Addendum 62*n*

Single-Zone & Dedicated-OA Systems

By Dennis Stanke, Member ASHRAE

ANSI/ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*,[1] has been modified by Addendum 62*n*[2], whose ventilation requirements alter the very heart of Standard 62. Addendum 62*n* contains a long-awaited update to the minimum prescribed ventilation rates — last updated in ASHRAE Standard 62-1989 — and it incorporates ventilation airflow "additivity" for dilution of both people-source and building-source contaminants. The updated version of the once-familiar table of prescribed breathing-zone ventilation rates now contains both per-person and per-unit-area values for each occupancy category.

Addendum 62*n* updates the calculation procedure for zone ventilation airflow, incorporating an adjustment for air distribution effectiveness. It also updates the calculation procedure for system intake airflow for different ventilation systems and clarifies the prescribed approach for multiple-zone system design — required for years but also widely misunderstood and largely ignored by designers. (Incorrect intake calculations often result in multiple-zone recirculating systems that provide too little ventilation — especially for some fully occupied VAV zones.)

Finally, the addendum specifically identifies some operational control options that can reduce (or increase) intake airflow to match ventilation capacity with a changing ventilation "load," saving preconditioning energy while maintaining the required ventilation to the occupants.

What Are the New Ventilation Rates?

Table 1 shows minimum breathing-zone ventilation rates* for several important occupancy categories, comparing the prescribed rates from Addendum 62*n*, Table 6.1, with the previous rates from Standard 62-2001. The minimum cfm/person rate (R_p) dropped for many categories (except for some retail categories, where it increased from the previously prescribed "zero" per-person rate) because the ventilation basis for people-source contaminants changed from satisfying *unadapted visitors* to satisfying *adapted occupants*. However, the addition of a minimum cfm/ft^2 rate

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* Although Addendum 62*n* shows ventilation rates in both IP and SI units, this paper uses IP, except in selected specific calculations. This is because 62*n* uses rational conversions, not mathematical.

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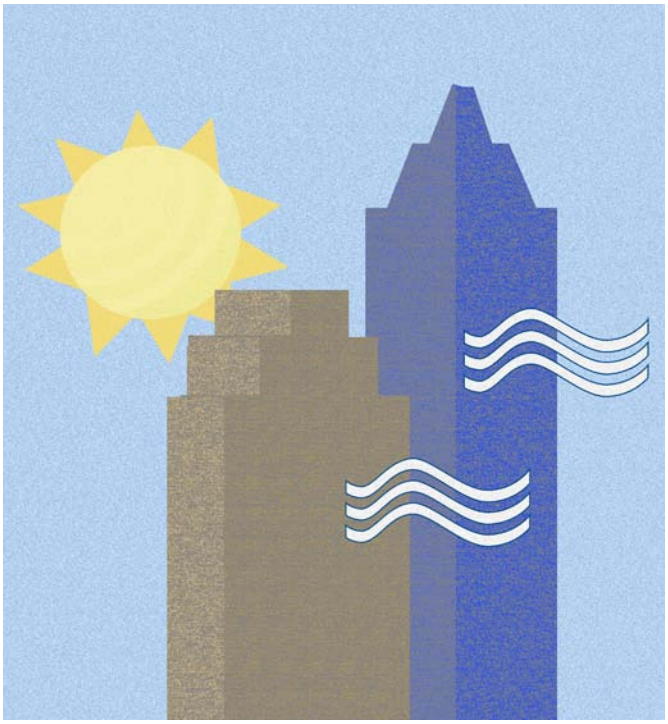
(R_a) for each category to dilute building-source contaminants moderates those drops in the "effective" per-person breathing-zone rates (i.e., the sum of the people- and area-related rates, divided by zone population). But be careful of simple, general comparisons; new default occupant densities and new options for population averaging can result in significant changes to "traditional" ventilation rates.

Underlying the prescribed rates, which only apply to no-smoking areas, is the premise that all other "general" requirements in the standard are met (i.e., that the drain pan drains, humidity is limited, filters are used, and so on). Of course, compliance has always meant meeting general requirements, but Standard 62-2001 and its addenda extend and clarify these requirements, moving many design decisions from "good practice" to "mandatory." As in the past, Table 6.1 includes default occupant densities for each category, but as before, these default values should only be used if reasonable for the application or if the actual design density is unknown.

What Is the New Procedure?

Addendum 62*n* prescribes a step-by-step procedure for ventilation system design to help designers *consistently* find the minimum ventilation airflow required in the breathing zone, in the ventilation zone, and at the outdoor air intake.



Zone Ventilation Calculations

Addendum 62*n* includes the following three-step procedure, which results in correct application of the prescribed rates to *each ventilation zone*.

