The GreenBook

Green your Building with Airflow Measurement

EBTRON®

Thermal Dispersion Airflow Measurement

Breathe Easier!

Indoor Air Quality

Specify EBTRON thermal dispersion airflow measurement technology on your high-performance buildings

Breathe easier by improving IAQ. It's not only green, but ensuring the comfort and well-being of the occupants makes good business sense since the benefits realized from increased productivity can offset the total cost of energy to operate a building. EBTRON® can provide airflow measurement solutions that result in energy efficient building operation and improved IAQ.

EBTRON® manufactures a full line of airflow measurement devices to meet any application requirement and budget. Take advantage of our more than 25 years of experience in measurement and control. Contact EBTRON® or one of our 80 + independent representatives today. EBTRON® will show you how to use airflow measurement devices to satisfy LEED® credit requirements, save energy and help green your building.

partner in ASHRAE Headquarters renewal

EBTRON® Thermal Dispersion Airflow Measurement

U.S. GREEN BUILDING COUNCIL MEMBER

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INTRODUCTION

Control of HVAC system airflow rates is essential for the successful operation of high performance buildings.

Outside air and building pressure are fundamental to ASHRAE Standard 62.1 compliance; a prerequisite for acceptable indoor air quality (IAQ). Outside air for the dilution of contaminants requires precise monitoring and control of outside airflow rates into the building at each air handling unit. Proper pressurization through control of airflow rates is essential to limit moisture development within the building envelope and for temperature and humidity control.

EBTRON has been a leader producing thermal dispersion airflow measurement products since 1984. Our trained application specialists, combined with an extensive local representative network, assure your designs meet the performance requirements demanded for today's 21st Century buildings.

AIRFLOW MEASUREMENT PRODUCTS

EBTRON airflow measuring devices (AMD) are the result of the Company's more than 25 years of experience manufacturing high-performance thermal dispersion instruments. AMDs are available to measure in ducts or plenums, fan inlets and a range of specialty applications and can interface with any building automation system (BAS).

EBTRON's thermal dispersion technology relates the velocity of the air to the power and rise in temperature of a heated element in a moving air stream. EBTRON uses a precision, bead-in-glass, self-heated thermistor as the heated element and another precision thermistor to measure the ambient air temperature. Multiple sensing points are used to produce an average velocity for true volumetric airflow (CFM or L/s). Each sensing point is individually calibrated at up to sixteen points to NIST-traceable airflow standards. Most models include a temperature output signal.

Unlike differential pressure flow rings or crosses that have very little sensitivity at low air velocities and use "percent of full scale" accuracy pressure transducers, the sensitivity to airflow increases as the flow rate decreases. As a result, accuracy is "percent of reading". Greater sensitivity results in better accuracy, especially with turn-down, compared to differential pressure-based devices and vortex shedders. As a result, the technology is ideal for the measurement of the relatively low airflow rates typically found in most HVAC applications. Long term stability is assured by the selection of high quality thermistors and signal processing components. Unlike pressure-based devices and vortex shedders that frequently require field calibration and auto-zeroing, EBTRON does not recommend periodic calibration of its airflow measuring devices. In fact, there is no auto-zero function in any EBTRON airflow measuring device. It simply is not required.

"NO COMPROMISE" DESIGN

Only the highest quality, stable, bead-in-glass thermistors are used in our airflow and temperature measuring devices.

Waterproof epoxy sensor potting compounds assure long life of sensors, even in the harshest environments.

Gold plated interconnects on all critical electrical connections result in years of trouble-free operation. Switching power supplies reduce heat and energy consumption while increasing the life of the devices.

Electrically isolated output signals protect circuitry and facilitate interfacing to the host BAS.

Space-age alloys and high-tech plastics result in lightweight devices that are cost-effective to ship, easy to install and endure the elements that today's HVAC systems are exposed to.

FEP plenum rated cables remain strong and pliable, even under the extreme temperatures associated with outdoor air intakes.

Kynar® coated wires are abrasion resistant and assure long-life in HVAC environments that are subject to continuous vibration

EBTRON prides itself on manufacturing only the highest quality products. Our "no-compromise" philosophy is evident throughout all of our product lines.

The Advantage product line was originally comprised of two distinct series, the GOLD Series and the SILVER Series. In 2008 the HYBRID Series, combined key features of both. All Advantage products are complete AMDs that include the sensor probes and transmitter. As a result, no additional transmitters or transducers are required to interface with your BAS. This results in single source responsibility with improved accuracy and lower equipment first-cost. Transmitters are available with traditional analog output signals (0-10 VDC/4-20mA) as well as RS-485 (BACnet® MS/TB, BACnet® ARCNET, Modbus RTU, JCI® N2-Bus), Ethernet (BACnet® TCP/IP, Modbus) or Lon®, all at no additional charge.

Which Series is best for you?

Series selection is based on the type of sensor probe, application, interface requirements and budget.

What sensor probe should you use?

AMD sensor probe selection is dependent on your application. Consult EBTRON or your local representative for application engineering and product selection support. AMD sensor probes are available for the following measurement applications:

Duct/Plenum Airflow Measurement (-P Sensor Probes)

Duct/plenum probes are ideal for applications requiring out-of-the-box accuracy. This type of AMD has the most predictable performance when installed in accordance to published placement guidelines. Duct/plenum mounted AMDs are ideal for supply/return (or exhaust) airflow tracking and the direct measurement of outside air intake flow rates. Their versatile probe design allows them to be installed after the duct work is installed.

Fan Inlet Airflow Measurement (-F Sensor Probes)

Fan inlet stations are designed to be installed directly in the inlet of centrifugal and vane axial fans without significantly affecting fan performance. This technology is generally applied when measurement in ducts or plenums is not feasible do to placement limitations or excessive branch ducts at the AHU.

Application Specific Airflow Measurement

EBTRON manufactures application specific AMDs for small ducts, classroom unit ventilators and desiccant wheel energy recovery ventilators.

Sensor Probe Compatibility	**GOLD**	**HYBRID**	**SILVER**
Max Sensors	16	4	2
Max Probes (dependent of sensor type)	4	4	2
User Interface			
16 Character Alpha-numeric LCD Display	•	•	
Display Individual Sensor Airflow & Temperature	•	•	
Push-button User Interface	•	•	
Dip Switch User Interface			•
EB-Link Infra-red Interface to PDA	•		
BAS Interface			
Linear 0-10 VDC/4-20mA (isolated from main circuit)	•	•	
Linear 0-10 VDC/4-20mA (isolated from 24 VAC)			•
RS-485 (BACnet ARCNET)	•		
RS-485 (BACnet MS/TP, Modus RTU, JCI-N2-Bus)	•	•	
RS-485 View Individual Sensor Values	•	•	
Ethernet (BACnet-Ethernet, BACnet-IP, Modbus TCP, TCP/IP)	•		
LonWorks Free Topology Interface	•		
Special Functions			
Field Cal Wizard		•	
"Live" or "Coefficient" Digital Offset/Gain Adjustment	•	•	
Digital Gain Adjustment Control			•
Output "Rate of Change" Dampening Filter	•	•	
Variable Output Integration		•	
Low Limit Airflow Cutoff	•	•	
Velocity Weighted Temperature Output	•	•	
Transmitter Circuitry and Construction			
Gold Cable Receptacle Pins	•		
Circular DIN Receptacle		•	•
Switching Power Supply	•	•	
UL Listed	•	•	•

LEED® CERTIFICATION

Based on LEED 2009 for New Construction, Schools and Core & Shell.

Today's society is keenly interested in developing and supporting the green initiative. EBTRON products can help in obtaining a number of LEED® points, either directly or indirectly, and are an essential component of any green, high performance building.

Measurement for monitoring and/or control is a prerequisite for the effective and efficient operation of today's high performance buildings. Failure to provide measurement devices for monitoring and control of critical building systems can result in reduced energy efficiency, occupant health and building longevity.

EBTRON products can make a difference in a building's performance.

EA Prerequisite 1 – Fundamental Commissioning

Prerequisite 1 in Energy and Atmosphere (EA) requires that a building has a commissioning authority and plan. That plan shall provide a means to verify the installation and performance of the systems to be commissioned.

The HVAC system is one of the primary energy-related systems that require commissioning. A number of parameters verifying the performance of this system can be documented using EBTRON products.

EBTRON CAN HELP YOU ACHIEVE LEED CERTIFICATION

Airflow measurement can be invaluable when designing for LEED certification. A single AMD can have a cascading effect on multiple LEED points. One credit in particular, IEQ Credit 1, provides one point for measuring outside air intake flow rates to all low occupant density spaces Credits that can be impacted by the use of EBTRON AMDs include:

- EA Prerequisite 1 – Fundamental Commissioning
- EA Prerequisite 2 – Minimum Energy Performance
- EA Credit 1 – Optimize Energy Performance
- EA Credit 3 – Enhanced Commissioning
- EA Credit 5/5.1/5.2 – Measurement, Verification & Submetering
- IEQ Prerequisite 1 – Minimum IAQ Performance
- IEQ Prerequisite 2- Environmental Tobacco Smoke Control
- IEQ Prerequisite 3- Minimum Acoustical Performance
- **IEQ Credit 1 – Outdoor Air Delivery Monitoring**
- IEQ Credit 2 – Increased Ventilation
- IEQ Credit 3/3.1/3.2 - Construction IAQ Management Plan - Construction and Occupancy
- IEQ Credit 5 – Indoor Chemical & Pollutant Source Control
- IEQ Credit 6/6.2 – Controllability of Systems - Thermal Comfort
- IEQ Credit 7/7.1/7.2 - Thermal Comfort - Design & Verification
- IEQ Credit 9 - Enhance Acoustical Performance
- IEQ Credit 10- Mold Prevention
- ID Credit 1 - Innovation in Design

Permanently installed EBTRON airflow/temperature monitors can verify that the building performance meets the Owners Project Requirements (OPR) and the Basis of Design (BOD). These techniques improve quality control by eliminating field measurement error while providing permanent documentation of critical parameters. In addition, permanently mounted AMDs can result in more cost effective monitoring (faster, more frequent intervals) and can be used for additional functions, such as control to improve building operation (and obtain additional LEED® points). Commissioning can be achieved using AMDs as follows:

1. Balancing:

    a. Set fan sheaves to obtain design flow rates of fan systems.

    b. Set variable frequency drive maximum and minimum speeds.

    c. Balance energy recovery ventilator intake and exhaust flow rates for proper ventilation and pressure control.

    d. Set damper minimum/maximum positions on modulating dampers or set fixed damper positions on manual damper systems.

2. Verification of equipment operation:

    a. Verify the operation of fans, motors, belts and variable frequency drives.

    b. Verify the operation of dampers and actuators.

3. Verification of performance:

    a. Verify energy consumption using both the airflow rate and temperature from the AMD.

    b. Verify design supply airflow rates at each air handler, floor and/or zone.

    c. Verify design discharge air temperature of heating/cooling coils when AMDs are installed downstream of coils.

    d. Validate coil performance by indicating the velocity and/or temperature profiles downstream of coils.

    e. Verify minimum and maximum outside airflow rates are achieved during operation.

    f. Verify pressurization at each specified pressure compartment (i.e. building, floor, zone, etc.) by monitoring airflow supply/return or supply/exhaust differentials.

EA Prerequisite 2 – Minimum Energy Performance

Prerequisite 2 requires establishment of the minimum level of energy efficiency for the buildings and systems to reduce the environmental and economic impact of excessive energy use via Whole Building Energy Simulation or the applicable ASHRAE Prescriptive Compliance Path.

<u>Minimum Outside Air Control</u>

EBTRON's duct or plenum AMDs are essential for the control of minimum outdoor air flow rates. On most systems, intake flow rates will vary dramatically as a result of damper hysteresis, transient wind pressure, stack effect and changes in mixed air plenum pressure (VAV systems). Simply resetting a damper or outside air fan to the same minimum position/speed may not result in maintenance of the desired setpoint. EBTRON testing has shown that the intake error associated with any one of these factors can result in intake fluctuations in excess of 30%. Cumulative errors are even greater. These uncertainties are not properly taken into account in most building energy models and as a result buildings may not perform as well as model predictions. The uncertainties are real, and significant benefits can be realized by monitoring and controlling minimum outside air intake levels on ALL systems, regardless of model predictions.

