ANSI/ASHRAE Standard 62.1 – 2010, *Ventilation for Acceptable Indoor Air Quality* -

Update, Analysis and Recommendations

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BACKGROUND

This paper is an updated version of similar ones published for several previous versions of ASHRAE Standard 62.1. Please study the complete standard discussed in this paper and review the bibliography. This descriptive paper should not be considered a substitute for the original and complete document, nor is it a shortcut to compliance with the standard. There are many issues to consider that are not discussed here.

ANSI/ASHRAE Standard 62.1 was first published in 1973 as Standard 62, which today continues to outline the minimum ventilation rate requirements intended to provide acceptable indoor air quality for new buildings or those with major renovations. In 2003, the scope of the Standard officially changed and a separate ASHRAE committee was formed to address the specific needs of Low-Rise Residential Buildings. The existing Standard became known as 62.1 and the new residential standard became 62.2.

Notwithstanding its numerous revisions since 1973, this standard has been an often misunderstood and misinterpreted document. Because of the rate-based nature of all three sanctioned procedures allowed for compliance (Ventilation Rate, IAQ and Natural Ventilation), this analysis focuses on the needs for reliable intake rate control and the risks included with popular indirect control methods. Design recommendations offered are intended to increase the potential for both predictable compliance and for the operating flexibility to accommodate future changes, while providing the greatest control reliability with the most energy efficient methods.

INTRODUCTION

This is a brief summary of selected parts of ASHRAE Standard 62.1-2010, *Ventilation for Acceptable Indoor Air Quality (IAQ) in Commercial, Institutional, Industrial and High Rise Residential Buildings* [1]*,* as it impacts and is influenced by ventilation control requirements, methods and equipment. Operational implementation of these requirements can have a sizeable influence on energy usage, when applied improperly or incompletely. Operational precision and design reliability are essential to minimize energy usage, when compliance with 62.1 and energy codes are simultaneous goals.

This ANSI-approved standard has been developed by a Standing Standards Project Committee (SSPC) of the American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc. (ASHRAE), under the 'continuous maintenance' protocol. At any point in time, the 'official' Standard is comprised of both the most recently published parent document and all current addenda. The next parent document will be published in 2013 to combine all addenda that were approved subsequent to the release of the original 62.1-2010 parent document. The result is a final version that is substantially different from the basic ventilation standard we have used since 1989. The 2010 edition includes a number of changes that remove inconsistencies and improve clarity. The significant changes from 2007 are:

- *Deletes Section 6.2.9. Ventilation for smoking spaces is no longer covered by the standard.*
- *Provides minimum requirements to clarify when ventilation systems must be operated.*

- *Relocates natural ventilation requirements to a new Section 6.4, adding a prescriptive Natural Ventilation. The standard also now requires that most buildings designed to meet the natural ventilation requirements include a mechanical ventilation system designed to meet the VRP or IAQ Procedure requirements; mechanical system operation must be activated whenever conditions preclude operation of the natural ventilation system (e.g., due to thermal comfort, noise, security, or other issues).*
- *Relocates Table 6-4 and other requirements related to exhaust systems to a new Section 6.5.*
- *Revises the IAQ Procedure to make it more robust. In informative Appendix B, provides a table of volatile organic compounds that designers might want to consider as possible contaminants of concern.*
- *Adds additional requirements related to the design of demand-controlled ventilation systems.*
- *Revises requirements for separation of outdoor air intakes from exhaust and relief air outlets by using Classes of Air already defined in the standard rather than descriptions of the air quality.*
- *Adds some occupancy categories to the ventilation rate table (Table 6-1) and revises ventilation rates for a few occupancy categories.*
- *Deletes ventilation requirements for health care spaces since they are now covered by* ASHRAE/ASHE Standard 170-2008, Ventilation of Health Care Facilities.
- *Adds minimum filtration requirements related to PM2.5, and changes minimum air cleaning requirements related to ozone to reflect changes in the U.S. EPA's ozone reporting procedures."*[1]

62.1-2010 Addenda status

At this writing, the new standard is barely one year old and several addenda / interpretations have already been addressed

Addenda Pending publication approval: **a, b, c**
Addenda status can be found at: http://www.ashrae.org/technology/page/132
Current review drafts may be commented upon at: http://www.ashrae.org/technology/page/331

62.1a (2010) Will be included in 2011 Supplement and 62.1-2013

Research data showed that adjustments to Table 6-2 – Zone Air Distribution Effectiveness were warranted. This addendum specifies that an underfloor air distribution system that provides low velocity air at 4.5 ft above the floor (less than 50 fpm) provides improved ventilation effectiveness, allowing them to be assigned a value of 1.2 for Ez , rather than the previous value of 1.0. Related language in Table 6-2 was clarified.

62.1b (2010) Recommended for 1st publication public review by SSPC ending 10/10/2010. In process.

In response to a change proposal, changes to the wording of Sections 5.12 and 5.12.1 are being proposed that are intended to make it clear that chemicals may not be added to water that will be used in humidifiers and waterspray systems, and that the water that is used must meet or exceed potable water quality standards.

62.1c (2010) Recommended for 1st publication public review by SSPC through 10/10/2010. In process.

This proposed addendum clarifies Section 5.9.2 regarding the conditions under which the ventilation system must be operated to provide exfiltration. It also proposes a change to the definition of "exfiltration" in Section 3 and modifies Section 6.2.7.1.4 to require compliance with 5.9.2, rather than restating requirements which may possibly become inconsistent with 5.9.2.

The *62.1 User's Manual* for 2010 is available at the ASHRAE Bookstore (www.ASHRAE.org). Work continues on *Guideline 19*, which is intended to provide design guidance for methods of compliance that exceed the minimum requirements of the Standard. Both of these supplemental documents should assist the designer and facility operator in the understanding of and compliance with the Standard.

ANALYSIS AND RECOMMENDATIONS

Our discussion of Standard 62.1 will mimic the sequence and structure of the document, provide recommendations for compliance and highlight methods to consider and assumptions to avoid. Our objectives have determined the content.

The Standard's "Purpose" and "Scope" are covered in Sections 1 and 2. To comply with the Standard, designers of mechanical ventilation systems are tasked to provide specific minimum rates of acceptable outdoor air to the breathing level of the occupied structures. In doing so, an acceptable indoor environment may be achieved providing improved occupant comfort, productivity and health. The procedures allowed for compliance with our national standard on ventilation are prescriptive or performance-based. Your selection should be evaluated for IAQ risk by the design practitioner.

DEFINITIONS

Section 3 addresses the definition of terms used within the Standard. Noteworthy is the Standard's definition of "acceptable indoor air quality" which is provided as

> "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction [1]."

