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Designing An ASHRAE 62-Compliant Ventilation System

While ASHRAE Standard 62-1989 tells designers how to devise ventilation systems that provide "acceptable indoor air quality," many don't understand how to apply the standard's instructions to actual applications.

Recent issues of the **Engineers Newsletter** have attempted to interpret ASHRAE Standard 62, "Ventilation for Acceptable Indoor Air Quality," and offered general suggestions for compliance, particularly with respect to ventilating multiple-space systems. This issue offers practical examples that demonstrate how to design an ASHRAE Standard 62-compliant ventilation system for each of four different HVAC system type/space combinations. Of course, **ultimate responsibility for interpretation and compliance rests with the individual designer and installer**.

A Quick Review

Before tackling the first example, let's briefly recap the four-step process for ventilation system design. Remember, too, that it's important to document all assumptions and calculations made along the way.

Step 1: Follow the general requirements for proper equipment and system design and for proper outdoor air treatment.

Step 2: Determine how much outdoor airflow is required for proper ventilation **in each space**.

Step 3: Determine how much outdoor airflow is needed **at the air handler** for proper system ventilation. (This step allows proper sizing of the coil(s) used to treat outdoor air brought into the system.)

Step 4: Multiple-space VAV systems only. Coordinate space and system minimum airflow settings. Be sure to include the ventilation fractions calculated for each space and for the system as a whole. (Recall that the "space ventilation fraction" is the fraction of ventilation air . . . a mixture of outdoor air and cleaned, recirculated air . . . needed in the supply air for a particular space or system.)

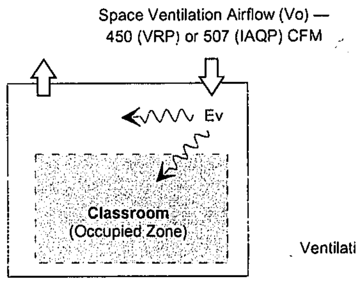
A Few Design Considerations

To successfully execute this process . . . particularly Steps 2 and 3 . . . and design a ventilation system that complies with ASHRAE Standard 62-1989, the designer must meet two challenges:

- **Adequately control contaminant sources.** The sidebar entitled "Contaminant Source Control Fundamentals" summarizes basic system and equipment requirements intended to curb contaminants at their source. Special emphasis is placed on controlling microbial growth.
- **Provide the required ventilation.** This is really a simplified restatement of Steps 2 and 3 above and is the focus of the examples offered in this issue.

Much of ASHRAE Standard 62-1989 is devoted to explaining two methods for finding the required outdoor airflow for individual spaces. Designers who choose to follow the prescriptive *Ventilation Rate Procedure (VRP)* use Table 2 of the standard to determine the minimum outdoor airflow rate based on space type. If it's a multiple-space application, they then solve Equation 6-1 to calculate the system-level outdoor airflow rate needed at the air handler. (Use of this procedure is described in greater detail in the "Determining Space and System Ventilation Requirements" sidebar.) Alternatively, designers can elect to follow the more subjective *IAQ Procedure (IAQP)*. This method entails numerous assumptions about relevant contaminant types and emission rates before the proper amounts of outdoor air can be calculated using the equations presented in Appendix E. As above, multiple-space applications use Equation 6-1 to find system-level outdoor airflow.

Figure 1: Single-Space, Constant Volume System



Space Type	Classroom
Occupancy	Intermittent ... 50 People Max. ≤ 50 Minutes; Normally Averages 30 People
HVAC System Type	Unit Ventilator with Local OA
Ventilation Effectiveness (Ev)	1.0

Now reacquainted with the ventilation system design process, let's tackle the first of four simple system design examples.