<u>Improved Air-side Economizer Control</u>

ASHRAE 90.1-2007 requires modulating air-side economizers. Control of air-side economizers is often very poor since most strategies rely solely on damper position and reset to achieve the desired mixed air or supply air temperature setpoint. Poor control results in lower energy efficiency. Economizer performance can be significantly improved by resetting the outside air intake setpoint between the minimum and maximum outside

air intake flow rates. This can be achieved on systems with full size or min./max dampers using EBTRON's duct or plenum AMDs. This strategy results in more stable temperature control while assuring that minimum intake rates are met and never exceeded. Proper economizer temperature control is analogous to VAV box space temperature control on pressure independent systems that reset the flow setpoint rather than the damper position directly to improve space temperature control and assure minimum and maximum ventilation rates. Implementing this strategy allows for sequencing of dampers, which results in lower pressure drop of AHU dampers, hence less fan energy. The integral temperature output can be used for high limit shutoff control in areas where use of dry-bulb temperature is acceptable. When supply and return (and/or exhaust) airflow measurement is added, net building pressure will also be maintained. The velocity weighted temperature feature on all GOLD and HYBRID transmitters can improve supply or mixed air temperature measurement accuracy compared to traditional serpentine sensors and should be utilized whenever possible.

Increased Efficiency of Exhaust Air Energy Recovery Ventilators (ERV)

ERV energy performance (and proper building pressure) requires that intake and exhaust rates are properly balanced. As with any outside air system, flow rates are significantly influenced by wind and stack pressures as well as mixed air plenum pressure variations on VAV systems. Units are often oversized and require adjustment in the field. On desiccant wheel ERVs, filters load on the intake side faster than they do on the exhaust side. The imbalance in filter loading results in decreased intake flow rates when compared to the exhaust. EBTRON manufactures desiccant wheel ERV intake/exhaust airflow measurement stations designed to solve this problem.

EA Credit 1 – Optimize Energy Performance

EA Credit 1 provides up to 21 points for increasing the building's level of efficiency above the baseline prerequisite.

The proper selection of AMDs for both monitoring and control can have a significant impact on the overall energy performance of a building compared to baseline values. Unfortunately, it is difficult to ascertain the actual performance of many of today's systems and sensors in real-world installations. As a result, the benefit of using high-performance AMDs is not always obvious to engineers and owners.

HVAC energy efficiency can be significantly improved by accurately monitoring key airflow rates, such as outside air intake flow rates or by assuring that air-side energy recovery systems are properly balanced and operating at maximum efficiency. Minimum outside air control, improved air-side economizer performance and increase energy efficiency on ERVs is discussed in the section for EA Prerequisite 2 and can be applied to EA Credit 1.

Proper selection of AMDs at the zone level on VAV systems is another area where real-world performance improvements can be realized. EBTRON's ELF-D thermal dispersion AMD and EBTRON's STA102-T thermal dispersion AMD for small ducts can allow for lower supply airflow rates, hence lower duct static pressures (less fan horsepower). Equally important, improved sensor accuracy at maximum turndown can significantly reduce reheat when compared to pneumatic flow technology that is typically used in VAV terminal boxes. It is not improbable for traditional terminal box flow technology to result in 20% or more error with turndown when the uncertainty of the DDC pressure sensor is considered.

EA Credit 3 – Enhanced Commissioning

EA Credit 3 requires additional verification after initial system verification required in EA Prerequisite 1.

The permanently mounted sensors and monitors discussed in EA Prerequisite 1 – Fundamental Commissioning can also be used as part of a long-term "continuous" commissioning plan.

EBTRON AMDs are designed with high quality components and are not subject to drift. Interface flexibility allows for fast and accurate measurement, independent of the BAS.

EA Credit 5/5.1/5.2 – Measurement, Verification & Submetering

EA Credit 5/5.1/5.2 requires ongoing accountability of building energy consumption over time.

The concept of installing measurement equipment for monitoring purposes is often overlooked. In many buildings, monitoring for control is only a subset of the sensors that should be installed so that the overall performance of the building can be monitored and maintained over time. Some examples of where EBTRON monitoring devices could be beneficial over time are as follows:

- Monitor outside airflow rates on fixed minimum and DCV systems with duct or plenum AMDs to make sure that minimum intake flow rates are maintained and DCV systems do not drive intake flow rates above design maximums (i.e. fully occupied levels) or below minimum levels affecting occupant health or building pressure. Monitoring also provides a method to verify that damper actuators, linkage, etc. have not malfunctioned.
- Monitoring for tenant submetering provides a process for corrective action if energy savings are not being met.
- Monitor supply airflow rates to detect filter loading, belt slippage/breakage, etc.
- Monitor "bleed" airflow across critical pressure zones with building/room pressure monitors to verify the integrity of the building envelope, seals and partitions.

IEQ Prerequisite 1 – Minimum IAQ Performance

Prerequisite 1 in Indoor Environmental Quality (IEQ) requires that buildings meet the minimum requirements of the Ventilation Rate Procedure (VRP) of ASHRAE Standard 62.1-2007.

The VRP is very clear; it specifies breathing zone outside air VENTILATION RATES based on space type, occupancy and area.

Low occupant density spaces, such as offices or other spaces having an occupant density less than 25 people per 1,000 square feet, have minimal changes in the specified outside air ventilation rate with typical changes in occupancy. Low occupant density spaces should have a duct or plenum AMD installed in each outside air intake. Minimum ventilation rates should be calculated using the guidelines of the ASHRAE 62.1 Users Manual and maintained during occupied periods. LEED® provides for an additional credit for the direct measurement of outside air intake flow rates in IEQ Credit 1 – Outdoor Air Delivery Monitoring. Demand controlled ventilation (DCV) methods using CO_2 based reset should BE AVOIDED on low occupant density spaces. The uncertainty associated with CO_2 DCV, especially at low occupant densities, cannot assure compliance with the Standard and in most cases will significantly under or over ventilate the space.

The industry trend on high occupant density spaces is to use CO_2 based DCV. Although the concept of resetting the ventilation rates based on CO_2 levels is attractive, the technique is prone to numerous errors that result from steady-state assumptions and measurement error. LEED® provides a point for the use of standalone CO_2 sensors in high occupant density spaces while requiring compliance with ASHRAE 62.1-2007. Unfortunately, CO_2 DCV alone will not meet the requirements of 62.1-2007.

Improved CO_2 methods can estimate the population using AMDs installed in the outside air intake and at each zone (mutlit-zone systems). However, the uncertainties of CO_2 based measurement may not meet the intent of Standard 62.1 or LEED®. More accurate methods to count the population will improve DCV performance and include turnstiles, or electronic counters such as EBTRON's thermal occupancy counter.

IEQ Prerequisite 2- Environmental Tobacco Smoke Control

Prerequisite 2 is designed to minimize exposure of the building occupants and its components to Environmental Tobacco Smoke (ETS).

If Option 2 is chosen, designated smoking rooms/areas must have a dedicated exhaust system to maintain proper pressurization and isolation of ETS.

EBTRON generally does not recommend direct pressure control of fans or dampers. However, in the interest of limiting overall costs, EBTRON recommends that the following pressure control method be used to maintain proper pressurization of smoking rooms/areas:

- Install a "bleed" airflow room pressure monitor between the smoking room and adjacent area.
- Install an automatic door closer on the entry door to the smoking room.
- Control the exhaust fan speed using a variable frequency drive (VFD) and maintain at least 0.02 inches of water gauge negative pressure with respect to the adjacent area.

IEQ Prerequisite 3 - Minimum Acoustical Performance (Schools only)

IEQ Prerequisite 3 is designed to ensure that classrooms are sufficiently quiet to permit effective communication.

HVAC energy efficiency can be significantly improved by accurately monitoring key airflow rates and improved efficiency can result in reduced fan speeds and size and therefore, reduced noise.

IEQ Credit 1 – Outdoor Air Delivery Monitoring

IEQ Credit 1 is designed to provide ventilation system monitoring to help sustain occupant comfort and well-being in accordance with the requirements of ASHRAE Standard 62.1-2007.

<u>Mechanically Ventilated Systems</u>

Low Occupant Density Spaces (under 25 people per 1,000 sq.ft.):

IEQ Credit 1 awards 1 point for installation of a direct airflow measurement device capable of measuring the minimum outdoor air intake flow with an accuracy of +/- 15% of the design minimum outdoor air rate as defined by ASHRAE 62.1-2007, for all mechanical ventilation systems where 20% or more of the design supply airflow serves non-densely occupied spaces. The airflow measurement device should be capable of generating an alarm when the airflow values vary by more than 10% from the design values.

This requirement can easily be achieved by using any EBTRON duct or plenum probe (GTx116-P, HTx104-P). Proper model selection is based on the size of the intake, budget constraints and the desired installed accuracy of the system

High Occupant Density Spaces (greater than or equal to 25 people per 1,000 sq.ft.):
Monitor CO_2 levels within all high occupant density spaces.

Changes to ASHRAE Standard 62.1 in 2004 resulted in variable ventilation rates, per person, with changes in occupancy. As a result, a single CO_2 setpoint can no longer meet the Standard since CO_2 levels, at best, can estimate the amount of outdoor air entering a space, per person. CO_2 must be combined with direct outdoor airflow measurement on all systems, and accurate zone airflow measurement on multi-zone systems to assure compliance with the Standard.

IEQ Credit 1 – Outdoor Air Delivery Monitoring (1 Point)

Provide a direct outdoor airflow measurement device capable of measuring the minimum outdoor air intake flow rate with an accuracy of +/-15% of the design minimum outside air as specified by ASHRAE Standard 62.1-2007. Generate an alarm if the rates are not within tolerance.

IEQ Credit 2 – Increased Ventilation

IEQ Credit 2 is designed to improve IAQ by providing at least 30% more breathing zone outdoor air than required by ASHRAE Standard 62.1-2007.

Breathing zone outdoor air is directly related to occupant productivity and health. When the cost of operating a facility takes into account the cost of employee salaries, it becomes obvious that productivity and health are important criteria when evaluating the overall performance of a building.

Typical employee costs, including salaries and benefits, are up to 50 times the cost of energy to operate a building. A 2% increase in productivity on an individual having an annual salary of $50,000 would equate to a $1,000 benefit per year to an end-user. The 2% increase is conservative. An increase in outdoor air at the breathing zone from 17 cfm to 22.1 cfm (based on the 30% increase required to meet IEQ Credit 2 and default values for office space in Standard 62.1) will cost the end-user between $2 and $10 per year per person, depending on the cost to condition the additional outside air. Clearly, there is a significant benefit to all by fulfilling the requirements of this credit.

Airflow measurement is a prerequisite for ensuring that ventilation rates specified by ASHRAE Standard 62.1 are delivered to the breathing zone in both low and high occupant density spaces.

IEQ Credit 3/3.1 – Construction IAQ Management - During Construction

IEQ Credit 3/3.1 is designed to reduce IAQ problems resulting during the construction/renovation processes.

Pathway interruption requires that the work area is negatively pressurized to minimize the migration of construction site contaminants. Depending on the type(s) of systems used in the construction and occupied zones, the use of AMDs to provide compartmentalized pressure control is essential.

In addition, verification of proper pressurization between construction and occupied zones can be accomplished by using one of EBTRON's "bleed" airflow sensors. These devices can be used as either permanent monitors or be removed and used on subsequent projects.

IEQ Credit 3.2 – Construction IAQ Management Plan - Before Occupancy

IEQ Credit 3.2 is designed to reduce indoor air quality problems resulting from the construction/renovation process prior to occupancy.

<u>Option 1 – Flush-out</u>

Requires that a total air volume of 14,000 cu.ft. of outside air per sq.ft. (while maintaining 60° F and relative humidity no higher than 60%) of floor area is provided to flush-out contaminants. This volume of air can be provided prior to occupancy or during occupancy during a "flush-out period" as specified by the requirement.

By installing AMDs to meet the requirements of IEQ Prerequisite 1 and IEQ Credit 1 you will already have provided the instrumentation required to meet this credit if the flush-out will be accomplished using the existing HVAC system. Simply use the outside air AMD to totalize the volume of air provided during the flush-out periods until the required air volume is achieved.

IEQ Credit 5 – Indoor Chemical & Pollutant Source Control

IEQ Credit 5 is designed to minimize the exposure of building occupants to hazardous particulates and chemical pollutants.

In addition to proper filtration, chemicals and hazardous particulates must be contained within boundaries as a result of proper, compartmentalized pressure control. Compartmentalized pressure control is most effectively accomplished by volumetric airflow control and/or tracking using accurate AMDs. Validation can be accomplished by monitoring pressure between critical pressure zones with "bleed" airflow sensors.

IEQ Credit 6/6.2 – Controllability of Systems

IEQ Credit 6/6.2 requires that a high level of thermal comfort control be provided to individual occupants or groups of occupants sharing spaces.
If local thermal comfort adjustments made by the occupants result in changes to the supply ventilation rates to the space, a cascading effect on system performance will result without proper monitoring and control. On VAV systems, this is generally understood (although often ignored). However, many other systems will also have significant changes in system performance. Examples of such systems include: under-floor systems with manually adjusted floor diffusers, constant volume systems that allow for local changes in supply flow rates to adjust space temperature and cycling heat pump systems without a dedicated outside air system.