This means that 62.1, like all ASHRAE Standards, assumes one out of five occupants (20%) may not be satisfied with the results of compliance and may express dissatisfaction, even if the Standard is followed perfectly. Many sources have concluded that the majority of HVAC systems designed in the U.S. do not meet the minimum ventilation rates prescribed during operation. In which case, the actual occupant dissatisfaction level is exponentially greater in practice [2]. It is not uncommon for rates to fall below levels that result in occupant dissatisfaction significantly greater than 50%. Many systems cannot meet the minimum airflow requirements at the occupied space during operation because of design choices and equipment limitations, or due to the dynamic nature of mechanical ventilation systems and the external forces acting on the building envelope.

The impacts from these continuously changing external conditions are not limited to Variable Air Volume (VAV) systems [2]. Outdoor airflow rates will also vary for systems that provide a Constant Volume of supply air (CAV) to the conditioned space, as a result of:

a) changes in wind and/or stack conditions on the intake system [3],
b) changes in filter loading,
c) changes in airflow requirements during an economizer cycle.

The lack of specific guidelines to overcome the effect of changing system dynamics on ventilation rates and air distribution for today's HVAC systems is partially to blame for many design deficiencies observed.

Unlike thermal comfort, the effect of indoor air quality is difficult to measure. Many believe that the outdoor air levels specified by ASHRAE are too low and should actually be increased, as indicated by published research and reflected in European standards from CEN Technical Committee 156 and their publication CR1752 [4].

OUTDOOR AIR QUALITY

Section 4 of the Standard describes a three-step process to evaluate outdoor air for acceptability. One of those steps requires examination of both the regional and local air quality by the building owner. The section also specifies the documentation required to support the conclusions of this preliminary review.

If the outdoor air quality is found to be unsuitable per Section 4, then treatment may be required as indicated in §6.2.1. Outdoor air treatment involves removal of the particulates and/or gases encountered that are in excess of the minimum standards cited by cognizant authorities in §4.1.

SYSTEMS AND EQUIPMENT

Section 5 specifies the minimum systems and equipment required under Standard 62.1. §5.3 states,

> "Mechanical ventilation systems shall include controls, manual or automatic, that enable the fan system to operate whenever the spaces served are occupied. The system shall be designed to maintain no less than the minimum outdoor airflow as required by Section 6 under any load condition.
>
> ***Note:*** Variable Air Volume (VAV) systems with fixed outdoor air damper positions must comply with this requirement at minimum system primary airflow. [1]."

This current section has already been revised with an addendum being prepared for public review. The 2011 proposed draft addendum (DA-40) of the new section reads as follows:

> ***5.3*** ***Ventilation System Controls.*** *Mechanical ventilation systems shall include controls in accordance with the following:*
>
> ***5.3.1*** *All systems shall be provided with manual or automatic controls to maintain no less than the outdoor air intake flow (V_{ot}) as required by Section 6, under all load conditions or dynamic reset conditions.*
>
> ***5.3.2*** *Systems with fans supplying variable primary-air (V_{ps}) or variable mixed-air flow, including single-zone VAV and multiple-zone-recirculating VAV systems shall be provided with one or more of the following:*
>
> *a. Outdoor air-intake, return air dampers or a combination thereof that modulate to maintain no less than the outdoor air intake flow (V_{ot})*
> *b. Outdoor-air injection fans that modulate to maintain no less than the outdoor air intake flow (V_{ot})*
> *c. Other means of ensuring compliance with Section 5.3.1*

Because the requirements in the Standard for compliance are set forth "under any load condition" and in the future to possibly include "dynamic reset conditions," we are being asked to maintain a constant rate of outdoor airflow in dynamic systems. One can logically conclude, there should also be a requirement for continuous airflow measurement at the intake of all air-handling units with automatic controls providing an occupied space with a constant rate of outdoor air, regardless of the system size, type or point of operation. Doing so would alleviate several issues, clarifying application and compliance questions in §6.2.7 Dynamic Reset; §7.2.2 Air Balancing; and §8.4.1.8 Outdoor Airflow Verification.

A continuous outdoor air measurement requirement was included in the draft Standard 62-89R before becoming much more complicated and vague to the point of confusion. It is also required in §8.3.1.2 Outdoor Air Delivery Monitoring and supported in sections 7.4.3.2, 10.3.2.1.4 of Standard 189.1-2009 *Standard for the Design of High Performance Green Buildings*[11].

Standard 62.1 encourages us to use direct measurement feedback for continuous control on all VAV designs, even those using a powered outdoor air system (i.e. injection fan, HRV/ERV, smaller DOAS, etc.)[10]. Although not contained in the Society's 'minimum' standard, ASHRAE's 62.1 User's Manual is highlighting the potential source of problems and a few of the more obvious means to avoid them.

We believe that Section 5 of the Standard points to the use of airflow measuring devices at the intake of all systems and in the supply air to critical zones of VAV systems. This allows for not only improved operating savings, continuous verification of compliance and use as a diagnostic and energy management tool, but also may be used to reliably reset intake rates based on changes in space population. Knowing the population at any point in time allows automatic controls to reset the control set point for outdoor air intake rates in direct response to those changes.

Popularly known as "Demand Controlled Ventilation" (DCV), technology is available to count or estimate zone populations in real time and used to reset intake and supply flow set points. A simple comparative analysis has shown them to be surprisingly cost effective. When compared to the potential energy savings without negatively impacting occupant comfort, productivity and health, there is little reason to avoid it. We will discuss the limitations and risks of CO_2-based DCV within §6.2 on the Ventilation Rate Procedure and further under §6.2.7 Dynamic Reset.

PRESSURIZATION & MOLD

Problems identified immediately after publication of Addendum 62x (62-2001) generated Addendum 62ai (renamed 62.1a for the 2007 version). The 2007 addendum only addressed the need for positive pressure during "periods of dehumidification." The current language for §5.9, however, clarifies several issues, including exceptions to the 65% RH requirement and for labs and industrial spaces.

> "**5.9** **Dehumidification Systems.** Mechanical air-conditioning systems with dehumidification capability shall be designed to comply with the following.
>
> **5.9.1** **Relative Humidity.** Occupied space relative humidity shall be limited to 65% or less when system performance is analyzed with outdoor air at the dehumidification design condition (that is, design dew point and mean coincident dry-bulb temperatures) and with the space interior loads (both sensible and latent) at cooling design values and space solar loads at zero.
>
> ***Note:*** System configuration and/or climatic conditions may adequately limit space relative humidity at these conditions without additional humidity-control devices. The specified conditions challenge the system dehumidification performance with high outdoor latent load and low space sensible heat ratio**.**
>
> **Exception:** Spaces where process or occupancy requirements dictate higher humidity conditions, such as kitchens, hot tub rooms that contain heated standing water, refrigerated or frozen storage rooms and ice rinks, and/or spaces designed and constructed to manage moisture, such as shower rooms, pools, and spas.

Proposed Addendum 62.1c (2010) is in process after public review and should replace 5.10.2 on Exfiltration.