Example 1: Single-Space CV System

The first system example, represented in Figure 1, consists of a single classroom with local outdoor airflow; a unit ventilator provides constant-volume (CV) cooling. Though the classroom is designed to accommodate up to 50 occupants, that many people are never present for more than 50 consecutive minutes; so, it can be considered an **intermittent occupancy space**. On average, there are 30 occupants in this room during a normal day. With these

Contaminant Source Control Fundamentals

"Source control" of contaminants is a critical aspect of designing a ventilation system that complies with ASHRAE Standard 62-1989. Filtration effectively removes a number of common particulate "pollutants" from the building environment. However, microbiological or "microbial" contaminants are sometimes too small to be filtered entirely from the air stream, so other means of source control must be provided. Why? Studies indicate that microbial agents are responsible . . . either directly or indirectly . . . for the **sick building syndrome (SBS)** or **building-related illness (BRI)** problems in many of the buildings evaluated over the last five years.

Here's a "hit list" of source control suggestions, with particular emphasis on hindering microbial growth:

- Design the air handling system, including ducts and plenums, for cleanability (e.g., specify double-wall construction, foil-faced insulation, and access to drain pans and coils). Deprive micro-organisms of food and a place to live!
- Avoid introducing outdoor contaminants (e.g., vehicle exhaust, cooling tower "drift," etc.) into the building via the outdoor air intake.
- Exhaust air contaminated by stationary sources (e.g., copiers, chemical storage areas, combustion processes, etc.) locally. Do **not** allow it to mix with room air and return to the central air handler.
- Filter supply air for particulates and microbial contaminants (e.g., specify low-leak filter options). If particulate loading is high, specify dust collectors rather than filters.
- Filter supply air to remove gaseous contaminants by specifying sorption techniques such as charcoal filters
- Control humidity so that it's maintained above 30 percent, i.e. the survival rate of some airborne agents increases at low relative humidities, and below 60 percent, i.e. micro-organisms need water to grow.
- Specify sloped, cleanable drain pans to avoid microbial slime buildup.
- Specify antimicrobial treatment of drain pans, filters and equipment walls. ●

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facts in mind, let's design an ASHRAE 62-compliant ventilation system.

Space Ventilation. To provide the required ventilation, first determine how much outdoor airflow the classroom needs. Begin with the Ventilation Rate Procedure. Table 2 of the standard indicates that the minimum outdoor airflow rate for classrooms is 15 cfm per person. Assuming that the ventilation effectiveness is 1.0, i.e. that 100 percent of the air supplied to the classroom actually enters the occupied zone which is shaded in Figure 1, the classroom requires 15 cfm/person × 30 people, or **450 cfm**, to comply with ASHRAE Standard 62-1989.

Of course, if we're comfortable enough to make assumptions about the classroom furnishings and contaminant sources, the IAQ Procedure could be used instead. Assume that: All furnishings emit low levels of VOC's (volatile organic compounds), there are no other noxious contaminants of concern and occupant odors are the primary contaminant to be controlled through dilution rather than filtration. To assure adequate odor-related comfort, the IAQ Procedure dictates that the carbon dioxide level in the space must not exceed 1,000 ppm. If we assume that the outdoor air contains 350 ppm of CO_2 and that each occupant generates CO_2 at the rate of 0.011 cfm, then the classroom needs **507 cfm** of outdoor air for compliance; i.e. $N / Cs - Co = (0.011 \text{ cfm/person} \times 30 \text{ occupants}) \div (0.001000 - 0.000350 \text{ parts by volume})$. In the preceding equation, N represents the contaminant generation rate; Cs and Co represent the volumetric concentration of the contaminant in the space and outdoors, respectively.

System Ventilation. Regardless of the method used to determine space ventilation needs, the next step is to discover how much outdoor airflow the system requires. Since there's only one space in this example, system and space ventilation requirements are identical: Compliance with the standard demands **450 cfm** via the Ventilation Rate Procedure or **507 cfm** via the IAQ Procedure.

Determining Space and System Ventilation Requirements

Because of its prescriptive nature, many designers elect to use ASHRAE Standard 62-1989's *Ventilation Rate Procedure (VRP)* to determine outdoor airflow needs at the space and system levels. Here are the steps entailed:

1

Qualify outdoor air quality. Table 1 of the standard lists air quality criteria for outdoor air, as set by the U.S. Environmental Protection Agency (EPA). Based on these criteria, the designer must evaluate the building site and provide whatever filtration is required to assure that outdoor air brought into the building is acceptable for ventilation. In some instances, it may even be necessary to reduce outdoor airflow during critical periods.