1. Referring to *Table 1* (an excerpt from 62*n*, Table 6.1), look up both the people-source ventilation rate (R_p in cfm/person) *and* the building-source ventilation rate (R_a in cfm/ft^2). Establish the *zone floor area* and *zone population*. The latter is the largest (or average) number of occupants expected to occupy the zone during normal use. Using these values, solve Equation 6-1 ($V_{bz} = R_p \times P_z + R_a \times A_z$) to find the required outdoor airflow for the *breathing zone*.

2. Referring to *Table 2* (an excerpt from 62*n*, Table 6.2) look up the default value for zone air-distribution effectiveness (E_z), which is based on selection and placement of supply diffusers and return grilles. This effectiveness value, which is similar to "air-change effectiveness" (described in ASHRAE Standard 129) for well-mixed spaces, allows the designer to account for any ventilation air (delivered by the diffusers) that bypasses the breathing zone.

3. Solve Equation 6-2 ($V_{oz} = V_{bz} / E_z$) to find the outdoor airflow required in the air supplied to each ventilation zone. This volume of outdoor air must be supplied for ventilation, regardless of heating or cooling airflow requirements.

Let's use numbers to demonstrate how these three steps determine the needed outdoor airflow for a north-facing office area with overhead supply diffusers and return grilles. Referring to *Table 1,* the "office space" occupancy category requires a "people outdoor air rate" of R_p = 5 cfm/person** and an "area outdoor air rate" of R_a = 0.06 cfm/ft^2. If the office comprises 1,500 ft^2 of open-plan space and is occupied by 10 people (150 ft^2/person) solving Equation 6-1 ($V_{bz} = 5 \times 10 + 0.06 \times 1500 = 50 + 90 = 140$), tells us that at least 140 cfm (67 L/s) of outdoor air must be delivered to the breathing zone. The default zone air-distribution effectiveness for this configuration is 1.0 when cooling and 0.8 when heating. Now, we can solve Equation 6-2 and learn that our example office space requires at least ($V_{oz} = V_{bz} / E_z = 140/1.0 = 140$ cfm) 14 cfm/person of outdoor airflow when cooling and at least ($V_{oz} = 140/0.8 = 175$ cfm) 17.5 cfm/person when heating.

Since 1989, Standard 62 has required 20 cfm/person for office-space breathing zones, so this particular office space needs less outdoor air per person to comply with 62*n*. However, lower occupant density might require *more* airflow per person, and higher occupant density (common in private offices) would require *much less* airflow per person. If our example was an "executive" office, designed for five people (300 ft^2/person), it would require 115 cfm or 23 cfm/person (10.9 L/s per person), but if it was an "technical professional" office, designed for 20 people (75 ft^2/person), it would require 190 cfm or only 9.5 cfm/person (4.6 L/s per person).

System Ventilation Calculations

After determining outdoor airflow (V_{oz}) for each ventilation zone, outdoor air intake flow (V_{ot}) is calculated for the ventilation system as a whole. The procedure for finding the required outdoor air intake flow varies with the configuration of the

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** cfm × 0.4719 = L/s; ft^2 × 0.0929 = m^2

	62-2001, Table 2		62*n*, Table 6.1			Per Person Rate	
Occupancy Category	**People Outdoor Air Rate**	**Area Outdoor Air Rate**	**People Outdoor Air Rate**	**Area Outdoor Air Rate**	**Default Occupant Density**	**62-2001**	**62*n***
			R_p	R_a			
	cfm/person	cfm/ft^2	cfm/person	cfm/ft^2	#/1000 ft^2	cfm/person	cfm/person
Office Space	20	—	5	0.06	5	20	17
Conference/Meeting	20	—	5	0.06	50	20	6.2
Art Classroom	15	—	10	0.18	20	15	19
Classroom (Ages 5 – 8)	15	—	10	0.12	25	15	14.8
Classroom (Ages 9+)	15	—	10	0.12	35	15	13.4
Lecture Classroom	15	—	7.5	0.06	65	15	8.4
Multiuse Assembly	15	—	7.5	0.06	100	15	8.1
Retail Sales	—	0.30	7.5	0.12	15	20	15.5

Table 1: Comparison of breathing zone ventilation rates for several occupancy categories.

ventilation system. Addendum 62*n* defines three configurations: single-zone, 100% (or "dedicated") outdoor air, and multiple-zone recirculating systems.