5.9.2 ***Exfiltration.*** *For a building, the ventilation system(s) shall be designed to ensure that the minimum outdoor air intake equals or exceeds the maximum exhaust airflow.*

Exception: *When outdoor air dry-bulb temperature is below the indoor space dew point design temperature.*

Exception: *Where excess exhaust is required by process considerations and approved by the authority having jurisdiction, such as in certain industrial facilities.*

Note: *Although individual zones within a building may be neutral or negative with respect to outdoors or to other zones, net positive mechanical intake airflow for the building as a whole reduces infiltration of untreated outdoor air."*

Noting the proliferation of mold in buildings, the ASHRAE Board stated that sound moisture management should take precedence over energy cost savings when it issued *Minimizing Indoor Mold through Management of Moisture in Building Systems* in June 2005 [5]. This Position Paper outlines recommendations by describing issues related to the topic and highlighting resources available through the Society. This policy will eventually trickle-down through the society's organization and eventually impact technical programs, research and standards.

Included in their recommendations for proper moisture management are:

- Building and system design, operation and maintenance provide for drying of surfaces and materials prone to moisture accumulation under normal operating conditions.
- Mechanical system design should properly address ventilation air.
- The sequence of operation for the HVAC system should contain appropriate provisions to manage humidity, control pressurization and monitor critical conditions[5].

We believe that one flaw in the committee's position is in not recognizing the potential for high humidity alone to provide sufficient moisture content for mold growth. Studies have shown that a temperature between 30°F – 86°F [-17°C - 30°C] and humidity of only 70% RH (non-condensing infiltration), mold growth has appeared on plasterboard, brick and concrete within 3 days. At 65.3°F [18.5°C] (with adequate RH and "inadequate" substrate) mold has been demonstrated to grow on building materials after 6 hours. It was shown to take only 1 hour with "adequate" substrate [2, 6].

Part of the solution to preventing infiltration of unfiltered and unconditioned humid air appears to be fairly simple. In 1996 the Florida Solar Energy Center first published a case study which identified that an extremely small negative pressure differential created conditions that lead to mold problems in a small commercial building. This was later supported by a 2002 Journal article whose recommendations indicated that differential pressures as low as +0.004 to +0.008 in. WG [1 to 2 Pa] will prevent moisture infiltration problems.[7] This counter-flow overcomes most of the natural pressures that power moisture migration, namely: vapor, temperature (stack), and wind pressures. Those periods when pressurization flow is insufficient to counter infiltration are generally limited in duration. Thereafter, the flow of air to the direction of higher dew point temperature can remove any residual moisture in the wall cavity.

The author(s) of the 2010 *User's Manual* did not appear to understand that directed pressurization flow can overcome infiltration, prevent mold growth and overcome some of the effects of wind and stack pressure. We disagree with some of their conclusions and characterizations.

> "Pressurization is a minimum requirement to limit excessive infiltration of high dew point outdoor air but it does not prevent a number of other conditions that can occur, for example:

- Even though the building as a whole may have more outdoor air intake than exhaust, stack and wind effects can cause large regions, such as entire levels or facades, to be negatively pressurized; [Comment: Pressurization flow is not intended to compensate for all wind and stack pressure and wind pressure does not accumulate. Only the mechanical system can create pressurization flow. The net pressurization of wind alone, without mechanical systems, is zero. The positive face is offset by a negative leeward face.]
- Individual zones within the building may be required to have neutral or negative pressure, such as some laboratory and industrial spaces; [Comment: This is true and does not contradict, but provides motivation for the use of compartmentalized pressurization flow control.]
- A building that is excessively pressurized may cause damage to the structural integrity of the building envelope, or cause other problems, such as difficulty closing doors;" §5.9.2, p,42 [Comment: Again, true, and not a contradiction.]

In response to this, engineers should understand that pressurization flow could mitigate the impact of these pressures, but cannot eliminate them. Controlling airflow into and out of those spaces is the most stable and effective method of providing the needed control.

In fact, many on the ASHRAE Technical Committee for Moisture Management in Buildings (TC1.12) feel similarly to the opinions in the *User's Manual*. They tend to put all of their trust for infiltration control in sealing ability of the building envelope materials and construction. High quality envelope construction and moisture barriers are some of the most important factors in preventing infiltration in an energy efficient way. But they can not perform like Tupperware. There will always be some amount of leakage. Differential flow control can provide the means to prevent the migration of humid and untreated air, to the least amount of incremental energy needed. Control precision and stability should be primary objectives when the dynamic control of space pressurization is used.

The Standard has not yet addressed wind and stack effects, nor provided guidelines that reflect conditions that influence buildings in their normal environment. In addition, wind and stack driven infiltration during periods when the ventilation system is not operating, may be a significant factor influencing mold and fungal growth, e.g. offices and schools during closures. Designers and building operators should consider a limited night setback mode with provision for humidity and pressurization flow controls. Such a provision would also tend to compensate for the building-generated contaminants by supplying a base ventilation rate, sufficient for minimal pressurization flow. The 62.1 draft addendum (DA-40) proposed to replace §5.3 reflects this philosophy.

Another new section addresses an issue long a hindrance to the reliability of ventilation system components - accessibility.

5.13 Access for Inspection, Cleaning, and Maintenance

5.13.1 Equipment Clearance. Ventilation equipment shall be installed with sufficient working space for inspection and routine maintenance (e.g., filter replacement and fan belt adjustment and replacement).

5.13.2 Ventilation Equipment Access. Access doors, panels, or other means shall be provided and sized to allow convenient and unobstructed access sufficient to inspect, maintain, and calibrate all ventilation system components for which routine inspection, maintenance, or calibration is necessary. Ventilation system components comprise, for example, air-handling units, fan-coil units, water-source heat pumps, other terminal units, controllers, and sensors.

Systems are now also tasked with maintaining a directionally outward (positive) pressurization flow to provide an air barrier between the occupied space and attached parking garages.

> **5.15 Buildings with Attached Parking Garages.** In order to limit the entry of vehicular exhaust into occupiable spaces, buildings with attached parking garages shall be designed to:
>
> a. maintain the garage pressure at or below the pressure of the adjacent occupiable spaces, or
>
> b. use a vestibule to provide an airlock between the garage and the adjacent occupiable spaces, or
>
> c. otherwise limit migration of air from the attached parking garage into the adjacent occupiable spaces of the building in a manner acceptable to the authority having jurisdiction.

PROCEDURES

Section 6, Procedures, is the heart of the Standard. For compliance, designers must claim using only one of them. You may now choose between the Ventilation Rate Procedure (VRP) the Indoor Air Quality Procedure (IAQP) and newly adopted Natural Ventilation Procedure (NVP) to determine the minimum dilution rate required for design. The NVP essentially deals with mixed-mode designs and assumes that with windows closed a mechanical ventilation system must be present.

Designers and operators cannot selectively ignore the sections they do not like or combine parts from each procedure to achieve ventilation rates lower than those determined by the VRP alone. You must select only one. Great care should be given to the selection between these procedures.

