) Outdoor air dampers maximum opening can be limited (typically to 75%) to prevent excessive humidity issues or excessively cold primary air when the outdoor air is very cold.	Requires extensive networking between RTU and terminals for proper reaction.
Temperature Compensated Start	Digital communication provides zone data to this RTU routine for its calculation.	Known as optimum start or temperature compensated start, these routines predicts a daily start time of the HVAC system to pre-cool or pre-heat the building prior to occupancy in order to achieve the desired zone set points at the start of the occupied period.	Zone responds to RTU; RTU responds to any commissioned set points within RTU. Commonly not utilized.
SPECIAL FUNCTIONS OF COMMUNICATING VAV SYSTEM			
Fire Shutdown	When RTU shuts down, zone dampers close and terminal fans are stopped.	Activated by a binary input from a fire marshal panel or smoke detector. RTU shuts down and closes outdoor air dampers.	RTU shuts down. Terminals react based on initial commissioning script.
Smoke Purge **Zone Pressurization** **Smoke Evacuation**	For smoke purge or pressurization, all supply air dampers are modulated to deliver the maximum cooling airflow to the zone. Smoke evacuation mode causes all supply air dampers to fully close and the terminal fan to stop.	Economizer, power exhaust, and supply fan responses vary based on the RTU controller.	Terminals react based on initial commissioning script. Commonly not utilized without extensive building controls.

ADVANTAGES OF COMMUNICATING VAV SYSTEMS

Digitally connected VAV system components can provide several functional and operational benefits that cannot easily be achieved with other types of VAV systems.

Energy Savings

This digitally linked communicating functionality can lead to lower system energy consumption as a result of these linked control strategies:

- Reduced fan power through dynamic static pressure reset
- Lower ventilation rates provided by DCV to match actual building occupancy
- Various indoor fan operating modes to meet occupant operating energy needs
- Dynamic adjustment of supply air temperature to meet zone needs
- Reduced mechanical cooling energy by utilizing CEC Title 24 economizer Fault Detection and Diagnostics operational methods
- Fewer system operating hours provided by temperature compensated start
- Reduced use of higher cost electric reheat by utilizing central air source gas heat for occupied heating
- Reduction of morning pull down energy by utilizing unoccupied free cooling and temperature compensated morning warm-up and cool-down.

These energy savings strategies may be applied to VAV systems within facilities seeking to lower system energy costs and may also contribute to meeting requirements for LEED certification, as well as ASHRAE 90.1 and IECC requirements.

Enhanced Occupant Comfort

In addition, integrated communicating functionality can provide enhanced occupant comfort as a result of these linked strategies:

- System start based on zone occupancy scheduling and timed override
- Variable indoor fan operating modes to meet occupant comfort needs
- Supply air tempering during economizer operation at low outdoor air temperatures
- Constant building ventilation rates matched to building occupancy during economizer operation
- Use of DCV to satisfy zone IAQ needs
- Dynamic static pressure reset to reduce excessive terminal noise
- Dynamic adjustment of supply air temperature to meet actual zone needs

Carrier's i-Vu® Control System

As Figure 6 shows, Carrier's i-Vu controls can be factory-installed on the VAV rooftop units and are electronically linked to intelligent i-Vu zone controllers that are factory-installed on the Carrier VAV air terminals. Thus, linkage provides an efficient means to communicate, collaborate, analyze, and precisely control the VAV system.

Easy To Operate Controls: Integration for Carrier's VAV systems is simple and easy to apply and operate. Carrier's DDC integrated controls offer these operational advantages:

- Clear language display of air source operating status without any cryptic codes to interpret.
- Linkage is automatically engaged between the air source and zone controllers using a "plug-and-play" technology, reducing installation, set-up and commissioning time.
- Easy-to-read, easy-to-understand display of air source temperatures, pressures, and set points.
- Immediate alarm recognition with clear language alarm and event descriptions. Clear alarm history in each controller without any cryptic codes to interpret.
- On-board equipment diagnostics to minimize service time and maintenance costs.
- Single-source responsibility for control system integration.
- Factory-tested combinations

These advantages lead to easy, simple operation with quick installation and start-up that saves time and money.

