Airflow Controls and ASHRAE Standard 90.1-2013 – the Energy Code

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INTRODUCTION

ASHRAE Standard 90.1 is more than a minimum professional design standard. It is our nation's energy code. Methods and requirements in the code intended to save energy can have massive impacts on HVAC designs and a building operation's ability to provide adequate ventilation to their occupants. The implementation of some energy-savings strategies can have unintended consequences or underestimate their impact on occupant health and productivity.

For these reasons, building energy code provisions are continuously counterbalanced in opposition by mandatory minimum ventilation requirements. Both are important, but maximizing the benefit of one without hobbling the other, takes finesse and coordination by the designer and the decisions they make to satisfy both. It also takes a good understanding of the requirements for both requirements, in detail, to avoid tripping over them and creating a counter-productive situation.

For the purpose of this paper, we will examine how and where in the ASHRAE Standard 90.1-2013 document addresses issues relating to ventilation and pressurization, or other requirements that can be affected by more precise control. We will examine 90.1 to see where there might be some mutual support for 62.1, or contradictions. We will also provide some insight into the potential compliance issues presented and some possible solutions that improve 90.1 energy savings and help verify 62.1 compliance, avoiding both under or over ventilation.

After the standards, we will offer some advice on what is needed to ensure that your decision to implement a dynamic intake control strategy provides all of the control certainty and reliability that you expect.

Airflow Control Instrumentation's Potential Impact on Energy

There is no argument that airflow control precision will impact energy usage. The general effect of increased reliable control precision logically leads to more efficient use of energy. It also provides the ability to identify things that are out of balance and the integral means to compensate for them. However, there are several positive objectives that can be identified for their direct relation to energy usage:

1. Maintain required OA control at minimum fan power
2. Reduce or limit excess OA treatment for latent energy removal
3. Eliminate excessive heating or reheat at terminals
4. Minimize the fan energy needed for pressurization flow to control indoor humidity, moisture infiltration and mold
5. Provide superior DCV performance, using CO_2 with much greater precision, better reset capabilities and repeatability.

Stating the objectives is easier than selecting suitable control equipment and implementing an effective control strategy. Before we can consider these issues, we need to understand exactly what the code requirements specify. What challenges and opportunities do they offer?

ANSI/ASHRAE/IESNA 90.1-2013

The U.S. national energy code is ANSI/ASHRAE/IESNA 90.1-2013. This document was reviewed by the DOE and is required by statute to provide a determination whether the newer standard will improve energy efficiency. A positive determination was made and individual State certifications for Standard 90.1-2013 must be submitted by September 26, 2016. (https://www.energycodes.gov/adoption/process) After this date, it effectively becomes the energy law of the land, moving to be adopted by every state legislature in the country.

However, some processes lag behind. It was only recently announced that HUD and USDA issued a final determination accepting the 2009 IECC for single family homes & 90.1-2007 for multi-family buildings by not affecting affordability. Let's hope they move faster on 2015 IECC and 90.1-2013 before they become obsolete.

Although the laws and the process for review, comment and revision differ between states, the effort it takes to adopt a new code can be take a lot of time. This has led to multiple versions of the code to exist simultaneously, yet the basics of the code are the same in each jurisdiction. The versions of 90.1 currently adopted by state-wide certification vary between the 4 introduced chronologically over the past 10 years. Most are in some stage of the adoption process of the 2013 version, but many intentionally adopt an earlier version of the model code if any big part of it is questioned. Six states have no state-wide code, with each jurisdiction acting independently on their own. The code applies to all occupied building types, except for low-rise residential structures.

Following the ANSI consensus process, 90.1 establishes the minimum energy efficiency requirements for:

1. the building envelope,
2. HVAC,
3. service water heating,
4. power and lighting,

The largest section of this code is devoted to HVAC, signifying its complexity and importance of HVAC to overall energy efficiency. Within Section 6 on HVAC, there are several areas that are devoted to the energy impact from air system control, design and operation. It is organized to allow users a reasonable chance at finding specific topics and a logical process to implement a design strategy. It begins by describing the pathways to compliance allowed in the standard.

Compliance Paths (§6.2)

The standard begins by detailing what requirements are needed for compliance with the intention of the standard, namely: General, Submittals, Min. Equip. Efficiency Tables and one of the 3 optional methods listed for compliance. Depending on the size and type of structure you are dealing with, there may not be much of an option. First,

a. **Simplified Approach** (§6.3)

The Simplified Approach is limited for use with very specific building conditions, HVAC criteria and types. Quickly summarized, the more significant ones to airflow control are highlighted in BLUE. They can be used on buildings: ≤2 stories; < 25,000 ft^2 floor area; single zone systems only; variable flow requirements of §6.5.3.2.1; airside economizer per §6.5.1; exhaust energy recovery §6.5.6.1; manual changeover or dual set point thermostats; specific conditions for heating and use of heat pumps; insulated piping, plenums and ductwork; it must be air balanced; intake and exhaust provisions of §6.4.3.4; thermostats must prevent simultaneous heating and cooling; >10,000 cfm supply to have optimum start controls; compliance with DCV provisions of §6.4.3.8; et.al.