VENTILATION RATE PROCEDURE (VRP)

The VRP as defined in 6.1.1: "…The prescriptive design procedure presented in Section 6.2, in which outdoor air intake rates are determined based on space type/application, occupancy level, and floor area, shall be permitted to be used for any zone or system." [1] The key phrase is "prescriptive procedure in which outdoor air intake rates are determined…." Very simply, this implies the need for some form of airflow metering for determination and verification.

The VRP detailed in §6.2 is rate based. In fact, the entire Standard is rate-based, including the IAQP and NVP. The IAQP only provides the means to calculate allowable reductions in the design ventilation rate from those in Table 6-1 (see also Appendix D for alternate methods of calculation). The explicit statement to this effect was removed in an effort to render the language in the Standard more 'code enforceable.'

Designers claiming compliance with the VRP must be able to document and substantiate that minimum intake rates can be maintained during operation "under all load conditions," <u>at not less than</u> the higher of either code-required levels or those indicated by table 6-1 and the result of calculations required for the determination of outdoor air intake flow (V_{ot}) from the details found in §6.2.1 through §6.2.7.1.5.

One key to the determination of V_{ot} and thereafter V_{bz}, is Design Zone Population defined in 6.2.2.1.1 as the "largest (peak) number of people expected to occupy the ventilation zone". As we will see, this variable must be determined or assumed in the calculation for V_{bz} which defines the objective of the VRP in formula 6-1.

One subtle change within the 2007 Standard to remember included the usage and definition of "breathing zone." It is also important to recognize that required minimum rates are no be longer determined solely on occupancy "per person" since mid-2003. Separate component rate requirements are included to address both occupant and building-generated contaminants. The significance of this change to the validity of operational control strategies for systems with variable populations will become apparent later in this section.

6.2.2.1 Breathing Zone Outdoor Airflow. The design outdoor airflow required in the *breathing zone* of the occupiable space or spaces in a *zone*, *i.e., the breathing zone outdoor airflow* (V_{bz}), shall be determined in accordance with Equation 6-1.

$$V_{bz} = R_p P_z + R_a A_z \qquad (6\text{-}1)$$

where*:*

A_z = *zone floor area*: the net occupiable floor area of the *zone* m^2, (ft^2).

P_z = *zone population*: the largest number of people expected to occupy the zone during typical usage. If the number of people expected to occupy the zone fluctuates, P_z may be estimated based on averaging approaches described in Section 6.2.6.2.

Note: If P_z cannot be accurately predicted during design, it shall be an estimated value based on the zone floor area and the default occupant density listed in Table 6-1.

R_p = outdoor airflow rate required per person as determined from Table 6-1.

Note: These values are based on adapted occupants.

R_a = outdoor airflow rate required per unit area as determined from Table 6-1.

Note: Equation 6-1 is the means of accounting for people-related sources and area-related sources for determining the outdoor air required at the *breathing zone.* The use of Equation 6-1 in the context of this standard does not necessarily imply that simple addition of sources can be applied to any other aspect of indoor air quality." [1]

Once the outdoor air is determined to be acceptable or has been treated for use indoors, we can begin to determine how much is needed under our specific design situation.

First, we must calculate outdoor airflow requirements for the **breathing zone** (V_{bz}) and **zone** (V_{oz}), as detailed in §6.2.2.1 through §6.2.2.3 which can be summarized below with their corresponding equations and reference numbers:

- Calculate breathing-zone outdoor airflow - $V_{bz} = R_p P_z + R_a A_z$ (6-1)
- Determine zone air distribution effectiveness - E_z = Table 6-2
- Calculate zone outdoor airflow at diffusers - $V_{oz} = V_{bz}/E_z$ (6-2)

Then, determine the outdoor airflow requirements for the single zone **system** (V_{ot}) and calculate minimum outdoor air intake flow. We are given 3 general system types to choose from:

- Single-zone systems: $V_{ot} = V_{oz}$ (6-3)
- 100% OA systems: $V_{ot} = \sum_{all\ zones} V_{oz}$ (6-4)
- Multiple-zone recirculating systems
  Outside Air Intake: $V_{ot} = V_{ou}/E_v$ (6-8)

In Multi-zone recirculating systems, extends the basic equations for the single zone to include the variables needed to solve for V_{ot} (V_{ou} and E_v), as determined in §6.2.5.1 – §6.2.5.4 and summarized below. These will be examined in more detail later.

- Calculate the Zone primary outdoor air fraction: $Z_p = V_{oz}/V_{pz}$ (6-5)
- Determine the Uncorrected outdoor air intake:

- Accounting for Occupant Diversity:

$$V_{ou} = D \sum_{all\ zones} R_p P_z + \sum_{all\ zones} R_a A_z \quad (6\text{-}6)$$
$$D = P_s / \sum_{all\ zones} P_z \quad (6\text{-}7)$$

Total intake rate at the air handler can be directly determined with hand-held instruments, when used in accordance with prescribed standards, or by using an appropriate and permanently installed airflow measuring device. Total intake rate may be indirectly estimated by several other means (i.e. Supply/Return differential calculation, temperature balance, mass balance, steady-state CO_2 differential concentrations, etc.). However, the excessive uncertainty of indirect techniques introduces a significant level of risk.[2,7] The designer, facility owner and occupants should carefully consider the method employed prior to implementing any CO_2-based Demand Controlled Ventilation scheme as the sole method of intake rate control.

The VRP in §6.2 recognizes the magnitude of building generated pollutants, by adding the "building component" to the zone ventilation equation. Table 6-1 and the accompanying notes specify outdoor air requirements for specific applications/occupancies. Equation 6-1 (§6.2.2.1 above) is now based on the summation of ventilation rates per person (as CFM/p) + ventilation rates per floor area (as CFM/ft^2). Therefore, systems that meet these requirements will account for:

(a) the minimum requirements of Table 6-1, combined with
(b) the calculated volume of outdoor air required by 6.2 and
(c) the outdoor air quality requirements set forth in Section 4
(d) while "under any load condition,"

…and can claim that their ventilation system complies with the Standard through the VRP.

Under ideal and very specific conditions, CO_2 concentration differentials (inside to outdoors) can only reflect the rate that outdoor air enters the building on a per person basis – through any and all openings. Therefore, CO_2-based DCV with single 'ppm' set point control cannot be implemented under the new requirements of Standard 62.1 unless applied with excessive conservatism (over ventilation) and the accompanying increase in energy usage. Otherwise, CO_2-based DCV will invariably under ventilate some spaces, over ventilate other spaces or require that the Standard be interpreted to allow large airflow control errors that will result from using multiple CO_2 sensor inputs.

