Ventilation for acceptable indoor air quality

This article summarizes the major changes enacted in the new ASHRAE Standard 62-1989

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At long last, the revision to ASHRAE's Ventilation Standard has been published. It is titled, *"ASHRAE Standard 62-1989, Ventilation for acceptable indoor air quality."* Although the revision has been underway since 1983, the recommended ventilating rates are quite consistent with the recommended rates in *Standard 62-73* and the smoking-allowed rates in *Standard 62-1981.*

About the author

John E. Janssen, Member ASHRAE, has served as chairman of SPC 62-1981R since 1983 when an early review of *Standard 62-1981* was started. He also served as vice chairman of SPC 62-73R, the committee that produced *Standard 62-1981.* Janssen retired from Honeywell after 35 years during which he conducted research on controls for ventilation, temperature control, flowmeters and thermal radiation properties.

The prescriptive Ventilation Rate Procedure is admittedly an indirect method for controlling indoor air quality. It specifies the amount of outdoor air needed to dilute and remove contaminants for 91 different applications.

The Air Quality Procedure introduced in the 1981 edition has been retained. It is a direct procedure that requires the concentration of contaminants to be held below acceptable limits, but leaves the outdoor air flow rate unspecified. Thus, air cleaning systems can be used to reduce at least some of the contaminants (particulate matter) and may thereby reduce the amount of outdoor air needed. The big questions are, "How will the new standard change the design and operation of ventilating systems?" and "How will existing systems have to be modified?"

Major changes

There are two major changes in the new standard. First, the minimum outdoor air flow rate has been changed from 5 cfm (2.5 L/s) per person in "clean" environments to 15 cfm (7.5 L/s) per person. Second, the distinction between smoking-allowed and smoking-prohibited has been removed. Other additions provide opportunities for energy conservation.

Recommended ventilating rate. The 1973 Standard presented both minimum and recommended ventilating rates for 140 applications. The minimum ventilating rate specified for any application in the 1973 Standard was 5 cfm (2.5 L/s) per person. The recommended rate for most of these "clean" applications was 7-10 cfm (3.5-5.0 L/s) per person.

ASHRAE's first building energy standard (published in 1975) recommended use of the minimum ventilating rates in *Standard 62-73.* Thus, when *Standard 62-73* came up for review in 1978, one of the objectives was to justify the minimum ventilating rates. No technical data were found at that time to lead the committee to believe that 5 cfm of outdoor air was insufficient if there were no tobacco smoke or other significant sources of contaminants. This led to the two-tiered standard in 1981 that listed higher ventilating rates for applications where smoking was allowed.

Research results became available soon after the 1981 Standard was published that showed that more than 20 percent of the people entering a room regularly ventilated at only 5 cfm (2.5 L/s) per occupant would detect undesirable occupant body odor (Berg-Munch *et al.* 1986). It was found that 15 cfm (7.5 L/s) per occupant of outdoor air was needed to satisfy the odor perception of people entering the room. This lowered the steady-state CO_2 level from 2,500 ppm (5 cfm/person) to 1,000 ppm.

More recent studies in four U.S. Army training centers showed at least a 45 percent increase in respiratory infection among the recruits housed in energy-efficient barracks built in the late 1970s and early 1980s (Brundage *et al.* 1988). These barracks used only five percent outdoor air in the supply compared with up to 40 percent in older barracks that had lower infection rates. The supply was stated to be 36 cfm per occupant. Thus, five percent outdoor air in the supply was only 1.8 cfm per occupant. This is much less than recommended even in *Standard 62-1981.* Forty percent outdoor air found in the older barracks would equate to at least 14.4 cfm per occupant. This would be in line with *Standard 62-1989.* These facts led the Standard Project Committee 62-1981R to conclude that the minimum outdoor air flow rate should not be less than 15 cfm (7.5 L/s) per person.

There was a natural concern for the energy penalty this increase in ventilation might impose. Eto and Meyer of the Lawrence Berkeley Laboratory calculated the energy penalty of raising the outdoor air flow rate from five to 20 cfm for a typical office building located in 10 U.S. and three Canadian cities (Eto *et al.* 1988). They used DOE-2.1C simulations and weather tapes for the chosen cities. They concluded that the energy operating cost increase would be less than five percent. This seems to be a small price to pay for an improved indoor environment.

While 15 cfm (7.5 L/s) per person of outdoor air has now become the minimum, many applications require more outdoor air to dilute and remove contaminants other than biological emissions from the occupants. Volatile hydrocarbons from wall and floor coverings, furniture, finishes on draperies and upholstery, electrical insulation and plastics in computers and other electronic devices, cleaning materials, and other sources add to the contaminant load. Additional outdoor air is needed to control many of these contaminants.