When you have a significant number of single zone systems serving contiguous areas, controlled by thermostats alone, with airside economizers, unspecified intake controls, exhaust energy recovery and mandated to use DCV where required; it will take a concerted engineering and operations effort to avoid over/under ventilation and to dodge pressurization problems unless integrated automation controls and airflow instruments are involved. Whether the dehumidification systems are built-up or packaged, unitary or split, A/C or heat-pump; all of them will need to integrate minimum outdoor air intake control and economizer capabilities. It is difficult to coordinate the air performance between multiple systems, but the exact parallel performance may not be necessary so long as the minimums are exceeded. This may also be difficult to do economically in smaller systems without some very efficient and low cost measurement equipment combined with application-specific communicating controllers. One manufacturer already markets products designed to provide these capabilities and features.

b. **Mandatory Provisions** (§6.4)

Many of the more important airside Mandatory Provisions are reviewed below, but other provisions require minimum equipment efficiency ratings; load calculations and control requirements. The third and last pathway to compliance is a specialized system, combining the Mandatory items with special calculations.

c. **Mandatory Provisions** (§6.4) + **Alternative Compliance Path** (§6.6)

The Alternative Compliance Path is intended to be more flexible for use with unusual applications, but is primarily applicable to Data Center or Computer Room Systems. This method uses the application of maximum Power Usage Effectiveness (PUE) as calculated per climate zone (TABLE 6.6.1). This is a standardized method for classifying loads for efficiency calculations.

Mandatory Provisions

Ventilation System Controls (§6.4.3.4) and within it, **Damper Leakage** (§6.4.3.4.3) requires performance tested Shut-off Dampers for all intake and exhaust/relief systems. Leakage-tested return dampers are required on systems with airside economizers, in accordance with the accompanying Table 6.4.3.4.3 below.

It is interesting to note that 90.1 does not require AMCA Leakage-rating or performance certified products, only that the products have been tested "in accordance with AMCA Standard 500" (not necessarily AMCA certified ratings) and meet the leakage rates listed. We must conclude that the manufacturers' published performance data is all that is needed to comply, without comparative ratings and without being subject to periodic verification tests or challenge tests.

The leakage requirements in Table 6.4.3.4.3 are based on: climate zone, building height and application (whether it is an intake or exhaust/relief). There are leakage requirements for both motorized and non-motorized (gravity) dampers, also indicating when their usage is allowed. The equivalent of a maximum Class 1 leakage rating of 4 cfm/ft^2 (20 L/s-m^2) at 1" w.g. (250 Pa) is required for motorized dampers where indicated in the table. AMCA Class 2 maximum leakage is 10 cfm/ft^2 of face area (50 L/s-m^2) at 1" w.g. (250 Pa). These Leakage Classes mirror the leakage rating designations used for U.L. labeled smoke control products that have been endorsed for many years with a supervised rating and labeling program. This also means that there are many product designs that readily comply with the performance requirements.

All buildings in the following geographic areas and listed in the Table below, require ultra-low leakage motorized dampers on any height building, for both intake and exhaust openings. Climate Zones 1, 2, 5a, 6, 7, and 8 cover: Climate Zone 1 is the warmest and includes Hawaii and the southern tip of Florida, Alaska. Climate zone 8 is the coldest. Climate Zone 7 is the coldest in the continental U.S. and includes northern Maine, Minnesota, North Dakota, Michigan and northern Wisconsin. Our list in general covers: Hawaii, Guam, Puerto Rico, Virgin Is., Alaska, Florida, Southern and coastal Georgia, entire Gulf coast with Southern Texas, SW Arizona, all Northern Border areas, Rocky Mtns., New

England, North Central, and Upper Midwest. It excludes Western Mountain and most desert states, Southwest desert and coast, and coastal Washington and Oregon west of the mountains.

Table 6.4.3.4.3 Maximum Damper Leakage
cfm / ft² at 1.0 in. w.g.