Single-Zone Systems. In a single-zone ventilation system, one air handler supplies one ventilation zone with a mixture of outdoor air and recirculated return air. Single-zone rooftop units, packaged terminal air conditioners, classroom unit ventilators, and so on, are single-zone systems. For these systems, Addendum 62*n* defines required outdoor air intake flow as equal to the required zone outdoor airflow according to Equation 6-3 ($V_{ot} = V_{oz}$). Apparently for simplicity, this equation does not account for supply-duct leakage, which would increase V_{ot}, or recirculation of outdoor air that bypasses the breathing zone, which would reduce V_{ot}.

Dedicated Outdoor Air Systems. In a "dedicated" outdoor air system (DOAS), called a "100%-outdoor air system in Addendum 62*n,* one air handler serves the ventilation requirements of one or more ventilation zones, delivering the appropriate minimum outdoor airflow — without recirculated return air — to each zone. Terminal units (e.g., fan-coil units, water-source heat-pumps, or even chilled ceiling panels) handle the thermal loads within each zone. (Some designers call this type of ventilation system a "hybrid system," because it comprises a dedicated unit for ventilation air-handling and separate terminal units to handle thermal loads in occupied zones.) Like single-zone systems, all outdoor air entering the central air handler (assuming negligible duct leakage) reaches the ventilation zone diffusers. The required intake airflow is defined as the sum of the zone outdoor airflow values, according to Equation 6-4 ($V_{ot} = \Sigma V_{oz}$). Again for simplicity, the equation does not account for supply-duct leakage, which

Air Distribution Configuration	E_z
Ceiling Supply of Cool Air	1.0
Ceiling Supply of Warm Air and Floor Return	1.0
Ceiling Supply of Warm Air At Least 8°C (15°F) Above Space Temperature and Ceiling Return	0.8
Ceiling Supply of Warm Air Less Than 8°C (15°F) Above Space Temperature and Ceiling Return Provided That the 0.8 m/s (150 fpm) Supply Air Jet Reaches to Within 1.4 m (4.5 ft) of Floor Level.	1.0

Table 2: Zone air distribution effectiveness (E_z) for several configurations. Not all configurations from Table 6.2 are listed here.

Making Sense of Additivity

ASHRAE Standard 62 specifies minimum ventilation rates that are intended to result in indoor air that's free of harmful concentrations of known contaminants and that satisfies the senses of at least 80% of the occupants. (Though the rates prescribed in the standard seem to be based primarily on dilution of odors and irritants, they are presumed to be sufficient to adequately dilute potentially harmful contaminants as well.) Occupant satisfaction relates to the perceived intensity of odors and/or irritants from various indoor contaminant sources. These contaminants originate both from occupants (and their activities) and from the building (and its furnishings). While the relationships are complex, most experts agree that adding the outdoor airflow needed to dilute one odor or irritant to that needed to dilute another generally is the best simple model for dilution of odor and irritation effects. Accounting for the "additive" effect of contaminant sources really isn't new. Since 1989, the standard did so behind the scenes: Dilution rates for building-related contaminants were added to the per-person dilution rate for each occupancy category. For example, the standard previously required 20 cfm per person for offices: 15 cfm to dilute people-related odors and an additional 5 cfm to dilute building-related odors.

Using Equation 6-1 of Addendum 62*n*, engineers now can independently account for people-related and building-related contaminants using two ventilation rate requirements: one rate per occupant (cfm/person) and the other per unit of occupiable floor area (cfm/ft^2). To determine the required ventilation, simply multiply the per-person rate by the number of people in the space and the per-unit rate by the floor area; then, add the resulting airflow values together.

					Cooling		Heating	
Ventilation Zone	**People Outdoor Air Rate**	**Zone Population**	**Area Outdoor Air Rate**	**Zone Floor Area**	**Zone Ventilation Efficiency**	**Zone Outdoor Airflow**	**Zone Ventilation Efficiency**	**Zone Outdoor Airflow**
	R_p	P_z	R_a	A_z	E_z	V_{oz}	E_z	V_{oz}
	cfm/person		cfm/ft²	ft²		cfm		cfm
South Offices	5	20	0.06	2,000	1.0	220	0.8	275
West Offices	5	20	0.06	2,000	1.0	220	0.8	275
North Offices	5	20	0.06	2,000	0.9	244	0.8	275
East Offices	5	20	0.06	2,000	1.0	220	0.8	275
Interior Offices	5	100	0.06	20,000	1.0	1,700	0.8	2,125
North Conference Room	5	14.4*	0.06	2,000	0.9	213	0.8	240
South Conference Room	5	23.1**	0.06	3,000	0.9	328	0.8	369
Total Zone-Level Outdoor Airflow					$\Sigma V_{oz} =$	3,150	$\Sigma V_{oz} =$	3,830
Single-Zone Systems: Total Intake Air							$\Sigma V_{oz} =$	3,830
100%-Outdoor-Air System							$V_{ot} =$	3,830

* Average population (72% of 20-person peak population)
** Average population (77% of 30-person peak population)

Table 3: A ventilation design example with calculations for a small office building.

would increase V_{ot}. And, even though Equation 6-4 increases V_{ot} to account for breathing-zone bypass (when $E_z < 1.0$), non-recirculating systems cannot reuse this bypassed air or any "unused" outdoor air from partially occupied zones; as a result, in some cases, dedicated outdoor air systems may actually require more intake airflow than multiple-zone systems.