Table 1: Resultant Ventilation Rate/pp based on Fixed ΔCO_2 Set Point, using Steady-state CO_2 Formula and compared to current minimum requirements for different populations

(Area = 1,000 ft^2)

# People	Required Total OA	CFM/Person	CO_2 Rise [C_i-C_o]	Comments
7 (+17%)	95 CFM	13.5	807 ppm	} **Under ventilated**
6 **(base)**	90 CFM	15	700 ppm	using a 700 ppm differential set point
5 (-17%)	85 CFM	17	644 ppm	} **Over ventilated**
3 (-50%)	75 CFM	26	438 ppm	

Total OA CFM Required = 0.06 CFM/ft^2 + 5 CFM/person (Source: ASHRAE 62.1-2010, Table 6-1, offices)

Calculated using the concentration balance formula in ASHRAE 62.1 Appendix C, at Various Population Densities in an Office Space [2]

Indirect measurements for control typically carry such a large degree of uncertainty, one can never be secure that the controlled variable (ventilation rates) will not drop below or substantially exceed the mandated minimums under "all operating conditions."

Compliance with the IMC minimum ventilation requirements using CO_2 is not explicitly allowed. Section 403.3.1 requires that the "actual population" of the zone be used to determine the amount of outdoor air required. Approval is entirely at the discretion of the "Authority Having Jurisdiction," subject to a successful application for the variance. Compliance with ASHRAE 62.1 using CO_2 inputs is indicated in the *Manual*, but the method is the responsibility of the designer. The latest *62.1 User's Manual* [10] does attempt to offer possible alternatives, but the limitations in use and vagueness leave much to the determination of the individual designer – and entirely at your own risk.

MULTI-SPACE 'EQUATIONS' BECOME A DESIGN 'PROCEDURE'

Once the breathing zone outdoor air requirement is determined, the Standard requires an adjustment based on the distribution system efficiency and effectiveness. This makes complete sense since the air must reach the breathing zone to be effective.

Multi-zone recirculating systems are not as efficient as 100% OA systems and are therefore required to be factored by their approximate and relative inefficiency. We are given two methods to determine this factor:

1. Table 6-3, "default E_v" method
2. Appendix A, "calculated E_v" method

These methods produce significantly different results. The more precise one is contained in Appendix A and as might be expected, is more involved. The table's conciseness requires it to be more conservative and therefore is not as efficient in many situations.

For each multiple zone recirculating system (VAV or CAV), the primary outdoor airflow fraction must be calculated for all zones that may become 'critical' (only one zone can be critical on CAV systems). The "critical zone" is defined as the zone that has the highest percentage of outdoor air required in the primary air stream. When analyzing a VAV system dynamically, treat it as a CAV system.

As an example, if the supply air distribution system is located close to the return air, a short circuit is generally created. The Standard requires designers to use a zone air distribution effectiveness (E_v) of 0.5 which essentially doubles the amount of outdoor air required. In contrast to this example, a system with a ceiling supply and a ceiling return has a zone distribution effectiveness of 1.0 during cooling and 0.8 during heating. Therefore, the outdoor air set point must be reset seasonally or a more conservative and less energy-efficient factor must be used. This is another push by the standard to spot light the operating efficiencies of a dynamically controlled design.

Systems that provide a variable supply of air volume to the conditioned space are influenced by almost everything previously discussed. In addition, outdoor airflow rates will vary as a result of changes in mixed air plenum pressure. If the design did not assume the worst-case scenario when the outdoor airflow rate for the air handler was determined, outdoor airflow rates on VAV systems may need to be reset based on calculations of the multi-space equations (6-5 through 6-8, defined in §6.2.5 below), in order to avoid potentially excessive over ventilation and the associated energy penalty.

"**6.2.5 Multiple-Zone Recirculating Systems.** For ventilation systems wherein one or more air handlers supply a mixture of outdoor air and recirculated air to more than one ventilation zone, the outdoor air intake flow (V_{ot}) shall be determined in accordance with Sections 6.2.5.1 through 6.2.5.4. [Equations 6-5 through 6-8].

6.2.5.1 Primary Outdoor Air Fraction. Primary outdoor air fraction (Z_{pz}) shall be determined for ventilation zones in accordance with Equation 6-5.

$$Z_p = V_{oz}/V_{pz} \qquad (6\text{-}5)$$

where V_{pz} is the zone primary airflow, i.e., the primary airflow rate to the ventilation zone from the air handler, including outdoor air and recirculated air.

Note: For VAV-system design purposes, V_{pz} is the lowest zone primary airflow value expected at the design condition analyzed.

Note: In some cases it is acceptable to determine these parameters for only selected zones as outlined in Normative Appendix A.

6.2.5.2 System Ventilation Efficiency. The *system ventilation efficiency* (E_v) shall be determined in accordance with Table 6-3 or Normative Appendix A.

6.2.5.3 Uncorrected Outdoor Air Intake. The uncorrected outdoor air intake (V_{ou}) flow shall be determined in accordance with Equation 6-6..

$$V_{ou} = D \sum_{all\ zones} R_p P_z + \sum_{all\ zones} R_a A_z \qquad (6\text{-}6)$$

6.2.5.3.1 Occupant Diversity. The occupant diversity ratio (D) shall be determined in accordance with Equation 6-7 to account for variations in population within the ventilation zones served by the system.:

$$D = P_s / \sum_{all\ zones} P_z \qquad (6\text{-}7)$$

where the system population (P_s) is the total population in the area served by the system.

Exception: Alternative methods to account for occupant diversity shall be permitted, provided that the resulting V_{ou} value is no less than that determined using Equation 6-6.

Note: The uncorrected outdoor air intake (V_{ou}) is adjusted for occupant diversity, but it is not corrected for system ventilation efficiency.

6.2.5.4 Outdoor Air Intake. The design *outdoor air intake flow* (V_{ot}) shall be determined in accordance with Equation 6-8.

$$V_{ot} = V_{ou} / E_v \qquad (6\text{-}8)$$

" [1]

Advanced VAV control strategies can dynamically satisfy the requirements of §6.2.5.1 – §6.2.5.4 and therefore operate systems more efficiently than static strategies. This can be accomplished by automatically determining the critical zone fraction, to continuously calculating the corrected fraction of outdoor air. The calculation requires that the total supply airflow rate be continuously measured and the airflow rate of the critical zones use permanent airflow measuring devices capable of better than average accuracy, especially at low airflow rates.

Differential pressure-based airflow sensors traditionally provided with VAV boxes should not be used for these calculations. Although the OEM devices may be adequate in modulating a terminal box for thermal comfort, the combination of typically poor inlet conditions, low quality pressure pickups and low cost pressure sensors in the DDC controller will not result in the measurement accuracy necessary for proper calculation of Equations 6-1 and 6-5 through 6-8. Conservative mathematical modeling has demonstrated that typical VAV box measurement performance can be statistically exceeded by boxes without a measurement device [2]. Accurate airflow measuring devices having a total installed accuracy better than 5% of Reading at maximum system turndown should be installed in the supply ducts for critical zones.