Climate Zone / Bldg. Ht.	Ventilation Air Intake: Non-motorized[1]	Ventilation Air Intake: Motorized	Exhaust / Relief: Non-motorized[1]	Exhaust / Relief: Motorized
1-2 Any Height	20 (Class III)	**4** (Class I)	20 (Class III)	**4** (Class I)
3 Any Height	20 (Class III)	10 (Class II)	20 (Class III)	10 (Class II)
4, 5b, 5c < 3 stories	not allowed	10 (Class II)	20 (Class III)	10 (Class II)
4, 5b, 5c 3 or more stories	not allowed	10 (Class II)	not allowed	10 (Class II)
5a, 6, 7, 8 < 3 stories	not allowed	**4** (Class I)	20 (Class III)	**4** (Class I)
5a, 6, 7, 8 3 or more stories	not allowed	**4** (Class I)	not allowed	**4** (Class I)

[1] Non-motorized Dampers smaller than 24 in, in either dimension may have leakage of 40 cfm/ft²

Of significance in the table are the Yellow highlighted categories. These indicate that ALL structures < 3 stories listed in these Climate Zones require the highest rating for leakage on all exterior dampers (OA, EA/RA). Structures of ANY HEIGHT in Climate Zones 1 and 2 require these ultra-low leakage dampers as well.

These are very broad descriptions and should NOT be used for decision-making. Your determination of the climate zone applicable to any project should be based on the details located in Appendix B and Table B-1 of Standard 90.1. Lists of areas by U.S. counties are provided. Table B-2 lists climate locations for Canada, while B-3 lists climate locations in many other countries.

ASHRAE 62.1 Satisfaction is Integral to 90.1 Compliance

To begin, ASHRAE Standard 62.1 is listed as a Normative Reference. In other words, it is required for compliance with 90.1. The ventilation standard is additionally referenced within many sections of the Mandatory Requirements in 90.1-2013 for energy efficiency. Compliance with the ventilation standard is almost assumed, because it is a base requirement. It is mentioned in the body of the code mostly as an exception to some 90.1 requirements, for which compliance with the requirement could negatively impact the ability to satisfy 62.1. 62.1 takes precedence.

§12 – Normative References. "§4.1.7 Normative Appendices. The normative appendices to this standard are considered to be integral parts of the mandatory requirements of this standard…".

Section 6.4 are Mandatory Provisions.
§6.4.3.8 DCV – Automatic modulating control of outdoor air damper based on variable populations with Exceptions to the section for specific occupancy categories.

Section 6.5 Prescriptive Path to Compliance.
§6.5.1 Economizers – Exception to requirements in systems that include nonparticulate air treatment as required by Section 6.2.1 in Standard 62.1.

§6.5.2.1.1 Zone Controls without DDC – Exceptions to reheat/recool prohibition for zones without DDC, if the volume is less than the largest of 4 exceptions, including: the outdoor airflow rate required to meet the ventilation requirements of ASHRAE Standard 62.1 for the zone.

§6.5.2.1.2 Zone Controls with DDC - Exceptions for zones with DDC, the airflow rate in dead band must not exceed the larger of 4 possibilities, including: the outdoor airflow rate required to meet the ventilation requirements of ASHRAE Standard 62.1 for the zone.

§6.5.2.3.1 Dehumidification – Exception to simultaneous heat/cool where humidity controls are provided, the system is configured to reduce supply air volume to 50% or less of the design airflow rate or the minimum outdoor air ventilation rate specified in ASHRAE Standard 62.1, before simultaneous heating and cooling takes place.

§6.5.3.2.1 Fan Airflow Control – Combined with the capability to vary the supply fan airflow as a function of load, it will also comply with two speed fan control during economizer, except if volume of outdoor air required at low speed exceeds that delivered by this minimum speed. Then, the minimum speed shall be selected to provide the required outdoor air.

§6.5.3.2.4 Return and Relief Fan Control – Any size chilled-water or evaporative cooling system and DX systems ≥ 65,000 Btu/h [≥ 5.4 tons] will be required to maintain building pressure through differential supply-return (volumetric) airflow tracking. This satisfies 62.1 §5.9.2 *Building Exfiltration* but is specific as to method, going beyond the mandate describing the net result from this control method: "to ensure that the total building outdoor air intake equals or exceeds the total building exhaust under all load and dynamic reset conditions."

§6.5.3.3 Multiple-Zone VAV System Ventilation Optimization Control – These system types shall include means to automatically reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency as defined by Appendix A of ASHRAE Standard 62.1.

§6.5.7.1 (Exhaust Systems) Transfer Air – Conditioned air delivered to any space with mechanical exhaust shall not exceed the greater of: supply for heating/cooling; ventilation rate required or exhaust minus available transfer air. Available transfer air is the portion of OA that is: not required for other exhaust; not required to maintain pressurization of other spaces; and is not transferrable according to the Class of Air Recirc Limits in ASHRAE 62.1.

Demand Control Ventilation (DCV)

Ventilation Controls for High-Occupancy Areas (§6.4.3.8)

Spaces with high design occupant densities offer an excellent opportunity for demand control ventilation (DCV) systems since these spaces are seldom occupied at their design occupancy. DCV systems modulate the amount of outdoor air supplied to a space as a function of the number of people present, providing significant energy savings when spaces are only partially occupied.