Multiple-Zone Recirculating Systems. In multiple-zone recirculating systems, such as constant-volume reheat systems and nearly all varieties of VAV systems, one air handler supplies a mixture of outdoor air and recirculated return air to two or more ventilation zones. The required outdoor air intake flow can only be determined by properly accounting for *system ventilation efficiency*. The reason for this is because the intake airflow must be sufficient to ventilate the *critical zone*, which is the zone that requires the highest fraction of outdoor air in its primary airstream. Since a multiple-zone system delivers the same primary air mixture to each ventilation zone, proper minimum ventilation in the critical zone overventilates all other zones. As a result, some "unused" outdoor air recirculates (reducing required V_{ot}) while some leaves the building via the relief, exhaust, and exfiltration air streams (increasing required V_{ot}). Addendum 62*n* recognizes this behavior and accounts for it by incorporating system ventilation efficiency in the ventilation calculations.

System ventilation efficiency (E_v) can be determined using the default maximum values found in Addendum 62*n*, Table 6.3. These default values are based on the critical-zone ventilation fraction, found using Equation 6-5 ($Z_p = V_{oz}/V_{pz}$). Alternatively, system ventilation efficiency can be determined using the more accurate calculation procedure found in normative Appendix G of Addendum 62*n*. In either case, having found E_v, outdoor air-intake flow (V_{ot}) for the multiple-zone system must be determined using Equations 6-6, 6-7 and 6-8. Equation 6-6 $\left(V_{ou} = D \times \Sigma(R_p \times P_z) + \Sigma(R_a \times A_z)\right)$ establishes the required *uncorrected outdoor air-intake flow* while allowing the designer to account for system population diversity determined with Equation 6-7 ($D = P_s/\Sigma P_z$), provided breathing-zone outdoor airflow is based on peak (not average) zone population. Equation 6-8 ($V_{ot} = V_{ou}/E_v$) finds the *minimum outdoor air-intake flow* by dividing the uncorrected outdoor air intake flow by the system ventilation efficiency.

Ventilation Design Examples

To demonstrate the use of the design procedure prescribed in Addendum 62*n*, this article considers the design of two ventilation systems—a single-zone system and a 100%-outdoor air system. Each system is applied in two different building types: an office and a school. (Future articles will discuss the design procedure for multiple-zone ventilation systems.)

An Office Building

Let's review the design of a ventilation system for a small office building that contains the ventilation zones described in *Table 3*.

We began by looking up the outdoor air rates (R_p and R_a) in Table 6.1 and then used Equation 6-1 to find the breathing-zone outdoor airflow (V_{bz}) for each zone. In our example, we used the peak population as the expected occupancy for each office area. For the conference rooms, however, we elected to use the optional population-averaging approach described in Section 6.2.5. We used Table 6.1 default occupant densities for some zones and significantly higher densities (which may be more typical in individual offices) for others. According to a recent industry report,[3] average occupant density for some office workers exceeds 15 people per 1,000 ft² — significantly higher than the default density of five people per 1,000 ft² in Table 6.1.

Next, we established the zone air-distribution effectiveness (E_z)

for each zone based on the supply-air distribution configuration and the values shown in Table 6.2 (*Table 2*). Although the use of these values appears to be mandatory, it's reasonable to consider them as defaults, which are to be used whenever actual values are unknown. Higher-than-default values decrease required intake airflow and should be used cautiously (when justified by measurement or experience), since underventilation could result. Lower-than-default values, which should be used if more-than-typical bypass is expected, increase required intake airflow and may increase first cost and operating cost. For instance, if the ceiling-mounted supply diffusers and return grilles are tightly spaced, it may be reasonable to assume a lower E_z value during cooling, as we did for the north offices and the conference rooms in our example.

In our example office, the zone air-distribution effectiveness for heating is less than for cooling—i.e., $E_z = 0.80$ (or less) vs. 1.00. That's because our design uses ceiling supply and return, and delivers supply air that's warmer than 90°F (32°C) during heating operation. The lower E_z value for heating accounts for the tendency of warm supply air to float above the cooler, denser breathing-zone air.

We then used Equation 6-2 to find each zone's minimum outdoor airflow (V_{oz} in *Table 3*) during cooling and heating.