2

Look up the prescribed ventilation airflow ("outdoor air requirement" or OAR) for each space in Table 2 of the standard. Table 2 gives ventilation requirements for 81 different space types. Most ventilation requirements are expressed as "airflow (cfm) per occupant" since contaminant generation is presumed to be proportional to the number of people in the space. Rooms provided with local exhaust (e.g., rest rooms, kitchens, smoking lounges) may be ventilated with air supplied from adjacent spaces.

3

For each space, solve the equation $Vo = OAR \times Occ / Ev$. In this equation: Vo is the required volumetric flow rate of outdoor air; OAR is the applicable Table 2 value (expressed either as cfm per person or as cfm per sq ft); Occ represents space occupancy (usually the maximum design occupancy); and Ev is "ventilation effectiveness" . . . i.e., the fraction of ventilation air delivered to the space that actually reaches the occupied zone. For example, if Ev is 0.80, 80 percent of the air supplied to the space enters the occupied zone while the remaining 20 percent bypasses it.

It's important to understand the distinction between the "occupied zone" and the "occupied space." While the floor, walls and ceiling define the "occupied space," people are in the "occupied zone" which is between 3 and 72 inches above the floor and more than 24 inches from the walls. Ventilation airflow is required for the occupied **zone**, not simply for the occupied space.

Note, too, that a space is deemed "intermittent occupancy" if it's continuously occupied at maximum capacity for less than three hours. In such instances, space occupancy for the purposes of this equation can be the average occupancy, but not less than one-half of the maximum design occupancy.

4

Determine the total outdoor airflow required at the air handler to satisfy system ventilation needs. In a system with a dedicated supply air source per space, the required system-level outdoor airflow equals the sum of the outdoor airflow required in each space.

To determine the system outdoor airflow requirement for a **multiple-space system** . . . one with recirculated return air and a central air handler serving more than one room . . . perform these steps:

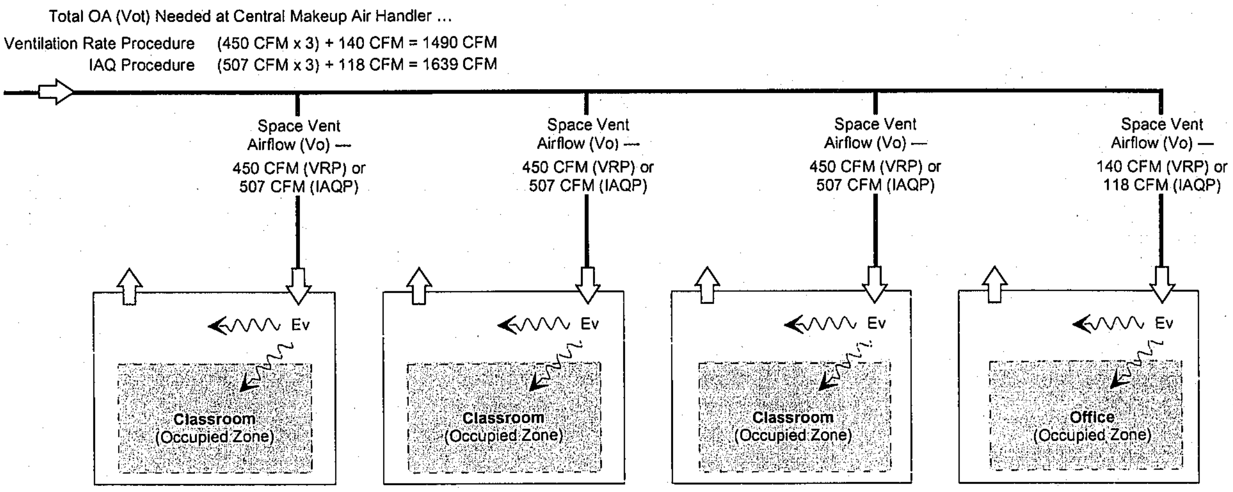
a) Calculate the **uncorrected** ventilation fraction, X, by dividing the sum of the space ventilation airflows (Von) by the sum of the space supply airflows (Vst): $X = Von / Vst$.