The Standard requires DCV for all zones that are

1. >500 ft^2 (50 m^2) and
2. ≥25 people per 1,000 ft^2 (100 m^2) design occupancy for ventilation and
3. where these spaces are served by an HVAC system that includes one or more of the following:
   - an airside economizer,
   - automatic modulating control of the outside air damper, or
   - design outdoor air capacities greater than 3,000 cfm (1,400 l/s)

The described parameters typically apply to assembly spaces such as: theaters, meeting rooms, places of worship, gymnasiums and ballrooms.

Exceptions to the DCV requirement include:

1. Systems provided with air-to-air heat recovery systems complying with §6.5.6.1,
2. Multiple zone systems that do not have direct digital controls at the zones (for example, systems with pneumatic zone thermostats),
3. Spaces where the design outdoor airflow is less than 750 cfm (600 l/s),
4. Spaces where >75% of the design outdoor airflow is exhausted from the space or transfer air that is required for makeup air, exhausted from other spaces. An example of this exception is a restaurant seating area where the return air from the space is used as tempered make-up for the kitchen hoods.
5. DCV is not required in any of the following 62.1 occupancy categories: correctional cells, daycare, sickrooms, science labs, barbershops, beauty and nail salons, and bowling alley seating.

In addition, the provisions in 62.1 and 170 (Healthcare Ventilation) exempt spaces like hospital wards, vivariums and laboratories where minimum air change rates are required by health and safety codes. Where DCV systems are provided they must maintain ventilation rates in accordance with local codes. Since most ventilation codes prescribe outdoor air intake rates proportional to the number of people in a space for at least one component of the total required ventilation rate, it follows that a DCV system should modulate outdoor air as a function of the space population.

The most commonly used indicator of the ventilation required to dilute people-related pollutants is carbon dioxide (CO_2) concentration. People expel CO_2 and other bioeffluents (including body odor) at a rate roughly proportional to their number and their activity level. Hence, CO_2 concentration is a good indicator of bioeffluent concentration and thus is a reasonable proxy for population for use with DCV. Actual or estimated current population total is essential for calculation of the required ventilation rate, if it is being used to adjust for a variable population. Lag time between occupancy and point of control, plus sensor accuracy issues and how the exterior CO_2 concentration is determined, are also major considerations.

CO_2 is not a contaminant to be removed and simple CO_2 set point controls to maintain a specific interior CO_2 level, will not satisfy the requirements of the *Ventilation Rate Procedure* of 62.1. Neither can CO_2 be used in the IAQ Procedure. Fortunately, the space types where its application is needed are a small portion of the total occupied space in occupied buildings.

Most ventilation codes use or mimic Standard 62.1's *Ventilation Rate Procedure*, which also dictates minimum ventilation per floor area for dilution of contaminants from building materials or items used in the space (for example, hair spray in a barber shop). Again, the provisions of 62.1 mandate that DCV control comply with these minimum ventilation requirements at all times during occupancy and under all load and dynamic reset conditions (62.1§6.2.7).

Controls (§6.4.3) – see also §6.4 Mandatory Provisions

DDC Requirements (§6.4.3.10)

New to 2013 is a requirement that all buildings described by a table of DDC Applications and Qualifications, must have DDC systems (TABLE 6.4.3.10.1). This is a BIG deal. There are several items in the table that apply only to new construction, while a greater number of applications would apply to alterations or additions. For example, DDC would be required in a new building with an air handling system supplying more than 3 zones and with a fan system bhp greater than 10 hp. An alteration or addition to an existing building would be required to use DDC for zone terminal units, if the existing zones served by the same AHU had DDC.

The DDC Controls required under this section must be capable of a number of mandatory functions, and also be capable to provide the control logic required in Section 6.5. Trending and graphical display input/output points are also specified for new buildings.

Prescriptive Path (§6.5)

Economizers (§6.5.1)

Airside economizers for "free cooling" cover a good portion of the Mechanical Equipment chapters. In many climates, their use can offer a significant reduction in energy use.

Section 6.5.1 requires that cooling systems have either an airside or a waterside economizer. Economizers are systems that use outdoor air as a source of cooling in place of or to supplement mechanical cooling when outdoor environmental conditions are favorable.

Air Economizers (§6.5.1.1)

Design Capacity (§6.5.1.1.1)

Air economizers (also called airside economizers) use modulating dampers to increase the amount of outdoor air drawn into the building when the outdoor air is cooler than the return air temperature and the system requires cooling. To meet the Standard's requirements, airside economizer systems must be able to supply 100% of the design supply air quantity as outdoor air for cooling.