At this point, we knew the *zone*-level outdoor airflow requirements, but how much outdoor airflow must enter the building at the intake(s)? The answer varied with the type of ventilation system selected.

Single-Zone System Design. Initially, we assumed that each ventilation zone was served by a single-zone, constant-volume rooftop unit, making it necessary to use Equation 6-3 to find the outdoor air intake flow (V_{ot}) required at each rooftop unit. Because we also assumed that all intake air reaches the supply diffusers (no significant duct leaks), the minimum intake airflow for each rooftop unit equals the minimum zone outdoor airflow ($V_{ot} = V_{oz}$) for the ventilation zone it serves. As shown in *Table 3*, the highest intake

Averaging Zone Population for Ventilation Design

In earlier versions of the standard, only "intermittent occupancy" zones (at peak population for three hours or less) could be designed for ventilation at the average population (but not less than one-half of peak population). Now, any zone may be *designed* for average population.

According to Addendum 62*n*, Section 6.2.5, the system must be designed to deliver the required outdoor airflow to each occupied breathing zone, but the design may be based on averages, in some cases. For instance, if occupancy (or supply airflow or intake airflow) varies, ventilation system design may be based on average population over a specific time period rather than on peak population. The averaging time *T* for a given zone is determined according to Equation 6-9, using zone volume and the breathing-zone outdoor airflow that would be needed at peak population. This "averaging" concept replaces the traditional population-averaging approach for intermittent occupancy.

Why averaging time *T*? The indoor concentration of any contaminant can be modeled using a first order ordinary differential equation. As most engineers vaguely remember, the solution to such an equation has the form ($C_i = C_o - e^{-t/\tau}\ldots$). Space time-constant is space volume divided by the outdoor airflow rate ($\tau = v/V_o$). In response to a "step-change" in contaminant sources, the concentration in the space rises exponentially, reaching 95% of its steady state value after three time constants. So, Equation 6-9 finds a three-time-constant averaging period, giving the zone a reasonable chance to respond to various short-term conditions in the space.

Averaging time may be applied to make design adjustments when changing conditions in the zone can be predicted. For instance, if fluctuations in zone population can be predicted, design breathing zone outdoor airflow may be calculated based on the highest average population over any *T* hour period. *Table 4* shows estimated population profile, averaging time and average population for several of the example zones used in this article. A cautionary note: overly aggressive zone-population averaging applied with the new, lower prescribed breathing-zone rates can sometimes lead to very low intake rates and inadequate ventilation.

Ventilation Zone	**Zone Floor Area**	**Zone Pop.**	**Breathing-Zone Outdoor Airflow**	**Ceiling Height**	**Averaging Time**	**Percentage of Peak Population by Time Interval**										**Avg. Zone Pop.**
	A_z	P_z	V_{bz}		T	**Operating Time "Blocks"**									**Avg.**	
	ft²	People	cfm	ft	hr	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5		People
Example Office	1,500	10	140	10	5.5*	30	50	50	100	60	80	80	100	100	91**	9.1
North Conference Room	2,000	20	220	10	4.5	50	50	50	100	100	50	50	50	50	72	14.4
South Conference Room	3,000	30	270	10	3.7	50	50	50	100	100	50	50	50	50	77	23.1
Art Classroom	2,000	40	760	12	1.6	75	75	50	100	0	0	100	0	0	81	32.4
Multiuse Assembly Area	3,000	300	2430	20	1.2	0	0	0	100	50	0	75	50	0	92	276

* For example, $T = 3 \times v/V_{bz} = 3 \times 1500 \times 10/140 = 321$ minutes or about 5.5 hours.

** For example, by inspection, highest average population as a percentage of peak = $(4 \times 100 + 1 \times 60 + 0.5 \times 80)/5.5 = 91\%$.

Table 4: Estimated population profile, averaging time, and average population for several of the example zones used.

airflow needed for each zone occurs during heating operation. The resulting total outdoor airflow for the system is 3,830 cfm.

Heating operation requires more intake airflow than cooling because we assumed that the supply-air temperature during heating is quite high, and that the discharge velocity of the diffusers is quite low. If each rooftop unit has only one minimum setting for the outdoor air damper, we would set it for the higher minimum airflow and size the heating and cooling coils for the corresponding percentage of outdoor air. If the rooftop can accommodate two minimum settings, however, we could reduce intake airflow to the lower value during cooling operation, thereby reducing the percentage of outdoor air and the required cooling coil capacity.