Table 1 is an abbreviated table from the new standard. It compares some of the 1989 recommendations with those of 1981 for the same applications. It is seen that the outdoor air flow rates now generally fall in the range recommended in the 1973 Standard and are somewhat lower than the smoking-allowed recommendations of the 1981 Standard. The changes were arrived at by analysis of the physical requirements needed to dilute occupant-generated carbon dioxide, occupant body odor, and the consensus of the committee members' experience.

Tobacco smoke control. Control of tobacco smoke presents a difficult problem. Exposure to tobacco smoke over a long period of time presents a risk of lung damage, cancer and heart damage. Non-smokers passively exposed to environmental tobacco smoke (ETS) are also at risk.

The great problem is that ventilation alone cannot effectively control the risk from ETS. Convection currents in a room may play a greater role than dilution with outdoor air. Air currents can carry the smoke from a smoldering cigarette directly into the breathing zone of a non-smoker. This can occur even outdoors where, in theory, the dilution problem is infinite.

The special problems presented in controlling ETS were recognized in the 1981 Standard. A two-tiered approach was used. One set of outdoor air flow rates was specified when smoking was prohibited and greater outdoor air flow rates were specified when smoking was allowed in a space. Experience with the 1981 Standard has shown that this has led to misinterpretation and an opportunity for misuse of the standard.

It was intended that in a space where smoking was allowed, everyone should be supplied with the smoking-allowed recommendation (for example, 20 cfm in an office space). It appears, however, that some users of the 1981 Standard have reasoned that, if only one-third of the occupants smoked, the system could be designed to provide one-third of the smoking-allowed recommendation and two-thirds of the smoking-prohibited recommendation (i.e., $[1/3 \times 20] + [2/3 \times 5] = 10$). This is only half of the intended ventilation rate.

A further opportunity for misuse occurred when buildings were built on speculation without knowing who the tenants would be or what their smoking policy would be. It was possible for a designer to assume a building would be smoke-free and thus reduce the cost of some equipment, especially cooling equipment. When the building was subsequently leased to tenants who allowed smoking, the occupants were exposed to excessive ETS. Thus, the SPC had a strong incentive to eliminate the two-tiered standard.

The need to raise the minimum outdoor air flow rate from five to 15 cfm (2.5 to 7.5 L/s) per person to control occupant-generated odors offered the opportunity to abandon the two-tiered standard. Leaderer and Cain (1983) measured the amount of ETS dilution needed to satisfy the tobacco smoke odor perception of people entering a space (visitors) where the occupants are smoking. They found that about 1,800 cu. ft. of smoke-free (outdoor) air per cigarette is needed to satisfy 70 percent of the visitors. This equates to 30 percent of the occupants smoking at a rate of 1.7 cigarettes per hour if the space is ventilated at a rate of 15 cfm (7.5 L/s) of outdoor air per occupant.

Thayer (1982) analyzed 41 data points from 10 different authors. These data were for adapted occupants (i.e. occupants who had been in the space at least 15 minutes and had become desensitized to the ETS odor). Thayer devised an irritation index and a dilution index to quantify the response to ETS. He used a national average smoking rate of 1.1 cigarettes per hour per smoker with one-third of the population smoking. At this rate, 15 cfm (7.5 L/s) per occupant of outdoor air would satisfy more than 80 percent of the occupants.

The SPC concluded from these two papers that the 15 cfm (7.5 L/s) minimum outdoor air ventilating rate could control a minimum amount of tobacco smoke. It should be recognized, however, that the relationship between health risk and tobacco smoke odor is a tenuous one. Indeed, the Foreword of *Standard 62-1989* states, "For substantive information on health effects, the Standard must rely on recognized authorities and their specific recommendations. Therefore, with respect to tobacco smoke and other contaminants, this Standard does not, and cannot, ensure avoidance of all possible adverse health effects, but it reflects recognized consensus criteria and guidance."

Dilution of tobacco smoke and other contaminants with less contaminated outdoor air is sometimes an imperfect control mechanism. It depends not only on the amount of dilution air, but on the degree of mixing achieved, convection currents, electrical space charge effects, and perhaps other factors.