The Standard has specific requirements for all the major elements that compose air economizers, including:

- How the economizer dampers are controlled;
- How the economizer is shut off when the weather is warm or humidity is too high, and no longer conducive to free cooling;
- Damper performance characteristics (minimum leakage in accordance with AMCA test standard); and
- How air is relieved from the building to prevent over pressurization.

Control Signal (§6.5.1.1.2)

Economizer damper control, described in the control sequences, is specifically prohibited from using mixed-air temperature alone for set point control, with one exception: systems controlled from space temperature, like single-zone systems. Historically, economizers were controlled from mixed air temperature but have been prohibited in the code.

There are two primary reasons why mixed air temperature should not be used to control the economizer.

1. **Improper sequencing**
   Having two control loops for the economizer and mechanical cooling is more likely to result in improper sequencing. For instance, if the economizer were being controlled to maintain a mixed air temperature set point while the cooling was controlled to maintain a supply air temperature set point, the two set points must be coordinated for proper sequencing. Because of fan heat, the mixed air temperature setpoint would have to be lower than the supply air temperature set point.

On variable air volume systems, fan heat varies, so maintaining coordination between the two setpoints is difficult. If set point reset strategies were used, these too would have to be coordinated.

2. **Difficulties in measurement of the true "average" temperature**
   Mixed air temperature is very difficult to measure. Even with a serpentine "averaging" sensor, stratification and radiant effects from the chilled water coil can cause sensor errors that are not correctable with this technology; neither can it identify the truer mass temperature of the air. ASHRAE sponsored research project RP-1045 which documented that air from a mixing box can remain stratified well after it has gone through the filters, coils and fan, making measurement of an average with a single sensor or serpentine sensor next to impossible. However, multiple independent sensors suspended perpendicular across the plane of airflow can provide a much more accurate DB temperature arithmetic average or velocity-weighted average.

   Mixed air temperature is acceptable for controlling the economizer for systems controlled from space temperature, such as single-zone systems. This is allowed because these systems typically do not have a supply air temperature sensor from which to control the economizer; controlling the economizer from the space thermostat alone could lead to low entering air temperatures, which in turn could lead to coil freezing.

   For variable air volume systems, fan energy savings can be enhanced if the dampers are sequenced rather than physically linked and/or operated in direct opposition to each other (when the outdoor air damper becomes fully open before the return air damper is closed, or return fan speed is reduced). This will reduce the pressure drop through the mixing box assembly during most operating conditions, which, for variable volume systems with fan volume controls, could reduce fan energy by as much as 20% - 30%.

High Limit Shutoff (§6.5.1.1.3)

As the outdoor air warms up, there will be a point where outdoor air intake rates will increase energy usage of the cooling coil rather than decrease it. At this point, the economizer must be shut off and the system operated to achieve the minimum outdoor air volume required for ventilation. The controller that causes this to occur is called the economizer "high limit" control or high limit switch.

The High Limit control set points have been updated in TABLE 6.5.1.1.3 for Air Economizers. Gone are the alternatives for Electronic Enthalpy and Dew-point with Dry Bulb temperatures. Set points are established with the intention of overcoming some of the reasons for historically poor performance of economizers.

Dampers (§6.5.1.1.4)

Return air, exhaust/relief and outdoor air dampers are required to meet the damper leakage specified in Section 6.4.3.4.3 (Table 6-A in the User's Manual). Outdoor air dampers and exhaust air dampers are required to have low leakage characteristics to help prevent air infiltration and exfiltration during unoccupied hours, but it is just as important for the return air damper to have low leakage characteristics.

The *90.1-2013 User's Manual*, gets specific regarding appropriate methods to satisfy ventilation standards, plus has revised requirements with significant changes to the maximum damper leakage allowed (§6.5.1.1.4) and new items for dynamic ventilation control on multiple zone VAV systems following Standard 62.1's Appendix A (§6.5.3.3). What do these requirements mean to outdoor air intake control? They seem to indicate the growing recognition of dynamic influences on air systems, especially intake systems.

Sensor Accuracy (§6.5.1.1.6) **for Air System Elements**

Calibrated instrument performance for economizer control is specified for the first time in the standard, even though the tolerances are fairly generous.

- Dry-bulb and wet-bulb temperatures ±2°F over the range of 40°F to 80°F;
- Enthalpy and differential enthalpy sensors shall be accurate to ±3 Btu/lb over the range of 20 to 36 Btu/lb;
- Relative humidity shall be accurate to ±5% over the range of 20% to 80% RH.

The standard addresses these outdoor, return, supply and mixed air properties, but does not address air velocity/volume measurement or airflow measurement instrument performance, when permanent instruments are available and being used in increasingly larger quantities to maximize air system operating performance and therefore minimize energy usage.