An even better approach might be to simply lower the supply-air heating temperature to 90°F (32°C) or less while increasing the diffuser discharge velocity. According to Table 6.2, this would raise the maximum zone–air-distribution effectiveness to 1.0 and reduce the heating intake airflow for each zone to match the cooling intake airflow. The benefits include less intake airflow year-round, only one minimum outdoor air-damper setting, and increased comfort since reduced discharge temperature and longer throws result in less vertical temperature stratification.

Dedicated Outdoor Air-System Design. To determine the effect of a different ventilation system on outdoor air intake flow, we replaced the single-zone systems for our office with a dedicated (100%) outdoor air system. In this case, we assumed each ventilation zone is served by a single-zone, constant-volume heat pump (with no outdoor air intake). We also assumed all outdoor air is delivered directly to the ceiling mounted heat pumps from a central, constant-volume, dedicated outdoor air unit. This dedicated unit preconditions the outdoor air and delivers it through a ventilation duct system to each heat pump. Each heat pump, in turn, delivers both outdoor air and locally recirculated air from the plenum to the ventilation zone it serves.

For this system configuration, we found outdoor air intake flow (V_{ot}) at the dedicated outdoor air unit using Equation 6-4. Assuming negligible duct leakage, all intake air reaches all supply diffusers, so minimum intake airflow simply equals the sum of the minimum zone-outdoor airflow values.

In this example, we assumed that the preconditioned outdoor air mixes with local return air, and that the mixture is then cooled or heated by the heat pump before it enters the ventilation zone. In this configuration, the highest of the heating or cooling V_{oz} value for each zone must be used to find V_{ot}. With the values for zone air-distribution effectiveness shown in *Table 3*, and assuming that all zones are in heating, as might be the case in cold weather for the first few hours of operation, we found that the dedicated outdoor air unit must handle 3,830 cfm of outdoor air.

In a system with several ventilation zones, it might seem reasonable that accounting for system population diversity could lower the intake requirement. This is not the case, however. Fluctuations in zone population can be incorporated (via

Equations and Variables from Addendum 62*n*

[6-1] $V_{bz} = R_pP_z + R_aA_z$

[6-2] $V_{oz} = V_{bz}/E_z$

[6-3] $V_{ot} = V_{oz}$ single-zone systems

[6-4] $V_{ot} = \Sigma V_{oz}$ 100% outdoor-air systems

[6-5] $Z_p = V_{oz}/V_{pz}$

[6-6] $V_{ou} = D\Sigma_{allzones} R_pP_z + \Sigma_{allzones} R_aA_z$
$= D\Sigma_{allzones} V_{bzp} + \Sigma_{allzones} V_{bza}$

[6-7] $D = P_s/\Sigma_{allzones} P_z$

[6-8] $V_{ot} = V_{ou}/E_v$ multiple-zone recirculating systems

[6-9a] $T = 3v/V_{bz}$ IP version

[6-9b] $T = 50v/V_{bz}$ SI version

where

A_z is zone floor area, the net occupiable floor area of the zone, ft² (m²)

D is occupant diversity, the ratio of system population to the sum of zone populations

E_v is ventilation efficiency of the system

E_z is air-distribution effectiveness within the zone

P_s is system population, the maximum simultaneous number of occupants in the area served by the ventilation system

P_z is zone population, the largest expected number of people to occupy the ventilation zone during typical usage (See caveats in Addendum 62n–Section 6.2.1.1)

R_a is area outdoor air rate, the required airflow per unit area of the ventilation zone determined from Addendum 62n–Table 6.1, cfm/ft² (L/s·m²)

R_p is people outdoor air rate, the required airflow per person determined from Addendum 62n–Table 6.1, in cfm/person (L/s·person)

T is averaging time period, minutes

v is ventilation-zone volume, ft³ (m³)

V_{bz} is breathing-zone outdoor airflow, the outdoor airflow required in the breathing zone of the occupiable space(s) of the ventilation zone, cfm (L/s)

V_{ot} is outdoor air intake flow, adjusted for occupant diversity and corrected for ventilation efficiency, cfm (L/s)

V_{ou} is the uncorrected outdoor air intake flow, cfm (L/s)

V_{oz} is zone outdoor airflow, the outdoor airflow that must be provided to the zone by the supply-air-distribution system at design conditions, cfm (L/s)

V_{pz} is zone primary airflow, the primary airflow that the air handler delivers to the ventilation zone; includes both outdoor air and recirculated return air

Z_p is zone primary outdoor air fraction, the fraction of outdoor air in the primary airflow delivered to the ventilation zone … for VAV systems, Z_p for design purposes is based on the minimum expected primary airflow, V_{pzm}.