On these systems, changes in the space temperature setpoint that change supply airflow rates will alter the breathing zone outdoor air. It may also affect coil performance, building pressure and humidity control. As a result, the following airflow rates should be monitored and controlled:

- Outdoor air intakes: Intake flow rates will change with changes in supply air volume if not monitored and controlled as a result of changing pressures in the mixing box. Uncontrolled intake flow rates can result in the inability of the system to maintain space temperature and humidity as a result of too much outside air (insufficient capacity to handle the latent load) or too little outside air (uncontrolled infiltration of high dew point outside air through the building envelope).

- Supply air: Supply airflow rates affect a system's ability to provide proper temperature and humidity control. Systems that allow occupant control of supply airflow rates to modify space temperature should, at a minimum, include supply airflow measurement high and low limit alarms.

- Return (or exhaust) air: If supply airflow rates are varied, building pressurization could be affected since the supply/return or supply/exhaust differential flow rate is directly related to building/space pressure. When combined with supply airflow measurement, return (or exhaust) airflow measurement can be used for airflow tracking to assure proper building pressure control, a prerequisite for proper space temperature and humidity control.

- Zone air: Supply registers only operate effectively over a specified range of airflow rates. EBTRON AMDs can drastically improve zone flow performance and thermal comfort by limiting minimum and maximum supply flow rates and setting alarms when applicable.

IEQ Credit 7/7.1 and 7.2 – Thermal Comfort – Design/Verification

IEQ Credits 7/7.1 and 7.2 require that a high level of thermal comfort be provided for the occupants.

When it comes to thermal comfort, proper control of airflow rates is an essential prerequisite. Generally, airflow rates cannot be properly maintained during operation without monitoring and feedback control.

The critical airflow rates that should be monitored and/or controlled to assure proper thermal comfort are as follows:

- Outdoor air intakes: Uncontrolled intake flow rates can result in the inability for the system to maintain space temperature and humidity as a result of too much outside air (insufficient capacity to handle the latent load) or too little outside air (uncontrolled infiltration of high dew point outside air through the building envelope).

- Supply air: Improper airflow rates will result in poor coil performance and discharge air temperature/humidity control.

- Return air: When combined with supply airflow measurement, return airflow measurement can be used for airflow tracking to assure proper building pressure control, a prerequisite for proper space temperature and humidity control.

- Zone air: Supply diffusers only operate effectively over a specified range of airflow rates. On VAV systems, measurement error (drift, low flow uncertainty) from traditional pneumatic airflow measurement devices cannot assure that the optimal range of flows are delivered, thus resulting in very poor diffuser performance and thermal comfort. EBTRON AMDs can drastically improve VAV zone flow performance. As an added benefit, accurate, thermal dispersion zone airflow measurement can also reduce wasted reheat, lower supply airflow rates at the box (lower duct static pressure) and improve DCV performance.

IEQ Credit 9 - Enhanced Acoustical Performance (Schools)

IEQ Credit 9 is designed to provide classrooms that are quiet to allow for effective communication.

HVAC energy efficiency can be significantly improved by accurately monitoring key airflow rates and improved efficiency can result in reduced fan speeds and size and therefore, reduced noise.

IEQ Credit 10 - Mold Prevention (Schools)

IEQ Credit 10 is designed to reduce the potential presence of mold in schools through preventative design and construction.

Accurately monitoring and controlling key airflow rates can result in proper building pressurization which could prevent the infiltration of moisture into the building envelope thereby reducing the potential for mold growth and water damage.

■ ASHRAE STANDARD 62.1-2007

ASHRAE 62.1 2007, *Ventilation for Acceptable Indoor air Quality*, is the industry standard defining ventilation rates of outside air required to provide acceptable IAQ. The Standard has two procedures, the VRP and the IAQ Procedure, which engineers and building owners must select only one for compliance. The IMC, 2006 & 2009 LEED® and many local codes reference the VRP for compliance. Both the VRP and IAQ Procedure specify ventilation rates for IAQ.

Because the IAQ Procedure has many subjective components, the use of the VRP is typically recommended by EBTRON. However, the IAQ Procedure can be extremely useful when used in conjunction with the VRP on contaminants that are present and detectable in buildings above threshold limits. However, when this is done, the minimum ventilation rates specified by the VRP must be maintained.

The VRP specifies breathing zone outside air based on space use, floor area and occupancy and the optimal design is dependent on whether the system is single or multi-zone and low or high occupant density.

Single Zone, low occupant density

Low occupant density spaces typically have occupancy levels greater than 70% of the maximum expected occupancy. For a typical office space, a reduction in occupancy of approximately 30% will only result in a decrease in the required outside air of 10%. The outside air reduction of 10% is well under the uncertainty of most DCV techniques, therefore eliminating the application of DCV on this type application.

For low occupant density, single zone spaces, the minimum outdoor airflow rates should be set to maintain or exceed the minimum requirements specified by the VRP of ASHRAE Standard 62.1 for the maximum expected occupancy. Note that the maximum expected occupancy for a space's current use may be less than the design occupancy of the space.

Install a permanently mounted, EBTRON duct or plenum AMD in the minimum outdoor air intake to monitor and/or control minimum outdoor airflow rates.

Multi-zone, low occupant density

As is the case with low occupant density single zone systems, there is little benefit of implementing DCV on this type of system.

For low occupant density, multi-zone spaces, the minimum outside airflow rates should be set to maintain or exceed the minimum requirements specified by the VRP of ASHRAE Standard 62.1. ASHRAE provides an easy to use Microsoft Excel spreadsheet for the determination of minimum ventilation rates with the ASHRAE 62.1-2007 User's Manual, available for sale from ASHRAE.

On multi-zone systems, the percentage of outdoor air required from zone to zone will typically vary as a result of varying thermal loads between zones. As a result, there will be at least one zone that requires more outdoor air as a percentage of the supply air than the others. This is known as the critical zone.

Critical zone fractions that are considerably higher than surrounding zones can have a dramatic impact on minimum ventilation rate required. This is especially true on multi-zone, mixed occupant density spaces having small, variable occupancy conference rooms. When one zone has a disproportionately high critical zone fraction, consideration for increasing the supply flow rate, providing recirculated plenum air or a installing a dedicated outdoor air system to the zone should be considered.

On some buildings, calculating the minimum ventilation rate based on seasonal load changes may result in some savings on minimum ventilation rates.

Install a permanently mounted, EBTRON duct or plenum AMD in the minimum outdoor air intake to monitor and/or control minimum out airflow rates.

Single Zone, high occupant density

High occupant density spaces typically, but not always, have significant changes in occupancy throughout the day. When an occupancy change results in a reduction of the required outdoor airflow rate by more than 10%, there is motivation to use some type of DCV strategy to reduce energy consumption.

DCV is compelling, but not always effective, as a result of uncertainties in the technique used to estimate changes in occupancy. The following methods may be used for DCV. Care should be taken when implementing any of these strategies and one should not forget that the core mission in providing outdoor air is to improve occupant satisfaction and well-being. EBTRON has developed an *ASHRAE 62.1 BACnet DCV Calculator* that can calculate the setpoint required for compliance with any of the DCV methods indicated below, thus eliminating overhead required making the cumbersome calculations by the host control system.

In all cases, install a permanently mounted, EBTRON duct or plenum AMD, in the minimum outdoor air intake to control minimum outdoor airflow rates.

CO_2-Based DCV

Changes implemented in 2003 to the VRP by *addendum n* redefined how CO_2 DCV could be used for compliance. CO2 levels do not directly indicate population as many incorrectly assume. At best, CO_2 levels indicate the rate that outdoor air is entering a space per person (OA cfm/person).

One method to use CO_2 is to monitor the differential CO_2 (ΔCO_2) level between the outside and interior space. Assuming steady-state and the default CO_2 production rate, typically that for office work, the ΔCO_2 level has a corresponding outside airflow rate for a given population (a transient-state model can also be applied). Reset the outdoor air setpoint to the calculated setpoint between minimum and design maximum population values. By resetting the outdoor air setpoint in this manner, the control system can adjust to changes in population. This method can be simplified using the straight-line approximation suggested by Stanke. Regardless of the method used, one should exercise extreme caution in relying on CO_2 DCV for Standard compliance since the uncertainty of this DCV technique is extreme and not generally understood by most users. In many cases CO_2-based DCV will under or over ventilate by more than 50%.

Another method uses the ΔCO_2 level between the supply air and zone. This differential is generally very small and sensor error becomes a significant factor. To minimize sensor error, a single sensor with sampling capabili-

THINK OUTSIDE THE BOX

The VRP requires that the application/use, floor area, supply airflow and occupancy of each zone be known to determine the ventilation rate required to satisfy the standard in "real-time".

Don't forget to take advantage of the counting systems that may already be in place in your facility when selecting a DCV system. Direct counting has far less uncertainty than CO_2 based strategies. Several examples of counting systems that may present but not part of your DCV strategy include the following:

- Computer logons of employees at their workstation
- Turnstile counters in arenas, theatres, etc.
- Electronic time card systems
- Video imaging counters for occupancy monitoring in large gathering areas (casinos, exhibition halls, etc.)

ties should be used to sample both the supply and space CO_2. This method uses the steady-state (or transient-state) model and the supply airflow rate to the space to estimate the population.

Direct Occupancy Count DCV

Direct occupancy counting systems, such as electro/mechanical turnstiles, thermal and video imaging sensors and other IR devices are a much more reliable method for DCV than its CO_2-based counterpart. On single zone systems, the breathing zone outdoor air is calculated by adding a fixed floor component to the variable occupancy component. Following VRP procedures, the corresponding outdoor air setpoint can be easily calculated and reset.

Scheduling DCV

The use of occupancy/time schedules can be an effective method for DCV. On single zone systems, the breathing zone outside air is calculated by adding a fixed floor component to the scheduled occupancy component. Following VRP procedures, the corresponding outdoor air setpoints can be easily calculated and reset using a time schedule.

Binary (occupied/unoccupied) DCV

Binary detection of occupancy is beneficial when spaces operate at near design occupancy levels (70% or greater) when occupied. In most cases, a simple IR or combination IR/ultrasonic detector is used to determine occupancy. On single zone systems, this technique will set the outside air intake setpoint to fully occupied conditions. This technique should be avoided if the space will be occupied frequently by a one or two people during "unoccupied" periods (example: a teacher stays in a classroom much of the day when the students are not present).

Multi-zone, high occupant density

There is also often justification to reduce the outside airflow rate below design occupancy conditions on multiple zone systems. However, meeting ASHRAE Standard 62.1 specified ventilation rates is not as straight forward since the fraction of outdoor air in the supply air required to satisfy each zone will differ from space to space.

In all cases, install a permanently mounted, EBTRON duct or plenum AMD, in the minimum outdoor air intake to control minimum outdoor airflow rates.

CO2-Based DCV

Multi-zone conditions complicate CO_2 DCV application. Many either ignore the multi-zone requirements of ASHRAE 62.1-2007 and treat multiple zones as a large single zone or use a zone CO_2 sensor to reset zone supply airflow rates and provide reheat. Treating multiple zones as a single zone does not meet the requirements of Standard 62.1 and zone reset will result in wasted reheat.

One method uses zone CO_2 levels and airflow measurement to estimate the population of each zone (or at least of critical zones). Once the population is known for each space, the ventilation rates specified by the Standard for mutli-zone recirculating systems can be established and the correct outdoor air setpoint be maintained based on zone occupancy, zone floor area and zone supply airflow rates. As with all methods relying on CO_2 levels, there is considerable uncertainty in the population estimates as a result of steady-state assumptions, CO_2 production level and CO_2 measurement error.

As with high occupant density, single zone systems the differential CO_2 (ΔCO_2) level between the supply air and zone could also be used to estimate the occupancy of each zone using a single, sampling sensor.

Direct Occupancy Count DCV

Direct occupancy counting systems is perhaps the best method for DVC. Once the population is known for each space, the ventilation rates specified by the Standard for mutli-zone recirculating systems can be established and the correct outdoor air setpoint be maintained based on zone occupancy, zone floor area and zone supply airflow rates.

Scheduling DCV

The use of occupancy/time schedules can be an effective method for DCV. The ventilation rates specified by the Standard for mutli-zone recirculating systems can be estimated and the correct outdoor air setpoint be maintained based on scheduled zone occupancy, zone floor area and zone supply airflow rates.