This emphasis on temperatures and humidity is hypocritical in light of the current section (§6.5.1.1.6). Airflow rates are arguably just as important to energy usage as other properties of air used in the HVAC ventilation system. Humidity and enthalpy in particular are very difficult to measure reliably, and these sensors have been notoriously inaccurate. Additional inputs (for airflow) should be considered to help enforce more efficient system operation and help make other inputs more valuable.

Variable Primary Air Systems Can Save even more Energy

VAV air distribution designs have been around for 50 years. They have proven to be very beneficial and potentially large energy savers. Now, the engineering community wants to spread the advantages of VAV to Constant Volume designs by requiring that all supply fans have variable speed controls or have a minimum 2-speed motors. Their speed is to be varied as a function of load. "Low or minimum speed shall be used during periods of low cooling load and ventilation-only operation."

This sets up an interesting situation forcing designers to consider active intake controls on what would otherwise be classified as "constant volume" systems, in order to compensate for the outdoor air proportional reductions due to changes in supply flow during normal operation.

Currently under consideration are several addenda that will influence designers and create situations that will make air systems more reliably controlled with airflow measurement inputs for all major air components: supply, return/relief and outdoor air. Here is what is being proposed.

Supply Fan Airflow Control (§6.5.3.2.1) addendum aj, 1st PR

Each cooling system listed in Table 6.5.3.2.1 shall be <u>designed to vary the supply fan airflow</u> as a function of load. In practical terms this means the use of a VFD or multi-speed motor. Minimum speed shall not exceed 66% of full speed if mechanical cooling is controlled directly by space thermostats and 50% (2:1 turn down) if space temperature modulates airflow (VAV). Although these are minimum requirements, we recognize that supply flows in VAV systems are regularly designed to turn down to 20% of full speed (5:1) and that 15% is not that unusual (6.7:1). Where systems provide the capabilities of operating reliably and effectively and lower fan speeds during periods of reduced load, they are rewarded with increased energy savings and a greater range of operation for comfort control.

VAV Setpoint Reset (§6.5.3.2.3) addendum ap, 1st PR

For multiple-zone VAV systems having a total fan system motor nameplate kW exceeding 4 kW with DDC of individual zones reporting to the central control panel, static pressure set point shall be reset based on the zone requiring the most pressure.

Changes to this section clarify when and how to apply the reset requirement. Additional provisions make this function and allow for manual correction of rogue anomalies, and include:

a. monitor zone damper position;
b. automatically detect those zones that may be excessively driving the reset logic; and
c. readily allow operator removal of zone(s) from the reset algorithm.

Return and Relief Fan Control (§6.5.3.2.4) addendum aj, 1st PR

The proposed requirement mandates that the **relief air rate shall be controlled to maintain building pressure directly or indirectly through differential airflow tracking**. Systems with constant speed or multi-speed supply fans shall also be allowed to control the relief system based on outdoor air damper position. This will be mandatory when approved, to all chilled-water and evap cooling systems and DX systems ≥ 65,000 Btu/h or 5.4 tons.

This proposed change combines good news with not-so-good news. The good news is recognition that differential airflow (ΔCFM or SA-RA) is a stable, reasonable and an acceptable means to control building pressurization flow directionality. Relief fan control for constant speed or multi-speed air handlers allows outdoor air damper blade position to modulate building pressure. The not-so-good news is that there is no relationship between blade position and flow rate without making a number of questionable assumptions. Implementation of this control method is likely to result in swings of pressure flow and no assurance of reliability during all operating conditions. Worst of all, the operator and the occupants may have no indication of poor performance or malfunctions.

Multiple-zone VAV Ventilation Optimization Control (§6.5.3.3) addendum ap, 1st PR

Multiple-zone VAV systems with direct digital controls to the zone level are required to provide an automated means to reduce outside air intake flows below design rates in response to changes in system ventilation efficiency as defined by ASHRAE Standard 62.1-2013, Appendix A. This is proposed to be a new mandatory requirement for Standard 90.1-2013. This capability is specifically highlighted under 62.1§6.2.7 Dynamic Reset, which also addresses DCV.

Each VAV box controller senses the current primary airflow (V_{pz}) and allows the calculation of the current zone outdoor-air fraction (Z_d). The building automation system totals the primary airflows and required outdoor airflows (V_{oz}) from all VAV boxes, and determines the highest outdoor-air fraction reported. Then the BAS solves the equations from Appendix A of ASHRAE Standard 62.1, calculating the system ventilation efficiency (E_v) and the system-level intake flow rate (V_{ot}) that is required at the current operating condition. This new intake flow rate set point is communicated to the air-handling unit or rooftop unit controller, which then adjusts the outdoor-air damper until the required amount of outdoor air is measured at the new set point.