					Cooling		Heating	
Ventilation Zone	**People Outdoor Air Rate**	**Zone Population**	**Area Outdoor Air Rate**	**Zone Floor Area**	**Zone Ventilation Efficiency**	**Zone Outdoor Airflow**	**Zone Ventilation Efficiency**	**Zone Outdoor Airflow**
	R_p	P_z	R_a	A_z	E_z	V_{oz}	E_z	V_{oz}
	cfm/person		cfm/ft²	ft²		cfm		cfm
South Classrooms (Age 9+)	10	140	0.12	4,000	1.0	1,880	0.8	2,350
West Classrooms (Age 9+)	10	140	0.12	4,000	1.0	1,880	0.8	2,350
North Lecture Classrooms	7.5	260	0.06	4,000	1.0	2,190	1.0	2,190
East Lecture Classrooms	7.5	260	0.06	4,000	1.0	2,190	1.0	2,190
Interior Offices	5	5	0.06	1,000	1.0	85	0.8	106
North Art Classroom	10	32*	0.18	2,000	1.0	680	0.8	850
South Multiuse Assembly	7.5	276**	0.06	3,000	1.0	2,250	1.0	2,250
Total Zone-Level Outdoor Airflow					$\Sigma V_{oz} =$	11,200	$\Sigma V_{oz} =$	12,300
Single-Zone Systems: Total Intake Air							$\Sigma V_{oz} =$	12,300
100% Outdoor Air System					$V_{ot} =$	11,200		

* Average population (81% of 40-person peak population)
** Average population (92% of 300-person peak population)

***Table 5:** Ventilation calculations for example school building served by single-zone system and 100% outdoor air system.*

averaging) into zone ventilation calculations, but population diversity for the entire system cannot. In other words, even though the system as a whole never contains the sum-of-zones design population, each zone must be ventilated as though it is occupied at design (peak or average) population. A dedicated outdoor air system does not receive credit for recirculated outdoor air from over-ventilated zones, and typically does not modulate ventilation airflow to the zones served. When determining intake airflow for the dedicated outdoor air unit, each zone must be considered to be at design occupancy.

A School Building

Next, let's review two ventilation system designs for a different type of building: a school that contains the ventilation zones described in *Table 5.*

As before, we followed the three-step procedure in 62*n* to find the zone-level ventilation requirements. To do so, we first used Equation 6-1 and Table 6.1 to find V_{bz} for each zone. For zone population, we used the expected peak occupancies for the classrooms and office areas, but we used average population for the art classroom and multiuse assembly area.

Second, we established the zone air-distribution effectiveness for each zone configuration, based on the values in Table 6.2 (see *Table 2*). We assumed that supply air during heating is less than 90°F (32°C), but we also assumed that the classroom and office diffusers do not provide sufficient velocity to deliver 150 fpm (0.75 m/s) air at the 4.5-ft (1.4 m) level. Therefore, we used $E_z = 1.0$ for the lecture rooms and assembly area, but we used an E_z value of 0.8 for the classrooms and offices during heating operation.

Third, we used Equation 6-2 to find the minimum outdoor airflow needed for each zone in both cooling and heating modes.

Because the minimum required outdoor air intake flow depends on the type of ventilation system, we again looked at two system types.

Zone Air-Distribution Effectiveness

All supply air leaving the ventilation zone diffusers may not actually arrive in the breathing zone. During heating operation, for instance, some portion of warm air from an overhead diffuser may simply float on cooler air in the space and never drop into the breathing zone (between 3 and 72 in. from the floor). Or, during cooling operation, some portion of cool air from an overhead diffuser may "short circuit" to a nearby (poorly placed) return grille, never reaching the breathing zone.

The fraction of the air supplied to a space that actually reaches the breathing zone can be characterized by zone air-distribution effectiveness (E_z). It is similar to "air-change effectiveness" (ACE) for well-mixed spaces, which can be determined in the lab using the methods in ANSI/ASHRAE Standard 129, *Measuring Air Change Effectiveness*. For laminar flow spaces, like some displacement and underfloor systems, ACE depends on ceiling height, so it is not necessarily a good indicator of the fraction of supply air reaching the occupants. (Both ACE and E_z values may be high with a nine-foot [2.75 m] ceiling, but with a 30-foot [9 m] ceiling, ACE would be higher than E_z, not equal to it; using an inappropriately high value [that is, E_z = ACE], would lead to underventilation when using Equation 6-2 to find zone outdoor airflow.)

Note that "air diffusion performance index" (ADPI), defined in the ASHRAE Handbook and ANSI/ASHRAE Standard 113, *Method of Testing for Room Air Diffusion,* is not directly related to air-distribution effectiveness; a poorly performing diffuser that dumps cold air onto an occupant's head has a low ADPI but a high E_z value.