Binary (occupied/unoccupied) DCV

Binary detection of occupancy is beneficial when spaces operate at near design occupancy levels (70% or greater) when occupied. In most cases, a simple IR motion detector or combination IR/ultrasonic detector is used to determine occupancy. The ventilation rates specified by the Standard for mutli-zone recirculating systems can be established and an approximate outdoor air setpoint be maintained based on maximum zone occupancy, zone floor area and zone supply airflow rates. This technique can be modified to use a ventilation matrix based on design occupancy and load if the space will be occupied frequently by a one or two people during "unoccupied" periods (see previous page).

LOW-RISK BINARY OCCUPANCY DETECTION DCV

The setpoint matrix below was established using ASHRAE 62.1-2007 guidelines on a three room classroom based on all occupancy combinations of either full occupancy (35) or zero occupancy. Binary sensors placed in each classroom would set the outside airflow rate to the outside air setpoint listed in the table (bottom left).

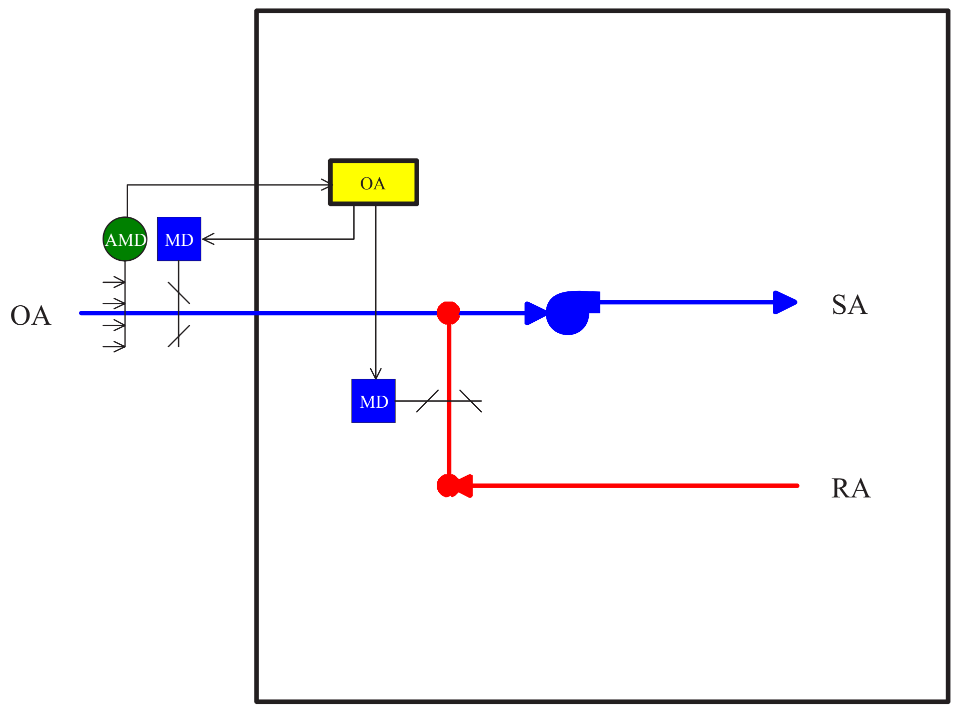
The actual outside air required for a given set of population and load conditions is listed in the table as "OA Required" (bottom right). The actual outside air delivered is listed as "OA Provided". Note that in all cases, the classrooms were adequately ventilated. Although the maximum demand controlled reductions was not achieved, this technique would never have placed the students at risk (our core goal?) as is possible with CO_2 DCV techniques.

Setpoint Matrix			
Rm. 1 Status	Rm. 2 Status	Rm.3 Status	OA Setpoint
OCC	OCC	OCC	1410
OCC	OCC	UNOCC	1035
OCC	UNOCC	OCC	1035
UNOCC	OCC	OCC	1035
OCC	UNOCC	UNOCC	605
UNOCC	OCC	UNOCC	605
UNOCC	UNOCC	OCC	605
UNOCC	UNOCC	UNOCC	0

Actual Conditions				
Rm. 1 Pop.	Rm. 2 Pop.	Rm. 3 Pop.	OA Provided	OA Required
33	28	34	1410	1322
33	28	1	1410	1037
33	3	1	1410	817
2	3	1	1410	425
33	28	0	1305	946
33	0	0	605	578
0	0	0	0	0

CV/VAV

Supply fan only, minimum OA mode



NOTES:

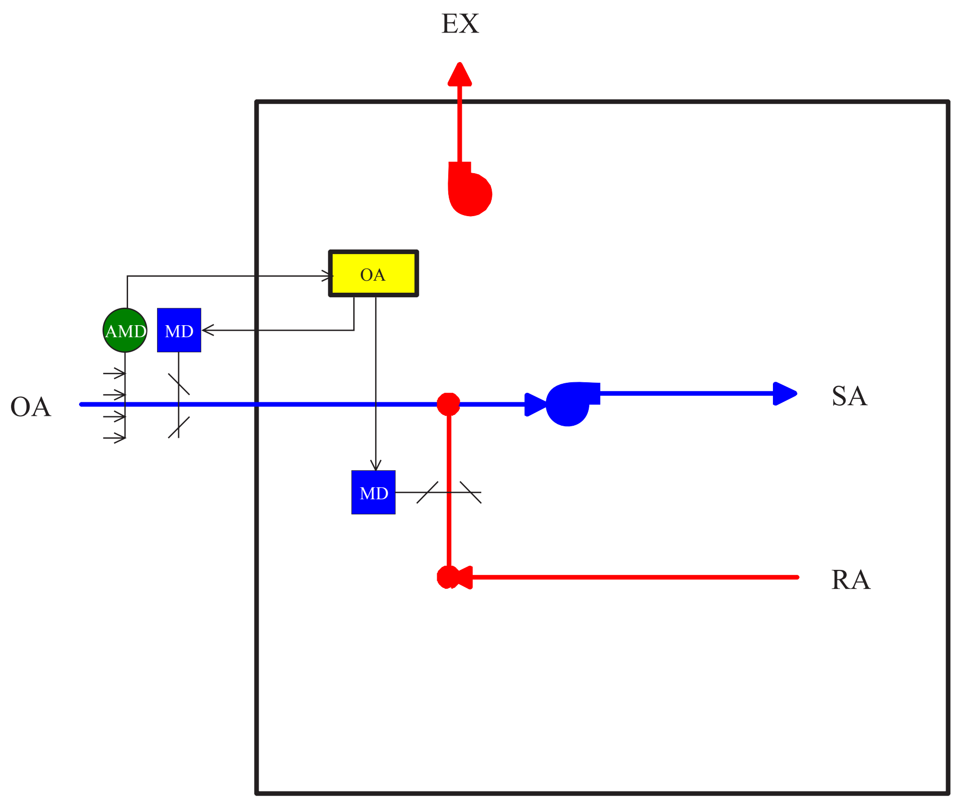
1. Modulate OA and RA dampers in sequence to maintain min. OA.
2. OA=Q_p

COMMENTS:

1. If OA is greater than desired Q_p, system requires exhaust or relief.
2. Not recommended for DCV since building pressure will vary considerably with changes in OA.

CV/VAV

Supply fan with constant exhaust or relief fan, minimum OA mode

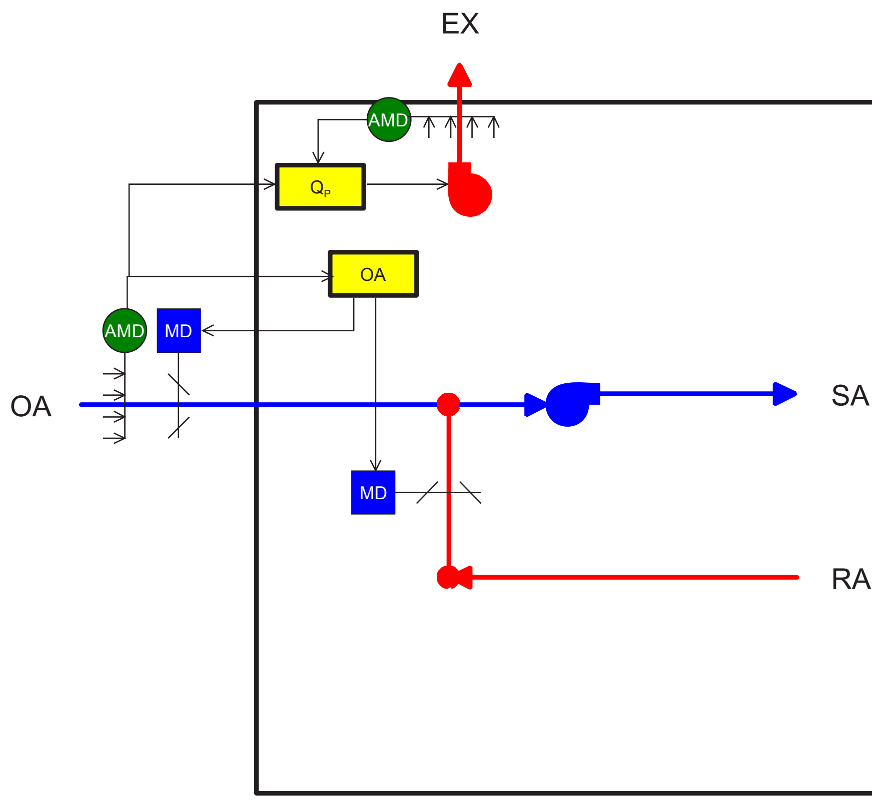


NOTES:

1. Modulate OA and RA dampers in sequence to maintain min. OA.
2. Use air balance measurement or permanently mounted AMD for constant volume exhausts (i.e. toilets).
3. OA-EX=Q_P
4. Not recommended for DCV since building pressure will vary considerably with changes in OA and here is no provision for exhaust airflow reset.

CV/VAV

Supply fan with variable exhaust or relief fan, minimum OA mode

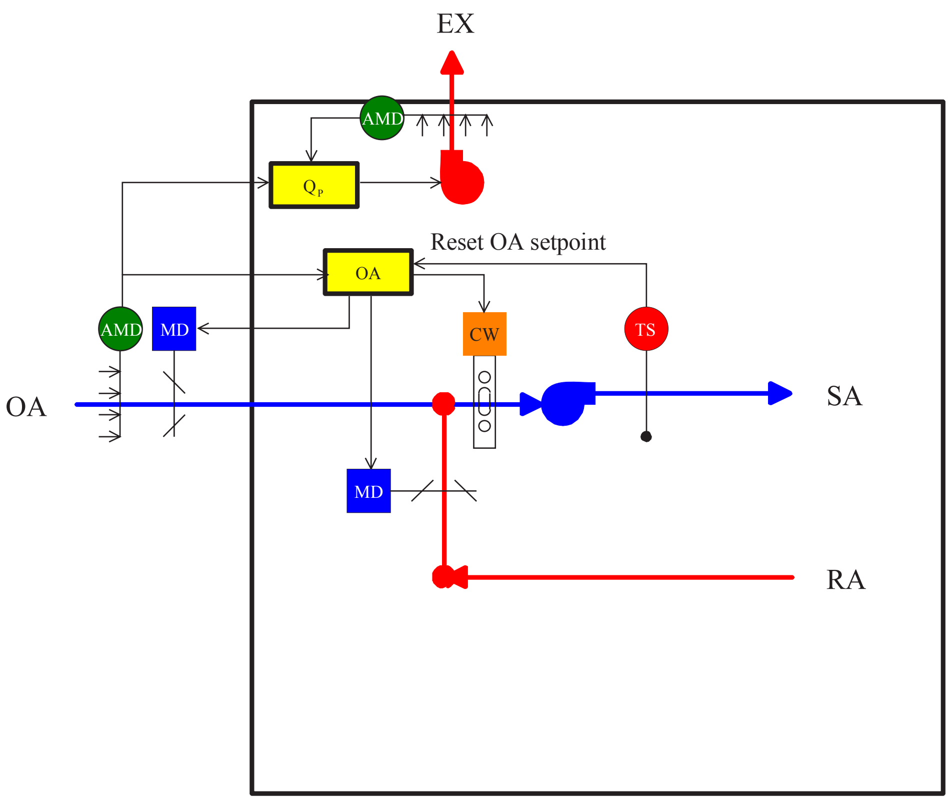


NOTES:

1. Modulate OA and RA dampers in sequence to maintain min OA.
2. OA-EX=Q_P
3. Modulate EX fan to maintain Q_P
4. Caution should be exercised when applying DCV.
    - Do not allow OA setpoint to fall below lowest EX flow.
    - Do not allow Q_P to over-pressurize the building when DCV OA requirements are high.