b) Identify the "critical space": That's the space that requires the highest percentage of ventilation air at minimum supply airflow. The critical space has the highest space ventilation fraction; that is, required outdoor air flow (Vo) divided by minimum supply airflow or Z.

c) Use Equation 6-1 of the standard . . . $Y = X / (1 + X - Z)$ . . . to calculate the **corrected** ventilation fraction, Y; i.e., a value that's greater than X but less than Z.

d) Compute the actual peak system outdoor airflow required by solving the equation $Vot = Y \times Vst$. ●

Figure 2: Four-Space CV/Makeup Air System



Space Type	Classroom
Occupancy	Intermittent: 30 People Avg.
HVAC System Type	Fan-Coil Units with Central Ventilation (Makeup) Air Handler
Ventilation Effectiveness (Ev)	1.0

Space Type	Office
Occupancy	7 People
HVAC System Type	Fan-Coil Unit with Central Ventilation (Makeup) Air Handler
Ventilation Effectiveness (Ev)	1.0

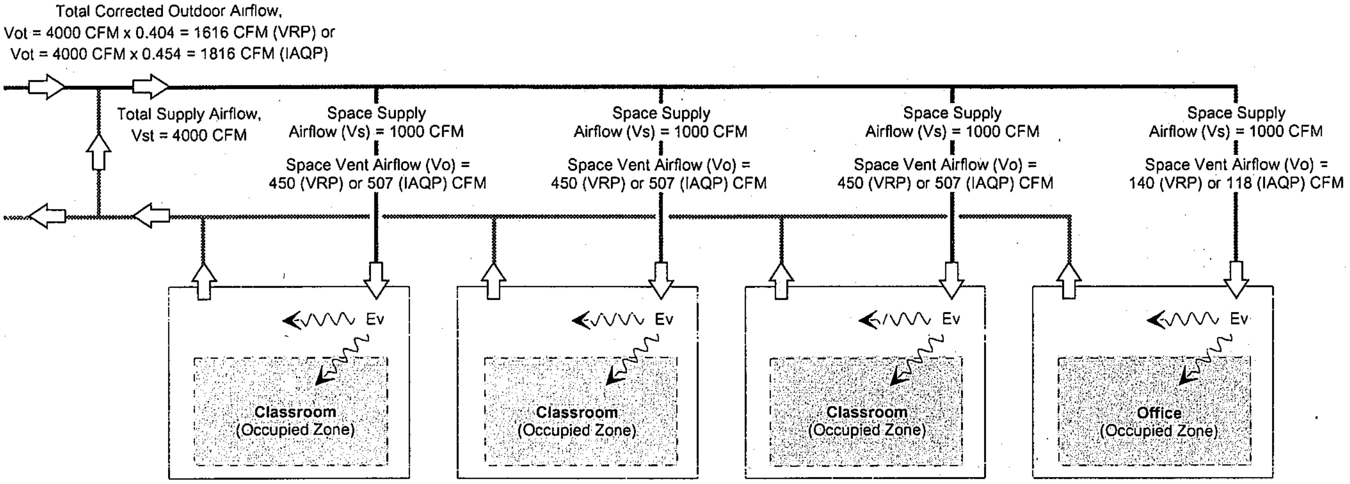
Example 2: Four-Space CV/Makeup Air System

In this example, let's expand the system to include four spaces, as shown in Figure 2. Add two more classrooms . . . each identical in size and average occupancy to the original space . . . plus an office area designed to accommodate seven occupants. Each space is cooled by a fan-coil unit; 100 percent outdoor ventilation air is ducted directly to each space from a central "fresh air" air handler.

Space Ventilation. The first task is to determine the ventilation requirement for each space. From the preceding example, we know that the Ventilation Rate Procedure dictates 450 cfm of outdoor airflow for each of the three classrooms. The office needs only 20 cfm/person × 7 occupants, or **140 cfm**. If the IAQ Procedure is used instead, again 507 cfm per classroom is needed while the office requires (0.011 cfm/person × 7 occupants) ÷ (0.001000 - 0.000350), or **118 cfm**.