The result from these multi-space equations can provide wide variations in outdoor airflow requirements in some systems. Increasing the critical zone supply flow while using reheat, can reduce total outdoor airflow rates and overall energy usage. This method has been simulated at Penn State University using the multi-space equation from Standard 62-2001, with published results showing greater energy efficiency than the same system supplying the maximum, worst-case V_{ot} continuously. The basic variables, relationships and the end results should be the same using the VRP of Standard 62.1.

The VRP continues and provides us with additional options to help make the design more specific to an engineer's needs and to the demands of the situation. You may…

1. design using the short-term "averaged" population, rather than the peak – 6.2.6 (6-9)
2. operate (and dynamically reset requirements) using "current" population data – 6.2.7, "DCV"

> **6.2.6 Design for Varying Operating Conditions.**
>
> **6.2.6.1 Variable Load Conditions.** Ventilation systems shall be designed to be capable of providing the required ventilation rates in the breathing zone whenever the zones served by the system are occupied, including all full- and part-load conditions [1].

The peak population value may be used as the design value for P_z. Alternatively, time-averaged population determined as described in §6.2.6.2, may be used to determine P_z.

Outdoor airflow rates can also be reduced if the critical zones have variable occupancy or other unpredictably variable (dynamic) conditions. Changes in occupancy (or ventilation 'demand') can be detected in many ways, as indicated in the 'note' below. Therefore, Demand Controlled Ventilation systems otherwise known as Dynamic Reset should not be limited to CO_2 measurement inputs alone.

§6.2.7 on Dynamic Reset addresses conditions where the ventilation system controls …

> "…may be designed to reset the outdoor air intake flow (V_{ot}) and/or space or ventilation zone airflow (V_{oz}) as operating conditions change.
>
> **6.2.7.1 Demand Control Ventilation** (DCV)
> **6.2.7.1.1** DCV shall be permitted as an optional means of dynamic reset.
> **Exception:** CO_2-based DCV shall not be applied in zones with indoor sources of CO_2 other than occupants or with CO_2 removal mechanisms, such as gaseous air cleaners."
>
> **6.2.7.1.2** The breathing zone outdoor airflow (V_{bz}) shall be reset in response to current occupancy and shall be no less than the building component (R_a*A_z) of the DCV zone.
>
> ***Note:*** Examples of reset methods or devices include population counters, carbon dioxide (CO_2) sensors, timers, occupancy schedules or occupancy sensors.

It is important to recognize here that nothing in the standard limits the definition or use of DCV to systems that are based upon solely upon CO_2 inputs. In fact, there are many more possibilities for DCV inputs and methods than are included in 6.2.7.1.2. Serious consideration should also be given to the control requirement for V_{bz} *never to be less than the building component of the DCV* zone. This cannot be prevented by minimum damper position alone.

6.2.7.1.3 The ventilation system shall be controlled such that at steady-state it provides each zone with no less than the breathing zone outdoor airflow for the current zone population.

It should also be noted that although the standard solves a "design" issue by specifying steady-state conditions, engineers must recognize that the assumed conditions will normally never exist in spaces that by occupancy definition and usage are "variable". The relationship between CO_2 concentrations and airflow rate per person exist ONLY if the prerequisite assumptions are known and true. There is no confirmed 'relationship' in the formula (C-1) without knowing all 5 of them at a specific point in time:

$V_o = N / (C_s - C_o)$, where:

- V_o = *outdoor airflow rate per person*
- V_e = breathing rate and C_e = CO_2 concentration in exhaled breath are mostly dependant on the activity level and diet of the occupants
- N = CO_2 generation rate per person is generally underestimated and varies
- C_s = CO_2 concentration in the space may contain large sampling errors
- C_o = CO_2 concentration in outdoor air cannot be assumed a fixed value

Each component variable also imparts its own uncertainty to the calculation, when used operationally for intake control. Other factors also influence the reliability of control strategies based on this method: Sensor precision (published 150 ppm error range = 28-30% OA intake uncertainty); Control lag and zero drift force accommodations (±75 ppm = +15% / -13% V_{ot}); Outdoor concentrations can vary significantly and cannot be assumed to be fixed (±50 ppm = +11% / -7% V_{ot}); Sensor sensitivity to environmental changes contributes to sensor error and reliability[12]. The accumulated potential RMS error can easily be as large as 50% of the volumetric set point. Although this may satisfy some engineers, "close" cannot be concluded from the error potential in these factors and variables.

It is a big problem for designers to select a method of control ventilation to the variably occupied space that does not violate compliance with the "no less than" V_{bz} minimums, which can only be calculated for the "current zone population."

This catch-22 generally forces many toward conservative solutions and over ventilate, to require a purge prior to occupancy, to hedge outdoor concentration averages in formulae and otherwise supplement the deficiencies in the control method to avoid problems. This does not sound very energy efficient and defeats much of the CO_2 hype which convinced designers to use DCV in the first place.

The next provision recognizes the significance of maintaining proper pressurization flow direction, which can be more problematic when ventilation rates vary with the population. A dynamically controlled exhaust rate may also be necessary.

6.2.7.1.4 When the mechanical air-conditioning system is dehumidifying, the current total outdoor air intake flow for the building shall be no less than the coincident total exhaust airflow.

6.2.7.1.5 Documentation. A written description of the equipment, methods, control sequences, set points, and the intended operational functions shall be provided. A table shall be provided that shows the minimum and maximum outdoor intake airflow for each system.

6.2.7.2 Ventilation Efficiency. Variations in the efficiency with which outdoor air is distributed to the occupants under different ventilation system airflows and temperatures shall be permitted as an optional basis of dynamic reset.

6.2.7.3 Outdoor Air Fraction. A higher fraction of outdoor air in the air supply due to intake of additional outdoor air for free cooling or exhaust air makeup shall be permitted as an optional basis of dynamic reset.

There is no direction in the Standard on how to implement Dynamic Reset using CO_2, which was left to be addressed by the *User's Manual*. This section of the Standard, independent of the *User's Manual*, would lead one to believe that CO_2 is a method of 'counting' and not an input to be used for direct ventilation control. They are two entirely separate things, defined by the level of certainty available by the method. Any reasonably accurate counting method could be used to reset a flow rate established and controlled by some other measurement means.

We recommend that you read the latest *62.1 User's Manual*, particularly sections 6.2 on the VRP and Appendix A on CO_2-based Demand Controlled Ventilation. It only discusses interior CO_2 measurement (using an assumed average for outdoor concentrations) as a means of partially satisfying the VRP through Dynamic Reset. The designer is "on-his-own" to determine how to satisfy the remaining part of the requirement. The *User's Manual* may not provide firm "how-to" guidance and may generate more questions than answers. But, it should help everyone get a better understanding of the committee's intentions and some directions they may use to seek solutions. Here are some excerpts from Appendix A.