CV/VAV

Supply fan with variable exhaust or relief fan, modulating economizer



NOTES:

1. Modulate OA, RA dampers and then cooling coil in sequence to reset OA setpoint to maintain supply air temperature.

2. OA setpoint must not fall below minimum required for IAQ /ventilation.

3. OA-EX=$Q_{P.}$

4 .Modulate EX fan to maintain $Q_{P.}$

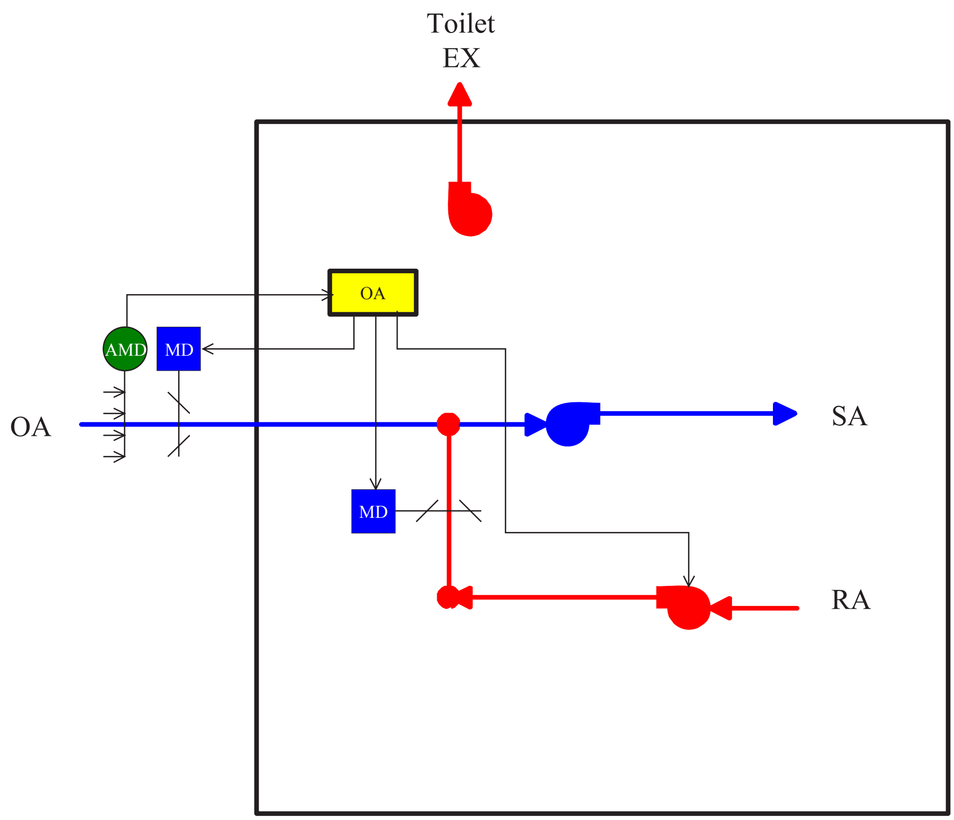
5. Caution should be exercised when applying DCV.

   - Do not allow OA setpoint to fall below lowest EX flow.

   - Do not allow Q_p to over-pressurize the building when DCV requirements are high.

CV/VAV

Supply/Return fan system, minimum OA mode (no relief at AHU)



NOTES:

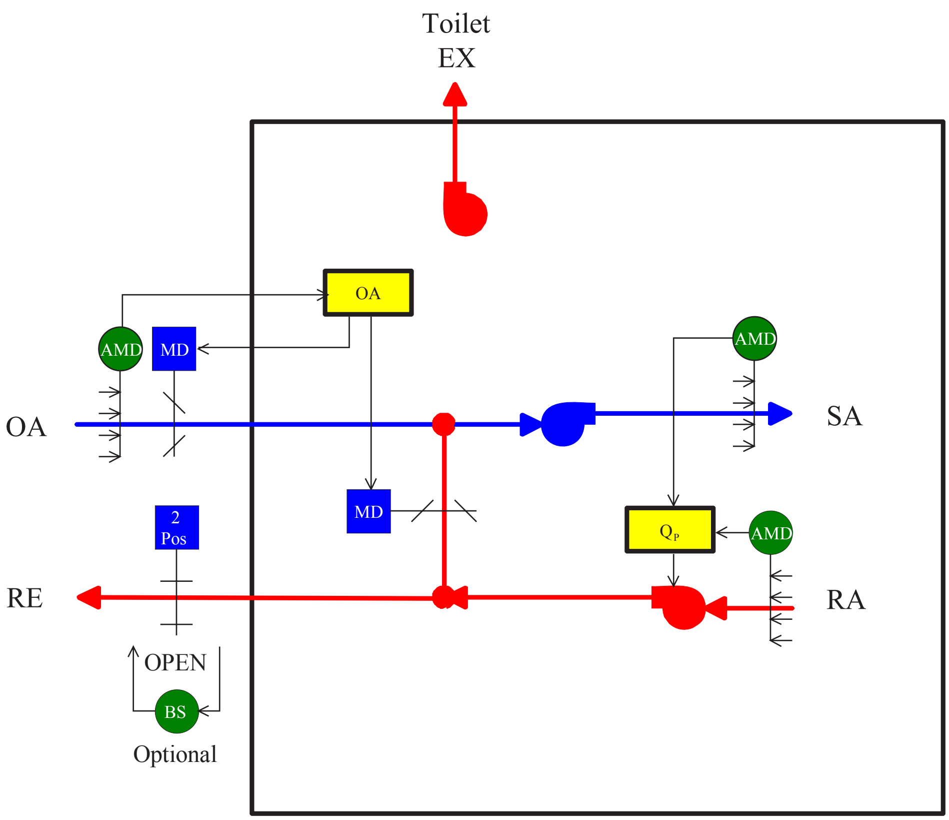
1. Modulate OA damper, RA fan and RA damper in sequence to maintain minimum. OA.
2. OA-EX=Qp

COMMENTS:

1. If OA is greater than desired Qp, system requires exhaust or relief.
2. Not recommended for DCV since building pressure will vary considerably with changes in OA.

CV/VAV

Supply/Return fan system, minimum OA mode (active relief at AHU)

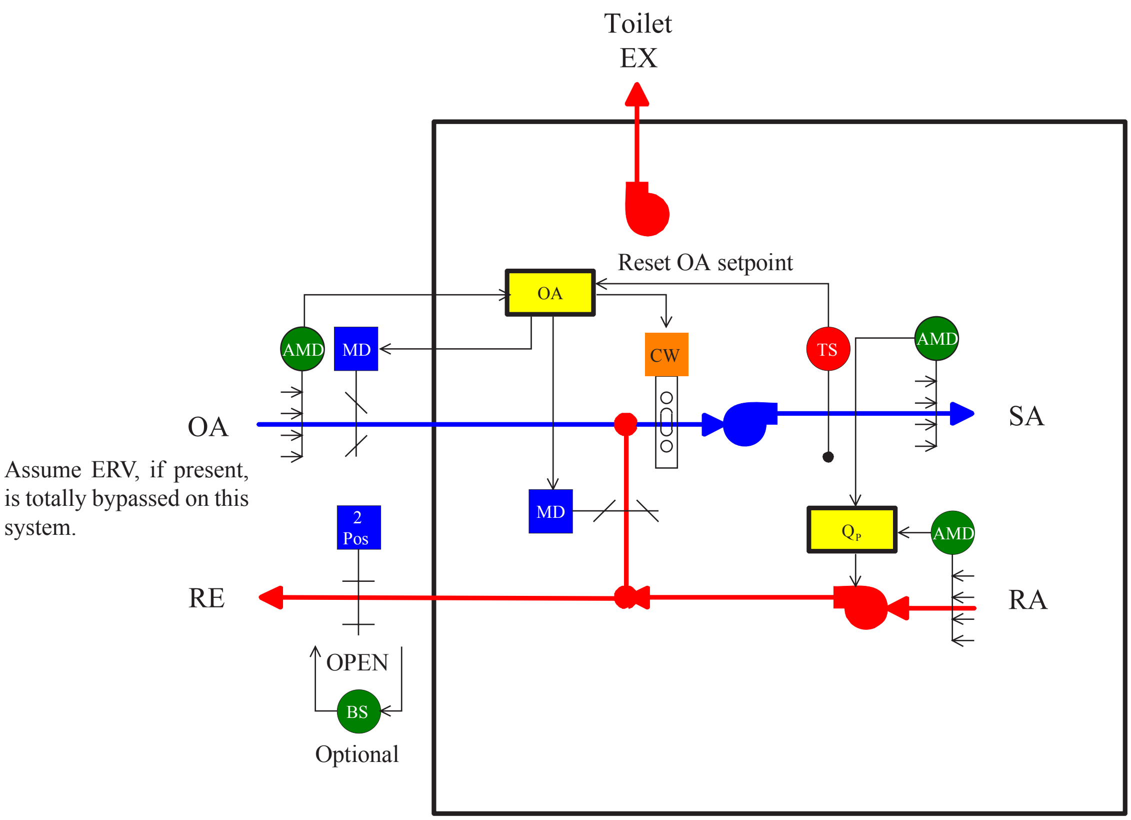


NOTES:

1. Modulate OA and RA dampers in sequence to maintain minimum OA.
2. SA-(RA+EX)=$Q_{P.}$
3. Modulate RA fan to maintain $Q_{P.}$
4. Caution should be exercised when applying DCV.
    - Do not allow OA setpoint to fall below EX flow.
    - Do not allow Q_P to over-pressurize the building when DCV OA requirements are high.

CV/VAV

Supply/Return fan system, modulating economizer

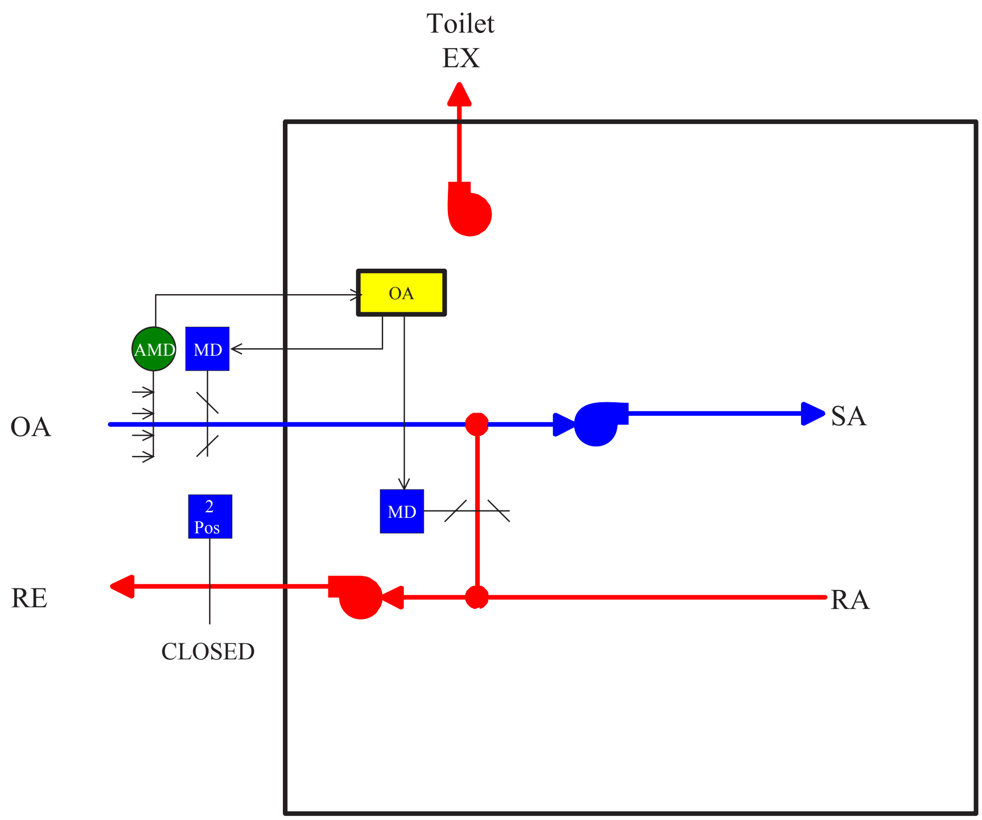


NOTES:

1. Modulate OA - RA dampers and then cooling coil in sequence to reset OA setpoint to maintain supply air temperature.
2. OA setpoint must not fall below minimum required for IAQ.
3. SA-(RA+EX)=Q_P exercised when applying DCV.
4. Modulate RA fan to maintain Q_P.
5. Caution should be exercised when applying DCV.
   - Do not allow OA setpoint to fall below lowest EX flow.
   - Do not allow Q_P to building when DCV requirements are high.