Fully programmable BAS equipment should be able to accomplish this, but the programming talent to implement the custom code described may not be readily available everywhere. BAS manufacturers will eventually develop control sequence templates or configurable applications specific to their equipment. Enterprising suppliers will also develop accessory modules designed to accept input variables, calculate outdoor air set points and communicate this reset to components that maintain the intake set point, independently of other control functions. All of these reset possibilities will require the continuous and accurate input of both total supply and outdoor air intake flow rates to successfully implement this proposed control strategy as a minimum code requirement for all multi-zone VAV systems. If approved together with this proposal, §6.5.3.2.4 will add the return air measurement to this compliment of instrumentation.

In a VAV system that uses communicating DDC controls, all of the necessary real-time data to implement this strategy is available digitally. Some of the control logic is described in the 2010 ASHRAE *62.1 User's Manual* under Appendix B. Refer to this User's Manual document for further information on Ventilation Reset Control.

Exhaust Air Energy Recovery Requirements (§6.5.6.1)

Systems with Exhaust Energy Recovery are required under the Simplified Approach §6.3.2 amongst a number of other energy conserving strategies.

Energy recovery systems are required for each fan system when the system's supply airflow rate exceeds the value listed in Tables 6.5 .6.1-1 and 6.5.6.1-2. Also required are a minimum of 50% energy recovery effectiveness and 50% of the difference between the OA and RA enthalpies.

The systems mandated to use exhaust energy recovery vary by: total operating hours per year (< or ≥ 8,000 hrs/yr); % OA at design airflow; and 5 groups of climate zones. The system size threshold for under 8,000 hrs/yr, ranges from SA fan capacities ≥4,000 cfm to ≥28,000 cfm. Two of the 5 climate zone groups with <30% OA do not require energy recovery. Thresholds are also indicated for design SA fan airflow rates and OA up to 80% or more. Systems operating ≥ 8,000 hrs/yr have much lower SA fan thresholds and most categories will require exhaust energy recovery.

When EER is provided, those systems are exempt from a number of other requirements, namely:

- DCV (§6.4.3.8)
- MZ-VAV Optimization Control (§6.5.3.3)
- Desiccant EER systems that include humidity controls and recover at least 75% of added heat are exempt from the general prohibition against simultaneous heating/cooling.

Recommendations for the Successful Application of Direct Control of Supply, Return/Relief and Outdoor Airflow

The reliability of direct airflow control depends on more than the capabilities of a single piece of hardware, the technology used or the quality of the installation. It is the entire system, design and implementation of the concept that impact operational performance.

To provide a truly functional outdoor air control mechanism, we first need to evaluate and select an airflow measuring device suited for the measurement of intake flow rates. A place to start is in the ASHRAE Handbook - 2013 Fundamentals, Table 36.16. Here commonly used instruments, permanent and hand-held, are listed, as used in commercial and institutional HVAC control. It should be noted that in this list, some are not suitable for permanent installation.

General characteristics, capabilities and limitations are included.

- Match a product's capability with the flow rates you are trying to control and the level of accuracy you desire to maintain. Compare the information in the Handbook to that provided by the manufacturer. If they do not agree, continue questioning.
- All measurement devices are not the same and cannot be lumped together for generalization. They are different in: basic technology, performance, limitations, applicability for an intended purpose. Do your homework and compare the alternatives. If the manufacturer cannot provide the technical information you need, skip them and move on to the next vendor.
- Design intake flow rates high enough to control and not be affected by transient wind gusts (> 150 FPM at minimum is recommended by one manufacturer who has reported years of success in these applications).
- Design intake flow rates low enough (generally < 500 fpm or 2.5 m/s) to avoid water carryover when located in proximity to louvers or plenum openings in the building envelope. **Water affects ALL measurement technologies and all measurement devices at the intake will get wet at some point in their service life.** Designers need to insure that water and snow cannot cause hamper the function or damage exposed components of the measurement device you select.

Consideration for some of the selection issues that contribute to total measurement error in active control for airflow rates, include:

- Measurement performance requirements dictated by placement conditions (resulting in variations in pressure profiles)
- Ability of the device to sample the cross section without creating an averaging error
- The requirement for and validity of the field calibration reference used, potentially adding more uncertainties due to manual measurement techniques
- Corrections to the device output required for zero drift, non-repeatability, nonlinearity and temperature effects
- Allowances for air density changes (temperature and altitude)
- Effect of improper installation
- Effect on performance of ineffective or nonexistent maintenance, and
- Avoiding impacts of the lowest-cost selection criteria (quality, features, pressure range, auto zero, temperature compensation and turndown capability)

Do not ignore potential sources of measurement error inherent in the technology being considered.

Just as important in the control process is selecting and right-sizing quality control dampers. Knowing the flow rate by measurement and being able to accurately and repeatedly adjust it, are not the same thing. You will need a good air "valve" sized to provide the needed authority over airflow rates during the majority of its stroke, in order to accomplish your goals.