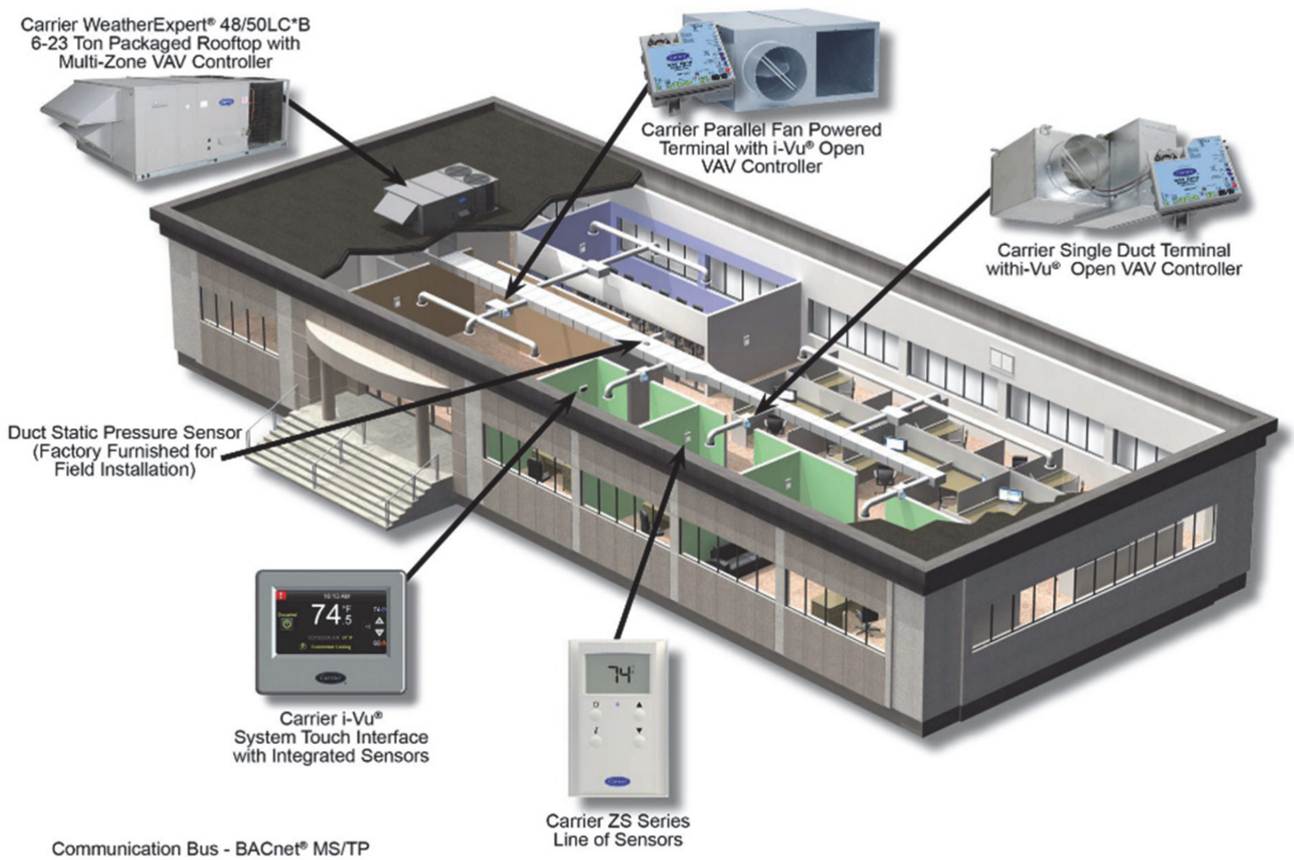

Fig. 6 – Linked VAV System with Carrier i-Vu® Controls

Building Management

To further enhance communication of vital system operating information, the i-Vu® building automation system can provide access and control of the integrated VAV system from anywhere by using a standard web browser, a tablet, or a smart phone. Equipment and system status can be viewed through dynamic equipment graphics and floor plans. These same graphical displays can be used to view and change set point and occupancy schedules.

When staying informed about building conditions is important, the i-Vu® system's powerful building trending and alarm capabilities can be quickly and easily accessed from anywhere internet access is available.

CONCLUSIONS

The communication ability of the zone controller combined with intelligent recognition of optimal air source operation can improve building comfort, minimize system energy consumption, and improve indoor environmental quality. Linkage of the air source and zone components through an integrated digital control system provides all of the aforementioned benefits as well as the flexibility and reliability of installing a Carrier-designed VAV rooftop or air-handling unit.

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