CV/VAV

Supply/Relief fan system, minimum OA mode (no relief at AHU)



NOTES:

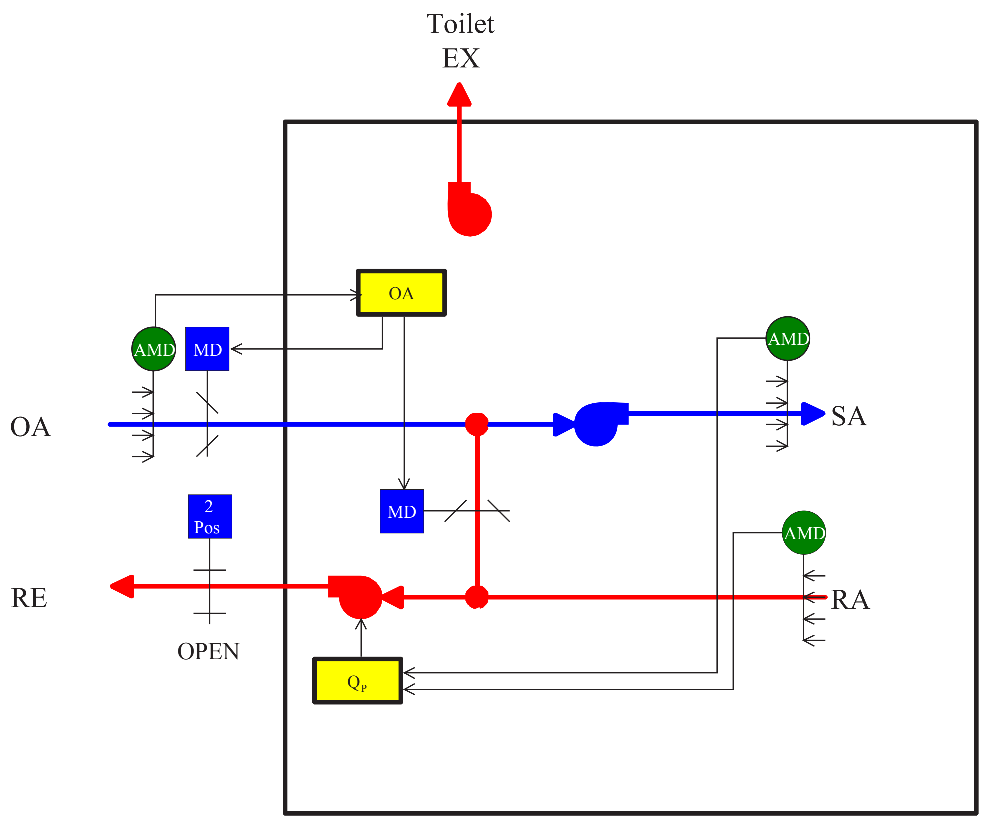
1. Modulate OA damper, RA fan and RA damper (Relief fan and Recirculation damper) in sequence to maintain minimum OA.
2. OA-EX=$Q_{P.}$

COMMENTS:

1. If OA is greater than desired Q_P, system requires exhaust or relief.
2. Not recommended for DCV since building pressure will vary considerably with changes in OA.

CV/VAV

Supply/Relief fan system, minimum OA mode (active relief at AHU)

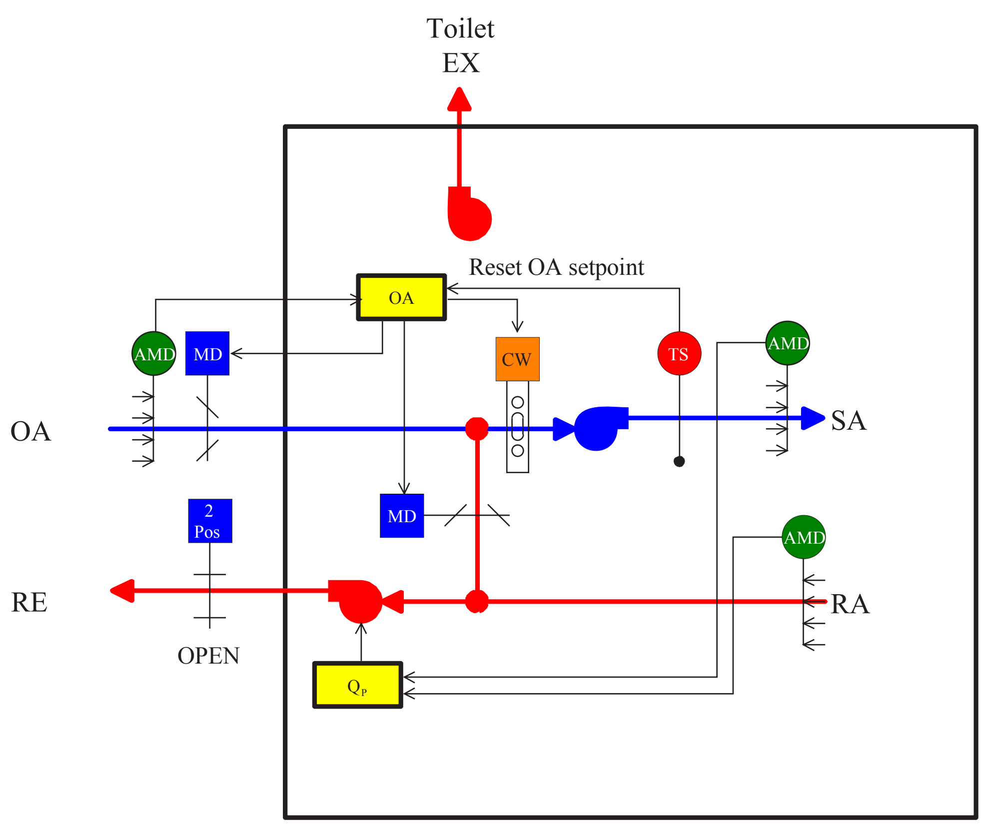


NOTES:

1. Modulate OA and RA dampers in sequence to maintain min OA.
2. SA-(RA+EX)=Q_P.
3. Modulate RE fan to maintain Q_P.
4. Caution should be exercised when applying DCV.
   - Do not allow OA setpoint to fall below EX flow.
   - Do not allow Q_P to over-pressurize the building when DCV OA requirements are high.

CV/VAV

Supply/Relief fan system, modulating economizer

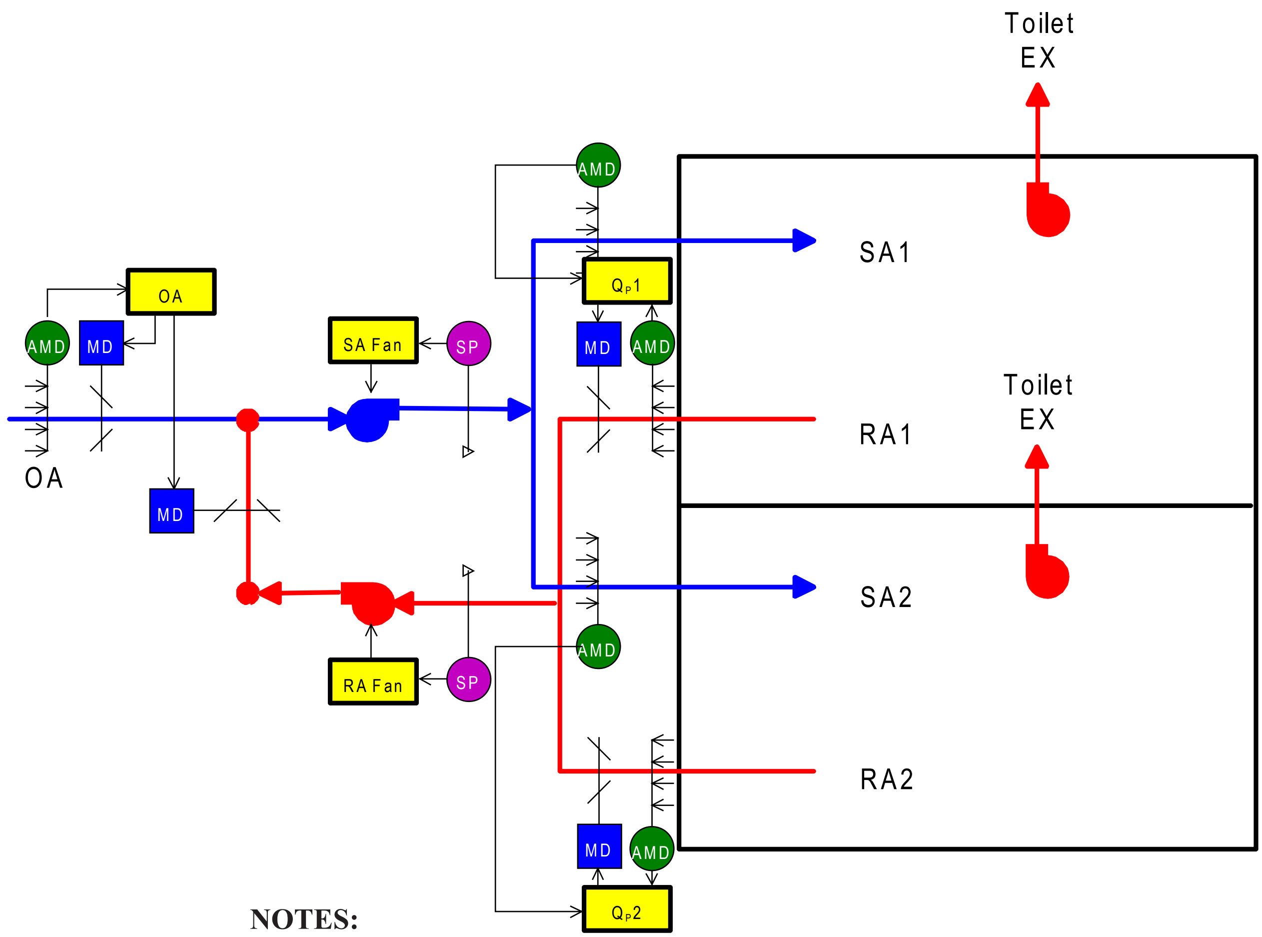


NOTES:

1. Modulate OA and RA dampers then cooling coil in sequence to reset OA setpoint to maintain supply air temperature.
2. OA setpoint must not fall below minimum required for IAQ.
3. SA-(RA+EX)=Q_P
4. Modulate RE fan to maintain Q_P.
5. Caution should be exercised when applying DCV.
    - Do not allow OA setpoint to fall below lowest EX flow.
    - Do not allow Q_P to over-pressurize the building when DCV requirements are high.

CV/VAV

Single Supply/Return serving multi-floor system, minimum OA mode (no relief at AHU)



NOTES:

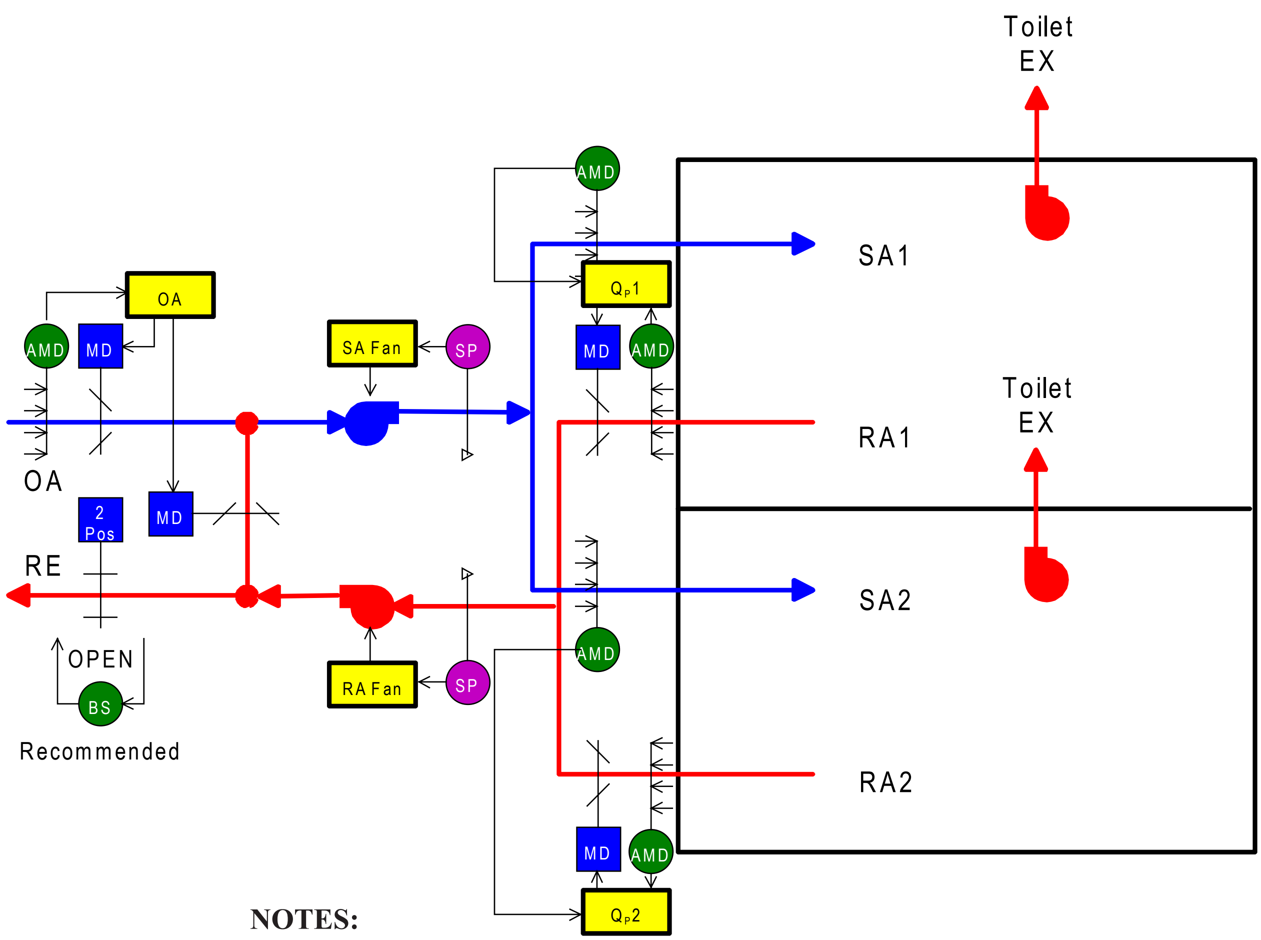
1. Modulate SA and RA fans to maintain duct static (w/reset)
2. Modulate OA and RA dampers in sequence to maintain total OA.
3. SA-(RA+EX)=Q_p at each zone.
4. Modulate RA floor dampers to maintain Q_p for each floor.

COMMENTS:

1. This method compensates stack effect on tight floor to floor construction, and without vertical path for stack flow (i.e. open stairwell, atrium and some elevator shafts).

CV/VAV

Single Supply/Return or Supply/Relief serving multi-floor system, minimum OA mode (active relief at AHU)



NOTES:

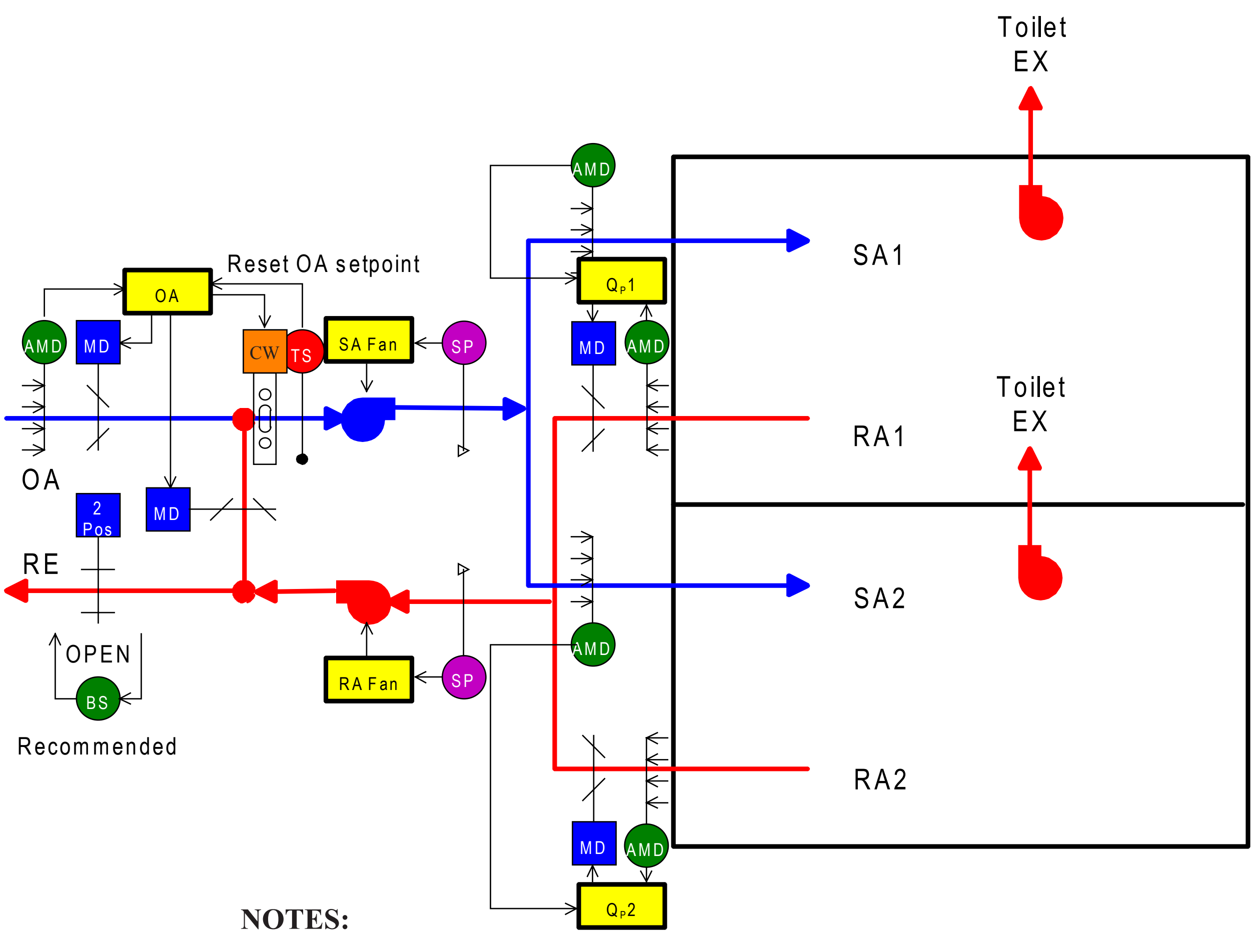
1. Modulate SA and RA (or RE) fans to maintain duct static (w/reset).
2. Modulate OA and RA dampers in sequence to maintain total OA.
3. SA-(RA+EX)=Q_p at each zone.
4. Modulate RA floor dampers to maintain Q_p for each floor.

COMMENTS:

1. This method compensates stack effect on tight floor to floor construction, and without vertical path for stack flow (i.e. open stairwell, atrium and some elevator shafts).

CV/VAV

Single Supply/Return or Supply/Relief serving multi-floor system, modulating economizer



NOTES:

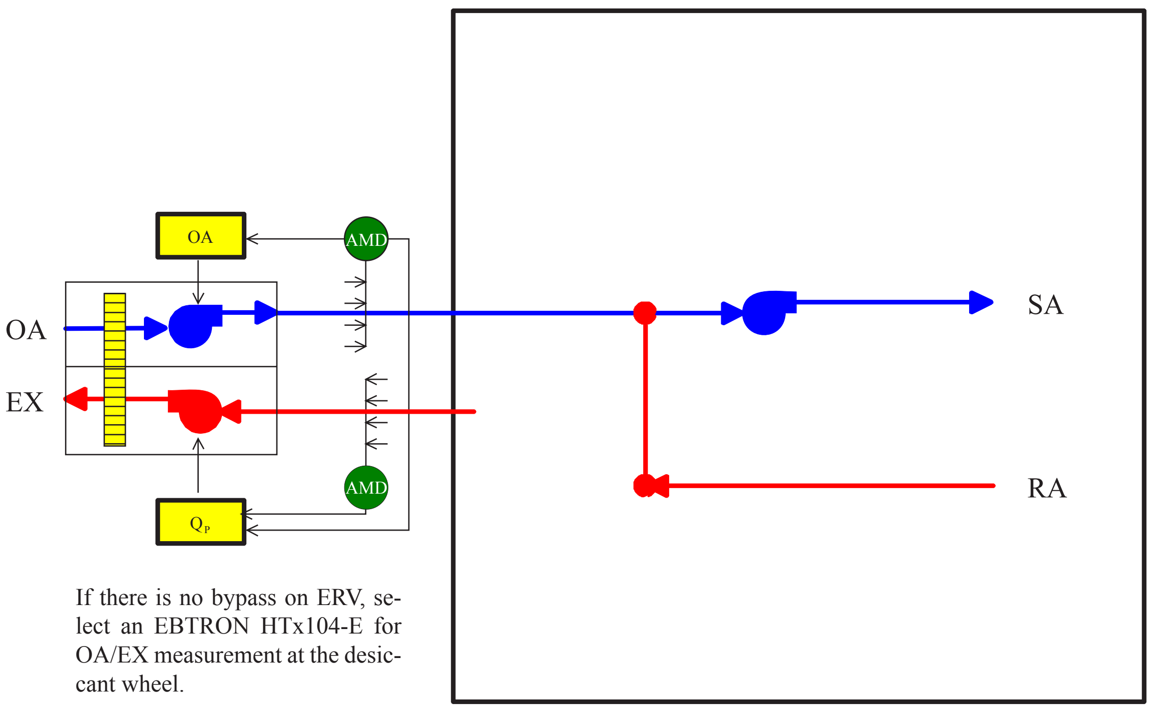
1. Modulate OA and RA dampers then cooling coil in sequence to reset OA setpoint to maintain supply air temperature.
2. Modulate SA and RA (or RE) fans to maintain duct static (w/reset).
3. SA-(RA+EX)=Q_P at each zone.
4. Modulate RA floor dampers to maintain Q_P for each floor.

COMMENTS:

1. This method compensates stack effect on tight floor to floor construction, and without vertical path for stack flow (i.e. open stairwell, atrium and some elevator shafts).

CV/VAV

Systems with minimum OA ERV, minimum OA mode



If there is no bypass on ERV, select an EBTRON HTx104-E for OA/EX measurement at the desiccant wheel.

NOTES:

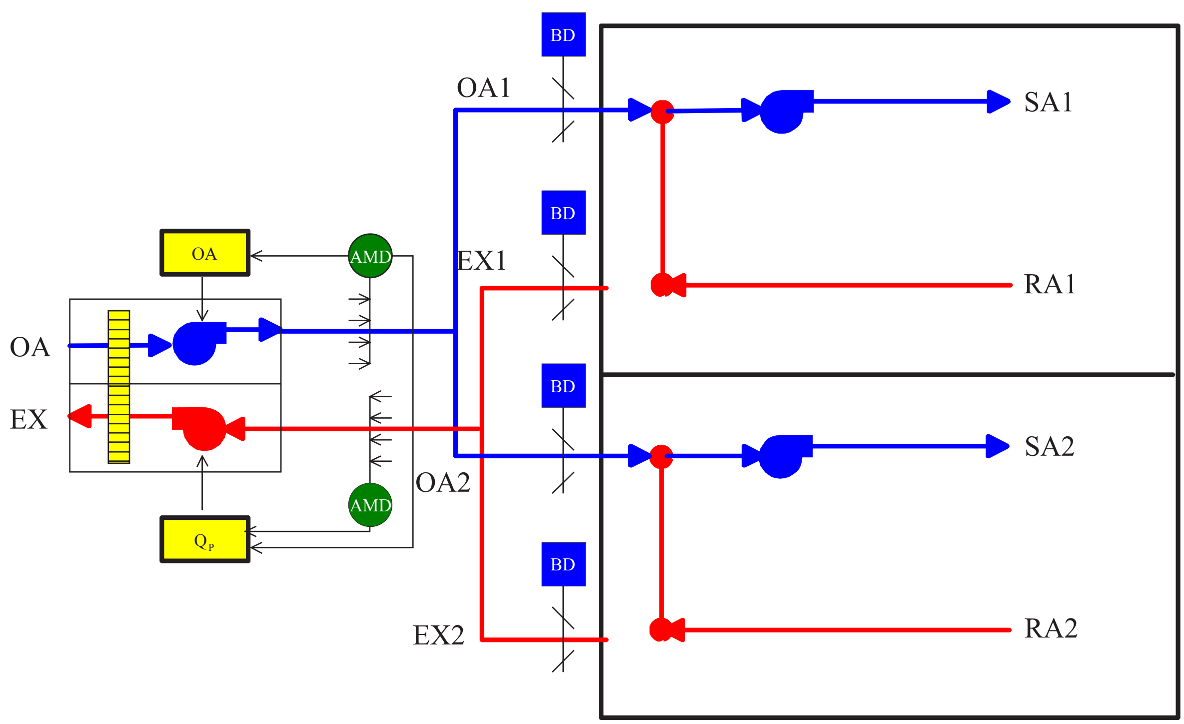
1. Modulate ERV OA fan to maintain min. OA.
2. OA-EX=Q_P
3. Modulate ERV EX fan to maintain Q_P.