- I recommend using high quality, extruded aluminum airfoil dampers, with long-lasting and nonbinding linkage for the best combination of control, leakage rated performance (required in 90.1 §6.5.1.1.3) and longevity.
- Select non-spring return proportional electronic actuators when possible, but this is more of a personal preference. Floating or incremental electric actuators, properly employed, can be just as effective. There is no direct correlation between damper blade position and controller output (0 to 100%) for floating control. If correlation is important, use an actuator with proportional control or position feedback. When the flow rate is continuously measured in a permanent position, feedback on air performance and actuator actions is better than blade position.

Implement a control strategy that optimizes the performance of your system.

- Use sequences that decouple linked dampers, don't depend on the intake damper modulating or its blade position alone to provide the control needed. A 20-30% fan energy savings may be available by avoiding operation with partially closed dampers. Modulating return fan speed may be a great alternative to damper control alone and provide better responsiveness.

Finally… slow it down!

- Many control sequences run faster than the controlled components can fully respond, setting up a situation where the adjustment is always chasing the position of the components. Instant response is not required or even desirable in most commercial situations. Set up your control sequences to adjust after updating sampled data at intervals longer than it takes for your actuator (or controlled component) to make a complete stroke, as mentioned previously. Once every few minutes is more than fast enough. Once every 5 minutes is probably better for most commercial comfort applications.

If superior operational performance is your goal, then you need to take the time to see that all of these steps are implemented.

CONCLUSIONS

We have seen that there are a number of requirements in the energy codes that dictate or encourage increased precision in ventilation and pressurization control. One area that is generally ignored is the non-VAV applications that would benefit from airflow measurement and active control.

Your core HVAC design objectives cannot be achieved if outdoor air intake flow rates vary from the desired set point (temperature and humidity control for thermal comfort, dilution ventilation for acceptable IAQ, proper pressure on entry/egress doors, energy efficient operation, low maintenance operation, etc.). Exhaust airflow rates must also be maintained to provide a constant airflow differential between the intake and exhaust rates on systems that use demand controlled ventilation (DCV) or have a modulating airside economizer for proper pressurization.

Flow rates will vary using a fixed position damper control scheme, regardless of the input indirectly determining the airflow set point (i.e. temperature, CO_2, mixed air pressure, etc.):

- Supply fan speed modulates VAV, DCV, Constant air change rates, DOAS or ERVs;
  as filters load,
  as external static pressure degrades fan performance,
  as exhaust varies and
  for systems with multi-speed fans
- Wind pressure changes
- Stack pressure changes
- Damper linkage hysteresis
- Damper deterioration, linkage binding and actuator slippage

Supply fan speed changes are well understood. Both ASHRAE and LEED mandate airflow measurement on all VAV systems as a result in changes in the mixed air plenum pressure downstream of the intake damper. Constant volume packaged roof-top air handlers between 5 and 25 tons encounter many of the same problems, yet owners are reluctant to add the necessary sensors and controls to fix the problem.

Direct measurement of outdoor, supply and return/relief airflow rates is a practical alternative with significant energy-saving and performance implications. Care should be taken in selection to insure that it is suitable for the design conditions and that operational performance can be verified. Some technologies are better suited for outdoor air velocities than are pressure-based devices. Life-cycle cost analysis should be used to evaluate alternative equipment or methods. Nominal first-cost savings will typically not justify high maintenance costs or poor performance.

Although not directed toward dilution ventilation rates or pressurization flow, many of the 90.1-2013 requirements in the Heating, Ventilating, and Air Conditioning Section 6 (p. 41-81) can have devastating impacts on ventilation rates, if the simultaneous requirements of ASHRAE 62.1 are suppressed or ignored. Almost every item in 90.1 previously discussed, if implemented without consideration of the entire regulatory environment, will detrimentally affect occupant health and productivity.

Dynamic ventilation response to changing operational requirements can be readily accomplished with active outdoor air intake systems, designed to provide a constant volume of airflow regardless of how conditions change, inside or outside the building. Measurement of intake flow rates not only provides feedback for a positive means of direct control and dynamic reset, but also provides a direct means to verify 62.1 compliance with minimum ventilation requirements “under all operating and dynamic reset conditions” and 90.1 compliance with variable operation and control requirements.

The best payoff from using permanent measurement for control is having the <u>means to maximize energy savings while providing sufficient airflow for proper building pressurization flow and the flexibility for the operator to choose an intake operating point</u> in response to changing conditions or priorities:

- maximum energy savings with verifiable minimum ventilation rates;
- maximum fan energy savings with reliable pressurization flow control;
- improving worker productivity by increasing ventilation, but capping conditioning costs by a predefined intake operating range;
- the ability to adjust intake set points as easily as changing the interior temperature control set points.

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