System Ventilation. Then how much outdoor air is required at the makeup air handler that serves this four-space system? Since the outdoor airflow provided to each space is constant, the total outdoor airflow required at the "fresh air" unit is simply the sum of all individual space outdoor airflows: Either **1,490 cfm** (450 cfm × 3 + 140 cfm) or **1,639 cfm** (507 cfm × 3 + 118 cfm), depending on the space ventilation method used.

Figure 3: CV Multiple-Space System



Space Type	Classroom
Occupancy	Intermittent; 30 People Avg.
HVAC System Type	Central CV Rooftop Unit
Ventilation Effectiveness (Ev)	1.0
Ventilation Fraction (Z)	0.450 (VRP) or 0.507 (IAQP)

Space Type	Office
Occupancy	7 People
HVAC System Type	Central CV Rooftop Unit
Ventilation Effectiveness (Ev)	1.0
Ventilation Fraction (Z)	0.140 (VRP) or 0.118 (IAQP)

Example 3: CV Multiple-Space System

Now let's use a constant-volume rooftop unit to cool and ventilate the four-room school, Figure 3. The rooftop unit handles a total airflow of 4,000 cfm, delivering 1,000 cfm of variable-temperature primary air to cool each space. Since the ventilation needs of the classrooms differ from that of the office. . . and because some return air recirculates through the rooftop unit. . . this is considered a multiple-space system.

Space Ventilation. As discovered in Example 1, proper space ventilation under the Ventilation Rate Procedure means providing each classroom with 450 cfm of outdoor airflow and the office with 140 cfm. Alternatively, the IAQ Procedure requires 507 cfm of outdoor airflow per classroom and 118 cfm for the office.

System Ventilation. Discovering the outdoor airflow required at the air handler in a multiple-space system requires solving ASHRAE 62-1989's Equation 6-1 (refer to the "Determining Space and System Ventilation Requirements" sidebar). Begin by calculating the ventilation fraction for each space: For each classroom, that's 450/1000 = 0.450 under the Ventilation Rate Procedure or 507/1000 = 0.507 if the IAQ Procedure is used. Similarly, the office ventilation fraction is either 140/1000 = 0.140 (VRP) or 118/1000 = 0.118 (IAQP). Since the ratio of outdoor-to-supply-airflow is largest for the classrooms, they are the "critical space" and the classroom ventilation fraction will be substituted for *Z* in Equation 6-1.

Next, we'll determine the **uncorrected** or average ventilation fraction, *X*, for the system at peak outdoor airflow. Using the Ventilation Rate Procedure, $X = (450 \times 3 + 140) / 4000 = 0.373$. If the IAQ Procedure is used, $X = (507 \times 3 + 118) / 4000 = 0.410$.

One of two errors is commonly made at this point in the design process.

Error 1: Some designers find the minimum ventilation airflow (*Vo*) required for each space, add them together to arrive at the total ventilation airflow (*Von*), then divide by the sum of the space design airflows (*Vs*). Though this approach provides average ventilation fraction, the critical space is always **under**ventilated.