COMMENTS:

1. Active control is required to compensate for filter loading, stack, and mixed air plenum pressure (VAV) effects and to partially compensate for wind, on forced makeup or ERV fan system.

CV (multiple AHU's)

Systems with single minimum OA ERV, minimum OA mode



NOTES:

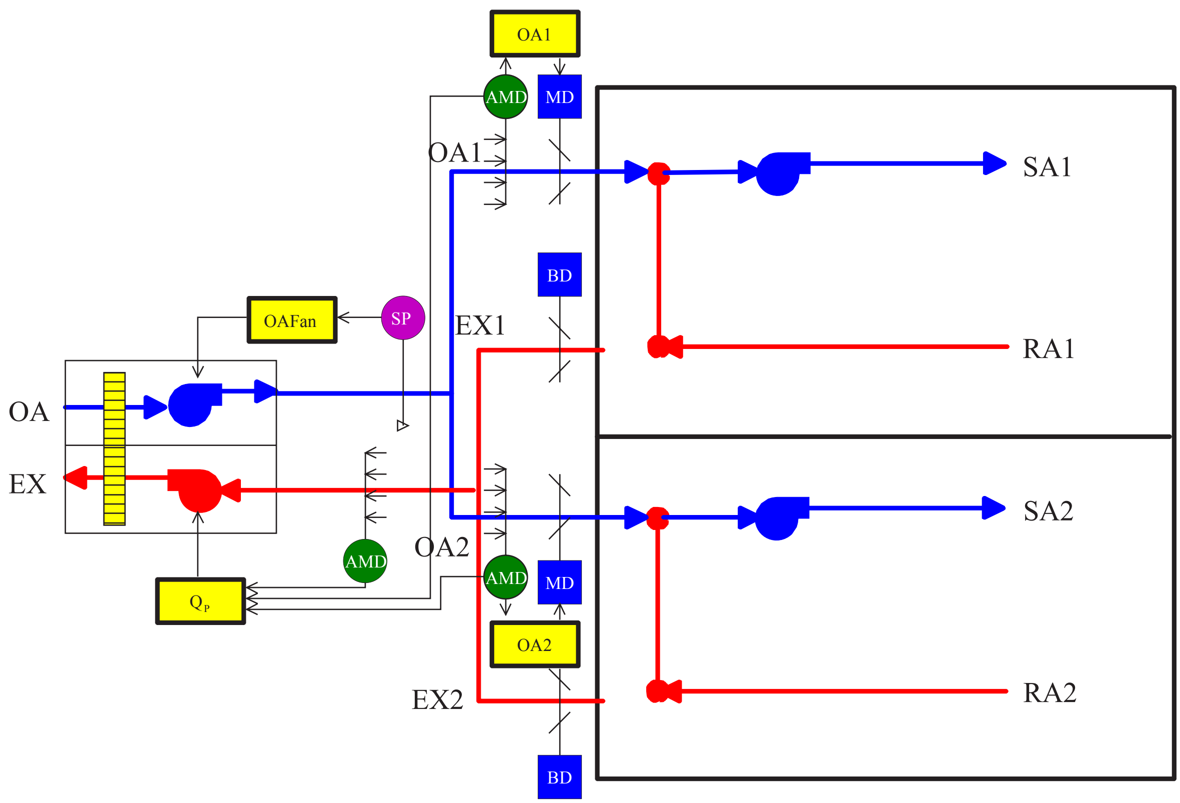
1. Modulate ERV OA fan to maintain min. OA.
2. OA-EX=Q_P
3. Use air balance measurement or permanently mounted AMD to manually balance OA and EX at each AHU zone.
4. Modulate ERV EX fan to maintain Q_P

COMMENTS:

1. Active control is required to compensate for filter loading, wind and stack pressure effects on forced makeup or ERV fan system.
2. Do not use manual adjustment to AHU zones on cycling fan systems.

VAV (multiple AHU's) –[low-rise only]

Systems with single minimum OA ERV, minimum OA mode



NOTES:

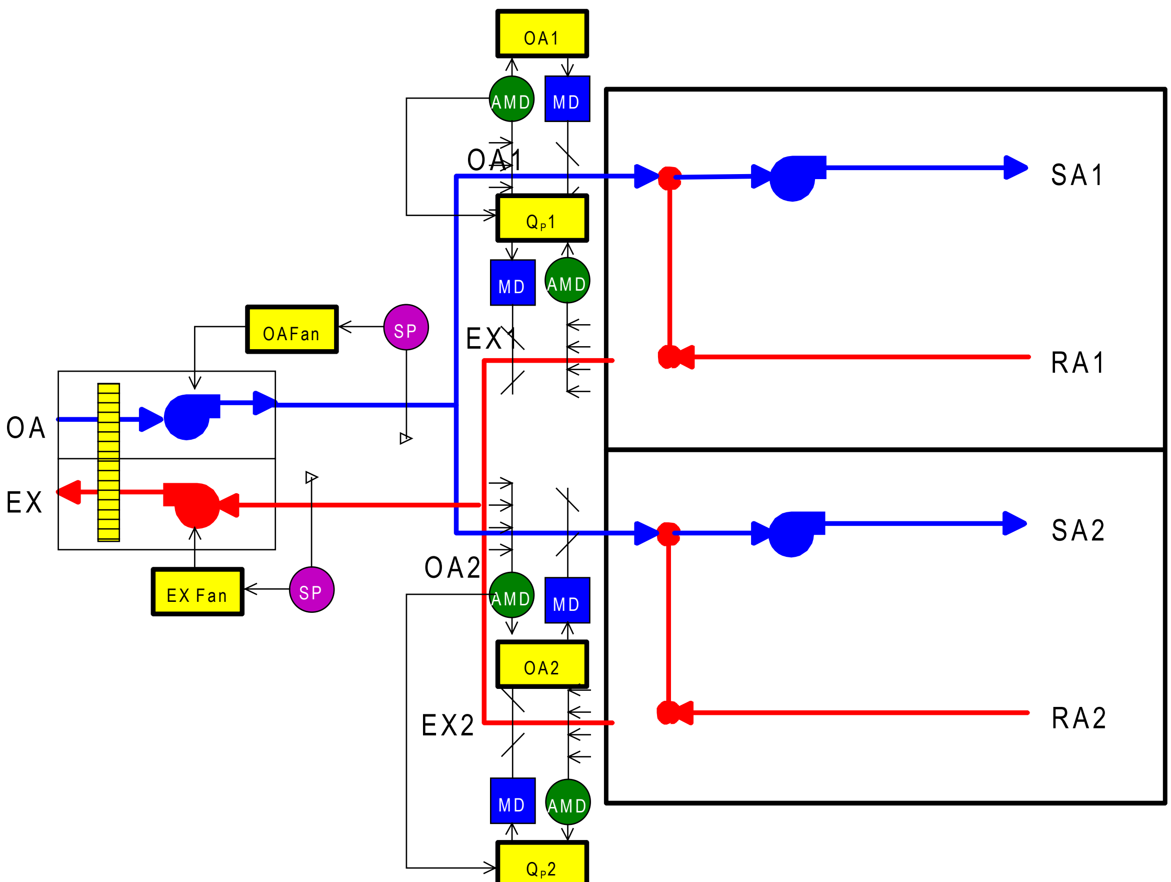
1. Modulate ERV OA fan to maintain duct static pressure (w/reset).
2. Modulate OA dampers to maintain AHU OA at each zone.
3. OA-EX=Q_P
4. NOT BEST METHOD: Use air balance measurement or permanently mounted AMD to manually balance OA and EX at each AHU zone.
5. Modulate ERV EX fan to maintain overall Q_P

COMMENTS:

1. Active control is required to compensate for filter loading, wind, stack and mixed air plenum pressure (VAV) effects on forced makeup or ERV fan system.

CV/VAV (multiple AHU's or FCU's) –[low or high-rise]

Systems with single minimum OA ERV, minimum OA mode



NOTES:

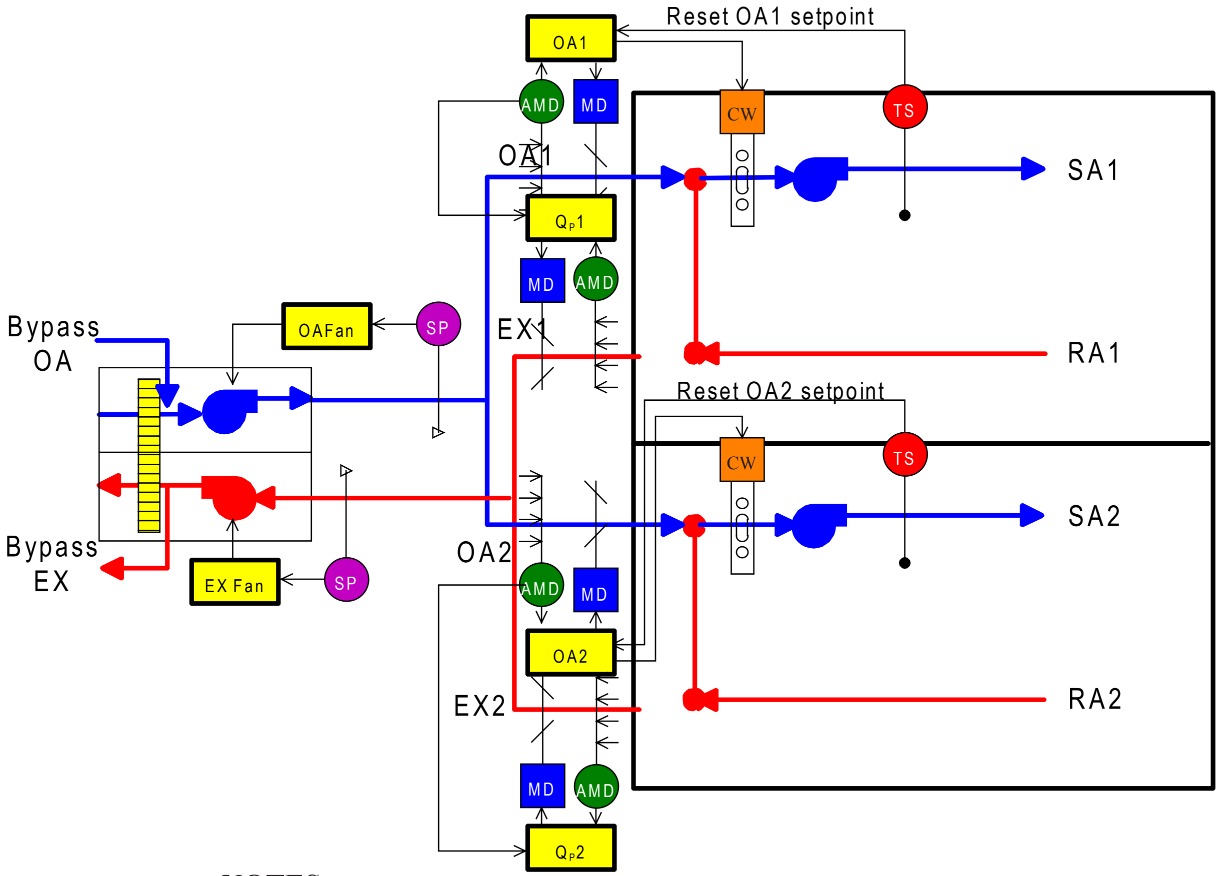
1. Modulate ERV OA and EX fans to maintain duct static (w/reset).
2. Modulate OA dampers to maintain AHU OA at each zone.
3. OA-EX=Q_p at each zone.
4. BEST METHOD: Modulate AHU EX dampers to maintain Q_p at each zone.

COMMENTS:

1. This method compensates for all external and system pressure effects.

CV/VAV (multiple AHU's or FCU's) –[low or high-rise]

Systems with single bypass ERV, modulating economizer



NOTES:

1. Modulate ERV OA and EX fans to maintain duct static (w/reset).
2. Modulate OA damper then cooling coil at each zone in sequence to reset zone OA setpoint to maintain supply air temperature.
3. OA-EX=Q_P at each zone.
4. Modulate AHU EX dampers to maintain Q_P at each zone.

COMMENTS:

1. This method compensates for all external and system pressure effects.

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