> *"Overview - This appendix describes how CO_2 concentration may be used to control the occupant component of the ventilation rate.* [AUTHORS' NOTE: This circumvents discussing how to handle the building component.] *The approaches described may be used to dynamically control ventilation in compliance with § 6.2.7." and "… it is most cost effective in those occupancies that have a high design occupancy density but which are not occupied at that density consistently. Examples include ballrooms, conference/meeting rooms, and lecture halls."* Pg. A-1
>
> *"…the steady-state assumption in Equation A-H is made not because the actual system is at steady-state but because the ventilation rate equation, Equation 6-B, is based on steady-state conditions." And "…In practice, acceptable performance will also hinge on the ability of the control system to sense CO_2 concentrations and adjust ventilation rates according to the equation.* Pg. A-3
>
> *"…the most accurate approach…results in actual differential CO_2 concentration measurement, this approach can also be the least accurate and reliable due to sensor inaccuracy.…The accuracy of differential CO_2 concentration measurement can be improved by using a single CO_2 sensor with a sampling pump, sequenced valves, and tubes piped to the zone and to the outdoors—but first costs will be higher."* Pg. A-4

The *User's Manual* implies that using CO_2-DCV for the direct control of intake rates is problematic, risky and inaccurate, violates the requirements of Chapter 4 - Ventilation in the IMC and may not even lead to compliance with the VRP requirements of Standard 62.1. This is a problem for the use of CO_2, should you expect to also satisfy the minimum requirements of the VRP.

What else does the *User's Manual* say about systems, controls and equipment that are not in the *Standard*? Quite a bit. The document is very well done and should provide significant help to many in the understanding and application of the Standard. Some of the more significant issues that are clarified include the following:

> *"Ventilation System Controls (§ 5.3)…The system must be designed to maintain the minimum outdoor airflow as required by § 6 under any load condition. …In order to comply, most VAV systems will need to be designed with outdoor airflow sensors and modulating dampers or injection fans."* Pg. 29-30
>
> *"In the past, the part-load ventilation requirement has been neglected in many VAV systems. In most cases, an active control system must be provided at the air intake and sometimes at the zone level to ensure minimum rates are maintained."* Pg. 31
>
> *"Variable Air Volume System …Note that a fixed-speed, outdoor-air fan without control devices will not maintain rates within the required accuracy …Using return air, outdoor air, and mixed air temperatures or CO_2 concentrations to measure* [AUTHORS' NOTE: Intake rates would be indirectly estimated in this example – not measured] *air intake percentage is usually inaccurate*

when the outdoor and indoor values are close together and thus should only be used with caution. Similarly, measuring [estimating] *outdoor air by taking the difference between supply- and return-airflow measurements will also seldom meet reasonable accuracy requirements due to cumulative errors in airflow measurement and the generally small outdoor airflow rate relative to supply and return-airflow rates."* Pg. 31

Because of the high risk of noncompliance and potential excess energy costs (or insufficient dilution air), intake rates should not and cannot be determined indirectly by the 'counting' device alone. So, how should your control strategy be designed to comply with Standard 62.1? For CONSTANT OCCUPANCY (or at least consistent populations) use design conditions to set a fixed outside air rate at the AHU in accordance with the Ventilation Rate Procedure and use an outside airflow station to maintain that level.

Unless occupancy is extremely variable, there is little to gain by using DCV with the requirements of ASHRAE 62.1-2010. In the example used in our IAQ Seminars, reducing a space population -10% would result in a reduction of the outside air by only 3.2%. Is that enough savings to accept the risk of non-compliance or negative impacts on productivity? Consider using occupied/unoccupied switches to reset outside air based on design occupancy of variable occupancy zones. [12]

For UNPREDICTABLY VARIABLE AND DENSELY OCCUPIED SPACES, other digital occupancy counting technologies are becoming available that will help users to comply with this standard, most codes and avoid all of the risk and uncertainty of using CO_2.

INDOOR AIR QUALITY PROCEDURE

The alternative IAQP is described in 6.1.2: "…This performance-based design procedure (presented in Section 6.3), in which the building outdoor air intake rates and other system design parameters are based on an analysis of contaminant sources, contaminant concentration limits, and level of perceived indoor air acceptability, shall be permitted to be used for any zone or system." [1] Any analysis of this procedure quickly reveals the clear discussion of airflow rate requirements based on varying contaminant levels.

Section 6.3 INDOOR AIR QUALITY PROCEDURE begins by outlining its objective – V_{bz} or V_{ot}

> **6.3 Indoor Air Quality Procedure.** Breathing zone outdoor airflow (V_{bz}) and/or system outdoor air intake flow (V_{ot}) shall be determined in accordance with Sections 6.3.1 thru 6.3.5.

The concept of providing "performance-based" solutions is desirable in principle. However, there are numerous risks associated with both the quantitative and subjective evaluations provided within the IAQ procedure that every designer should understand. Here are the specifics of the IAQP.

> **6.3.4 Design Approach.** Zone and system outdoor airflow rates shall be determined in accordance with Section 6.3.4.1 and 6.3.4.2 based on generation rates, target concentrations and other relevant design parameters (e.g., air cleaning efficiencies and supply airflow rates).
>
> **6.3.4.1 Mass Balance Analysis.** Using a steady-state or dynamic mass-balance analysis, determine the minimum outdoor airflow rates required to achieve the concentration limits specified in Section 6.3.2 for each contaminant or mixture of concern within each zone served by the system.
>
> **Notes:**

a. Appendix D includes steady-state mass-balance equations that describe the impact of air cleaning on outdoor air and recirculation rates for ventilation systems serving a single zone.
b. In the completed building, measurement of the concentration of contaminants or mixtures of concern may be useful as a means of checking the accuracy of the design mass-balance analysis, but such measurement is not required for compliance.

6.3.4.2 Subjective Evaluation. Using a subjective occupant evaluation conducted in the completed building, determine the minimum outdoor airflow rates required to achieve the level of acceptability specified in Section 6.3.3 within each zone served by the system.

Notes:
a. Appendix B presents one approach to subjective occupant evaluation.
b. Level of acceptability often increases in response to increased outdoor airflow rates, increased level of indoor and/or outdoor air cleaning, or decreased indoor and/or outdoor contaminant emission rate.

The SSPC has gone a long way toward making design results from the new IAQP more predictable and therefore useful. From equating the airflow rate components to those used in the VRP, to making the multi-part procedure interdependent (must perform all, not chose one from a list of alternatives as before) to adding a real stroke of common sense: allow the combined use of both procedures and make sure the results exceed the VRP-only minimum rates.

6.3.4.3 Similar Zone. The minimum outdoor airflow rates shall be no less than those found in accordance with Section 6.3.4.2 for a substantially similar zone (i.e., in a zone with identical contaminants of concern, concentration limits, air cleaning efficiency, and specified level of acceptability; and with similar contaminant sources and emission rates).

6.3.5 Combined IAQ Procedure and Ventilation Rate Procedure. The IAQ procedure in conjunction with the Ventilation Rate Procedure may be applied to a zone or system. In this case, the Ventilation Rate Procedure shall be used to determine the required zone minimum outdoor airflow, and the IAQ Procedure shall be used to determine the additional outdoor air or air cleaning necessary to achieve the concentration limits of the contaminants of concern.