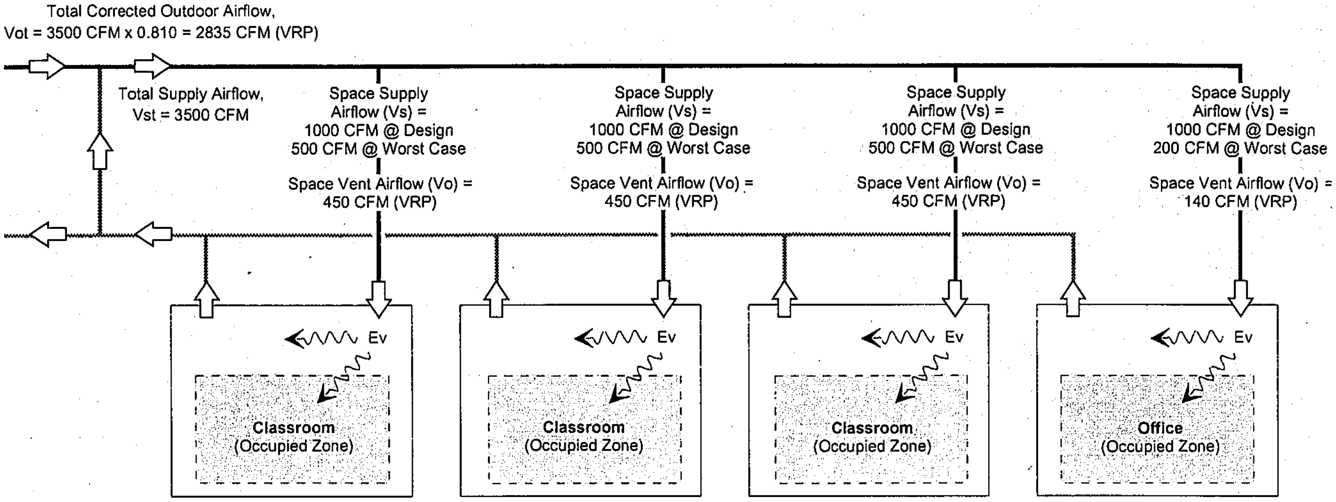
Error 2: Recognizing that the critical space needs more-than-average ventilation airflow, other designers set the system corrected outdoor fraction *Y* equal to *Z*, the "critical space" ventilation fraction. . . but the result is a system that's always **over**ventilated.

What's the solution to this dilemma? Solve Equation 6-1!

Having determined a value for *X*, let's now solve Equation 6-1 to find the **corrected** system ventilation fraction, *Y*: that's 0.373 / (1 + 0.373 - 0.450) = **0.404** under the Ventilation Rate Procedure or 0.410 / (1 + 0.410 - 0.507) = **0.454** under the IAQ Procedure.

Finally, using the corrected system ventilation fraction, we can calculate the outdoor airflow needed at the rooftop unit to adequately ventilate all four spaces: 4000 × 0.404 = **1,616 cfm (VRP)** or 4000 × 0.454 = **1,816 cfm (IAQP)**.

Figure 4: VAV Multiple-Space System



Space Type	Classroom
Occupancy	Intermittent; 30 People Avg.
HVAC System Type	Central VAV Rooftop Unit
Minimum Airflow Setting	50% of Nominal (500 CFM)
Ventilation Effectiveness (Ev)	1.0
Ventilation Fraction (Z)	450 / 500 = 0.900 (VRP)

Space Type	Office
Occupancy	7 People
HVAC System Type	Central VAV Rooftop Unit
Minimum Airflow Setting	20% of Nominal (200 CFM)
Ventilation Effectiveness (Ev)	1.0
Ventilation Fraction (Z)	140 / 200 = 0.700 (VRP)

Example 4: VAV Multiple-Space System

Our last example applies a VAV rooftop unit to the school, Figure 4. The rooftop unit cools and ventilates all four spaces by providing a varying volume of constant-temperature air to shutoff VAV terminals. As in Example 3, the differing ventilation needs of the classrooms and office coupled with recirculated return air make this a multiple-space system. Again, each space requires 1,000 cfm of primary air for cooling at design conditions. However, the four spaces don't peak simultaneously. Maximum airflow at the rooftop unit is 3,500 cfm with a load diversity of 0.875 (3500 / 4000). Note, too, that each space is assigned a minimum airflow; the classroom setting is 50 percent of nominal airflow or 500 cfm, while the office setting is 20 percent of nominal airflow or 200 cfm.

Space Ventilation. As in the preceding examples, the first task is to determine how much outdoor airflow each space requires for adequate ventilation. This time, we'll limit our discussion to the prescriptive Ventilation Rate Procedure since it's the method preferred by most VAV system designers. Given the same occupancies already described, we know that each classroom needs 450 cfm of outdoor airflow while the office requires 140 cfm.