Single-Zone System Design. First, we assumed that each ventilation zone is served by a single-zone, constant-volume unit ventilator or rooftop unit. Equation 6-3 ($V_{ot} = V_{oz}$) is used to find the outdoor air intake flow needed at each unit; it simply equals the minimum zone outdoor airflow. As shown in *Table 5*, some zones need more intake airflow in heating mode than in cooling because of lower zone air-distribution effectiveness. The total outdoor airflow for the system in this case is 12,300 cfm. As mentioned earlier, lowering supply air temperature when heating, and/or selecting better diffusers can reduce the required intake airflow (and unit capacity) as well as increase comfort by reducing vertical temperature stratification.

Dedicated Outdoor Air-System Design. Next, we assumed that each ventilation zone is served by a single-zone, constant-volume blower-coil unit (or a recirculating air handler) without an outdoor air intake. Further, we assumed that all outdoor air enters the system through a central, constant-volume, dedicated outdoor air unit. The entering outdoor air is preconditioned, so it is dry and cool (or neutral during heating operation), and is ducted to and discharged directly into each zone through "ventilation" diffusers. Given the system configuration, we used Equation 6-4 ($V_{ot} = \Sigma V_{oz}$) to find the minimum required outdoor air intake flow at the dedicated outdoor air unit; it's simply the sum of the minimum zone-outdoor airflow values

For this school example, preconditioned outdoor air enters each zone directly, and it is never "hot." We ignored the somewhat higher *heating* values and instead used the *cooling* V_{oz} values, which means that the dedicated outdoor air unit must handle 11,200 cfm of outdoor air, a little less total intake airflow than we needed using single-zone recirculating systems. As in the previous example, we cannot account for system population diversity in this constant-volume system, even though peak population does not occur in all zones simultaneously.

What About Part-Load Operation?

In the preceding discussion, we found the minimum "design" outdoor air intake flow for two different ventilation systems in an example office and an example school. Operationally, however, ventilation load varies with changes in supply-air temperature and population. Addendum 62*n* explicitly permits dynamic reset of intake airflow so ventilation capacity can be matched to ventilation load. This can save outdoor air-conditioning energy during periods of low ventilation load and avoid underventilation problems during periods of high ventilation load. Because "demand-controlled ventilation" is a broad topic, it will be addressed separately in a future article. Suffice to say, single-zone systems may be cycled on and off, or the intake damper minimum setting may be modulated in response to population changes. But, in dedicated outdoor air systems, the 100% outdoor air unit must deliver design ventilation air to all zones whenever any zone is occupied, unless individual zones include modulating dampers to control outdoor airflow based on zone ventilation demand. Note that the ASHRAE energy standard[4] requires energy recovery on 100% outdoor air units delivering 5,000 cfm (2360 L/s) or more; a dedicated outdoor air system with energy recovery may use less energy than multiple single-zone systems without energy recovery.

Anything Else?

For zones with strong contaminant sources, Addendum 62*n* prescribes minimum exhaust airflow to remove contaminants from the building. Minimum exhaust rates for nineteen zones are prescribed in Table 6.4 (not included here). This may be regarded as a significant change from Standard 62-2001, which specified exhaust rates for only a few zones and did not clarify whether it was just minimum exhaust flow, or both minimum exhaust and outdoor air supply flow (e.g., public restrooms). While most zones require either one or the other, some zones — such as art classrooms — require both minimum supply and exhaust airflow. Makeup air from outdoors (to replace exhausted air) may be supplied to a zone by any combination of first-pass outdoor air or outdoor air transferred from other zones.

Summary

The Addendum 62*n* "heart transplant" certainly changes the ventilation standard. There are no guarantees, but these expectations seem reasonable: that the generally lower breathing-zone rates will reduce some designer complaints about overventilation, that people- plus building-ventilation "additivity" will reduce effective per-person ventilation in high-density spaces but increase it in low-density spaces, and that the prescribed calculation procedures will reduce underventilation in some systems while increasing calculation consistency among designers. By changing the prescribed rates and at the same time encouraging better design procedures, Addendum 62*n* may lower ventilation system costs for some systems and improve indoor air quality in others. Time will tell.

References

1. ANSI/ASHRAE Standard 62-2001, *Ventilation for Acceptable Indoor Air Quality*.

2. ANSI/SHRAE Addendum *n* to ANSI/ASHRAE Standard 62-2001.

3. International Facility Management Association. 2004. *Project Management Benchmarks Report*. In "IFMA Research Shows Office Space Shrinking." Cited Aug. 20, 2004. Available from: www.ifma.org/about/prdetail.cfm?id=331&actionbig=3&actionlil=153 .

4. ANSI/ASHRAE Standard 90.1-2001, *Energy Standard for Buildings Except Low-Rise Residential Buildings.*