Note: The improvement of indoor air quality through the use of air cleaning or provision of additional outdoor air in conjunction with minimum ventilation rates may be quantified using the IAQ procedure.

Since there are numerous contaminants that either will not be detected or for which "definite limits have not been set," this portion of the procedure has significant risk associated with it. It is unlikely that all contaminants of concern will be evaluated or reduced to acceptable levels. It is also not practical to measure all potential contaminants and in some cases, such as with fungus or mold, measurement may not be possible.

Since airflow rates are typically reduced in the IAQP, the measurement and control of intake rates are even more critical, especially on systems where the thermal load change is independent of the occupants and their activities. In addition, caution should be exercised when reducing outdoor airflow rates since it is also required to maintain proper building pressure, helping to minimize energy use, improve comfort control and prevent mold growth within exterior wall cavities.

DESIGN DOCUMENTATION PROCEDURES

Section 6.6, Design Documentation Procedures, states:

> Design criteria and assumptions shall be documented and should be made available for operation of the system within a reasonable time after installation. See Sections 4.3, 5.1.3, 5.16.4, 6.2.7.1.5 and 6.3.6 regarding assumptions that should be detailed in the documentation."

Within Systems and Equipment §5.1.3, requires us to:

> … The design documents shall specify minimum requirements for air balance testing or reference applicable national standards for measuring and balancing airflow. The design documentation shall state assumptions that were made in the design with respect to ventilation rates and air distribution..

Providing permanently installed instruments and controls that result in, and used to verify compliance with ASHRAE Standard 62.1 is perhaps one of the best reasons to provide such devices as part of any HVAC system design. Standard 189.1 recognizes the potential contribution of these devices and specifies their use as an alternative means of compliance in §7.4.3.2 and 10.3.2.1.4. Continuous data inputs may also be used to aid start-up Test and Balance, Commissioning, Measurement and Verification (M&V) for energy usage calculations and ongoing diagnostics. More precise and more reliable control could be viewed as a bonus.

CONSTRUCTION AND SYSTEM START-UP

Section 7 addresses the construction and start-up phases of the project and has been included because a significant number of documented IAQ cases were a result of activities which took place during these phases of the project. The Construction Phase, addressed in Section 7.1.1 of the Standard, applies to "ventilation systems and the spaces they serve in new buildings and additions to or alterations in existing buildings." [1] The Standard addresses both the protection of materials and protection of occupied areas.

Mechanical barriers are specified in §7.1.4.2 to protect occupied areas from construction-generated contaminants. In addition, the HVAC system must be able to maintain occupied spaces at positive pressures with respect to the construction areas. In many cases, the HVAC system does not have adequate capacity and/or controls to provide a barrier to the migration of contaminants using positive pressurization flow. Designers must consider the condition of the existing ventilation system and its ability to maintain a pressurized environment for spaces expected to continue occupancy, prior to initiating physical construction activities at the site.

The start-up phase, covered in Section 7.2 provides guidelines for air balancing, testing of drain pans, ventilation system start-up, testing of damper controls, and documentation requirements.

§7.2.2, Air Balancing, requires that systems be balanced "at least to the extent necessary to verify conformance with the total outdoor air flow and space supply air flow requirements of this standard."[1] Unfortunately, the airflow rates of the system will vary after this activity has occurred, in most systems, for reasons discussed in the analysis of Section 5 - Systems and Equipment. When applied in accordance with the manufacturer's recommendations, some airflow measuring devices only require the verification of operation by Test and Balance professionals. This TAB "snap-shot" of airflow rates is analogous to providing a one-time setup for temperature control, which would not be very effective. Providing permanently mounted airflow measuring stations would also support compliance with and reduce the time required to supply the documentary requirements for ventilation set forth in §7.2.6 (c).

OPERATIONS AND MAINTENANCE

If the building is altered or its use is changed, the ventilation system must be reevaluated. Buildings that are likely to be changed or altered during their life span, should consider including a robust HVAC system design that takes into account changes in airflow rate requirements imposed by this Standard. Of course, provisions for permanently mounted airflow measurement devices and controls would significantly reduce both the cost and time associated with such changes as long as the HVAC load capacity could accommodate future requirements.

§8.4.1.7 addresses sensors. "Sensors whose primary function is dynamic minimum outdoor air control, such as flow stations…" are discussed in this section even though they were not mentioned under Section 5, Systems and Equipment. Section 8.4.1.7 requires that sensors have their accuracy verified "once every six months or periodically in accordance with the Operations and Maintenance Manual." [1] The Operations and Maintenance Manual for some factory-calibrated airflow measuring devices does not recommend field recalibration for two simple to understand reasons: field conditions are typically less-than-ideal for precision and the reference standard/equipment and method used generally have much greater uncertainty than either the device under test or the factory standards. Permanently calibrated airflow instrumentation (having effectively zero drift over their projected life) would have a significant advantage over other airflow measuring technologies and CO_2 sensors, whose sensors and transmitters are subject to frequent adjustments, zeroing or regular calibrations to correct for drifting analog electronic circuitry and sensors.

However, §8.4.1.8, Outdoor Air Flow Verification, only requires the verification of airflow rates "once every five years."[1] Since external and system factors change continuously influencing outdoor airflow rates, this requirement does little to assure that proper ventilation rates are maintained under normal operation over extended periods. It effectively places the verification burden of new building/system performance on the building operator, who is often not in a position to make such a determination. In fairness, this requirement was likely intended for smaller systems and those that do not vary their capacity during operation, but the item does not make that distinction.

> "If measured minimum airflow rates are less than the design minimum rate (±10% balancing tolerance) documented in the O&M Manual, they shall be adjusted or modified to bring them to the minimum design rate or evaluated to determine if the measured rates are in compliance with this standard."

This apparent contradiction with §8.4.1.7 and the assumption that the measurement device always needs adjustment, will likely be examined and clarified by the ASHRAE SSPC 62.1 committee in the near future. Permanent outdoor airflow measuring stations would provide continuous verification and the necessary control inputs to maintain ventilation requirements, automatically minimizing intake rates for energy usage and preventing other control inputs from causing a maximum intake limit from being exceeded.

CONCLUSIONS

ASHRAE Standard 62.1 prescribes dilution ventilation rates for acceptable indoor air quality. It should be clear to the building operator and the design professional that the dynamic nature of mechanical ventilation requires dynamic control to insure the continuous maintenance of specific predetermined conditions. As a rate-based standard, continuous airflow measurement should logically be a central component of any effective control strategy to assure acceptable indoor air quality, as recently implemented in the latest LEED Rating Systems (2012) credit requirement EQc1 – "Outdoor Air Delivery Monitoring" for New Construction, Existing Buildings and Core and Shell Construction, et. al. [9]

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