System Ventilation. As in Example 3, use Equation 6-1 to discover the system-level outdoor airflow requirement. Typically, a VAV system with load diversity requires the most ventilation when it's delivering maximum supply airflow; in this case, 3,500 cfm. To use Equation 6-1, we must first determine the space ventilation fractions. **In a VAV system, space ventilation fractions are highest when the minimum space airflow setting is in effect.** So let's calculate the ventilation fractions accordingly, i.e. the office ventilation fraction is 140/200 = 0.700 and the ventilation fraction for each classroom is 450/500 = 0.900. Since the classroom ratio of outdoor-to-supply-airflow is largest, it's the "critical space" and will again be substituted for Z in Equation 6-1.

Next, we'll calculate the **uncorrected** (average) ventilation fraction for the system: $X = (450 \times 3 + 140) / 3500 = 0.426$. Then solve Equation 6-1 to find the **corrected** system ventilation fraction: $Y = 0.426 / (1 + 0.426 - 0.900) =$ **0.810**. Having established a value for Y, the outdoor airflow needed at the rooftop unit to adequately ventilate all four spaces in the event of a "worst-case" system airflow imbalance can now be calculated, i.e. the critical space needs only minimum airflow while all others require design airflow. . . 3500 × 0.810 = **2,835 cfm**. This value seems pretty high, especially when compared to the 1,616 cfm that was needed for the constant-volume rooftop system in Example 3. Can it be reduced and still comply with ASHRAE Standard 62-1989?

Coordinate Space/System Minimum Airflow Settings. Notice that this is the first example that's required the use of Step 4 of the ventilation system design process. **In VAV systems only, the minimum space and system airflow settings are linked by Equation 6-1.** Said another way, raising the required minimum airflow setting for each space lowers the peak outdoor airflow required for the system and vice versa. Consequently, the maximum required outdoor airflow can't be determined without knowing the minimum space airflows.

Suppose we "limit" the system's "critical space" ventilation fraction, *Z*, to 0.700 by increasing the minimum airflow setting for each classroom by about 29 percent, from 500 cfm to 643 cfm. The corrected system ventilation fraction, *Y*, becomes 0.426 / (1 + 0.426 - 0.700) = **0.587**, making the "worst-case" outdoor airflow requirement 3500 × 0.587 = **2,055 cfm**. . . a 27.5 percent reduction. Of course, the arbitrary values used for illustration in this example result in a required system outdoor airflow that's still unrealistically high. Actual system calculations typically result in outdoor airflows ranging from 15 to 25 percent.

Coordinating space and system minimum airflow settings ultimately assures proper ventilation for all spaces and limits *Z* to the value used to size the outdoor air path. Further, restricting the value of all space ventilation fractions means that the outdoor air path can be sized to handle less than 100 percent outdoor air and still provide the minimum total outdoor airflow required by ASHRAE Standard 62-1989 for adequate ventilation. In actual VAV system design, increased space minimum airflow settings can be combined with control strategies that limit space ventilation requirements to reduce system operating costs.

In Conclusion

This **Engineers Newsletter** attempts to show how ASHRAE Standard 62-1989 impacts ventilation system design by applying four different HVAC scenarios in a similar building setting: A single-space, constant-volume system; a four-space, constant-volume/makeup-air system; a multiple-space, constant-volume system; and a multiple-space, variable-air-volume system. As these simple examples demonstrated, **the *method* of ventilation air delivery ultimately determines how much outdoor air must be provided for adequate ventilation.** Along the way, we reviewed the difference between designing a Standard 62-compliant ventilation system for single- versus multiple-space applications. The latter requires an additional. . . and, for a VAV system, iterative. . . design step: Coordinating the minimum space and system outdoor airflows to assure compliance at **all** load conditions.

Fortunately, the standard gives sufficient latitude for creativity when it comes to ventilation system design, particularly with respect to ventilation control strategies for multiple-space VAV systems. The only proviso is that the designer use sound, defensible logic and adequately document all assumptions and calculations.

Editor's Note: Watch for a discussion of ventilation reset schemes and how they perform in an upcoming **Engineers Newsletter.** ●

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