Table 1. ASHRAE Recommended Outdoor Air Ventilating Rates—Abbreviated Table (cfm/person)[a]

Application	1973 Min.	1973 Recom.	1981 No smoke	1981 Smoking	1989
Dining room	10	15-20	7	35	20
Bars & cocktail lounges	30	35-40	10	50	30
Hotel conference rooms	20	25-30	7	35	20
Office spaces	15	15-25	5	20	20
Office conference rooms	25	30-40	7	35	20
Retail stores	7	10-15	5	25	0.02-0.30[b]
Beauty shops	25	30-35	20	35	25
Ballrooms & discos	15	20-25	7	35	25
Spectator areas	20	25-30	7	35	15
Theater auditoriums	5	5-10	7	35	15
Transporting waiting rooms	15	20-25	7	35	15
Classrooms	10	10-15	5	25	15
Hospital patient rooms	10	15-20	7	35	25
Residences	5	7-10	10	10	0.35[c]
Smoking lounges	–	–	–	–	60

a- Flow is L/s taken as one-half the value in cfm (10 cfm = 5 L/s).
b- Value now given in cfm/sq ft of floor space (1 cfm/sq ft = 5 L/s sq m).
c- Residential ventilation was given in cfm/person in 1973, cfm/room in 1981, and air changes/hour in 1989.

Therefore, elimination of health risk through increased ventilation alone may not be possible.

Table 1 shows that applications where the smoking rate is expected to be greater than that assumed above and/or other contaminant sources are expected, the recommended ventilating rates are increased. They have been reduced from the 1981 smoking-allowed recommendations, however, because of the consensus among the SPC that the decreasing smoking rate and separation of smokers from non-smokers have reduced the problem. Many applications such as theaters and retail stores now prohibit smoking.

Multiple spaces and a common system. It is generally found that one air-handling system supplies the ventilation for more than one room or zone. The outdoor air requirements for these spaces are usually different. If the system supplies the fraction of outdoor air in the total supply that is needed for the zone or room with the greatest load, the other spaces will have more outdoor air than necessary. A new procedure (Australian Ventilation Standard 1980) has been added to permit averaging of the loads. Credit can be taken for the excess outdoor air that is recirculated from the overventilated spaces. Equation (1) describes the averaging process:

$$Y = X/(1 + X - Z) \qquad (1)$$

where

Y = Corrected fraction of outdoor air in the total supply

X = Sum of all zone outdoor airflows divided by the total supply

Z = Outdoor air fraction required in the supply to the zone of greatest ventilation demand

This procedure should be especially useful in office buildings where high-occupant-density open spaces, conference rooms and private offices are often served by a common air-handling system.

Intermittent or variable occupancy. The provision for adjusting the quantity of outdoor ventilating air to meet the actual occupant load that was introduced in 1981 has been retained. *Standard 62-1989* states, "When the contaminants are associated only with occupants or their activities, do not present a short-term health hazard, and are dissipated during unoccupied periods to provide air equivalent to acceptable outdoor air, the supply of outdoor air may lag occupancy. When contaminants are generated in the space or the conditioning system independent of occupants or their activities, supply of outdoor air should lead occupancy so that acceptable conditions will exist at the start of occupancy." Two figures are provided for determining the lag or lead time. This is an operating feature that may be useful in a number of applications.

Systems and equipment. Section 5 of the new standard contains discussion and recommendations on a number of system and equipment factors that affect the resulting air quality. This includes comments on infiltration, recommendations for the use of heat recovery equipment, comments on air distribution and thermal comfort, warnings about contamination of the make-up air, comments on duct construction, warnings about the need for local exhaust of sources such as fuel burning appliances, warnings about biological contamination, and discussion of the use of air-cleaning systems.

The discussion of biological contaminants from areas that are wet or exposed to high humidities is new. Also Appendix E has been added to provide guidance on the use of air-cleaning systems. If air-cleaning systems are used to reduce the outdoor air flow rates below the values given under the Ventilation Rate Procedure, the Air Quality procedure must be used. This policy is needed to ensure that those contaminants not removed by the air cleaning system do not reach unacceptable concentrations. Carbon dioxide may be one of the limiting contaminants.

Air quality procedure. The alternate and independent Air Quality Procedure was introduced in 1981 and has been retained. It leaves the outdoor air flow rate unspecified, but demands that contaminant concentrations be held below acceptable limits. Thus, it provides direct control of indoor air quality. Unfortunately, acceptable limits for many contaminants have not yet been defined by authoritative bodies. The National Ambient Air Quality Standard promulgated by the U.S. government is shown in *Table 2.* It defines acceptable outdoor air, and the indoor air should be at least this good.

These were the specifications presented in the public review of the draft of *Standard 62-1981R* and are presented in *Standard 62-1989.* The specification for particulates was changed in February 1989 and is now stated as:

Particles (PM10) 50 $\mu g/m^3$, 1 year
15,000 $\mu g/m^3$, 24 hours.

EPA made this change to emphasize the importance of particles smaller than 10 micrometers. These small particles penetrate deeper into the lungs and present the greatest health hazard. An Addendum is being processed to

Table 2. National Ambient Air Quality Standard

Contaminant	Long-Term Concentration Averaging $\mu g/m^3$	ppm		Short-Term Concentration Averaging $\mu g/m^3$	ppm	
Sulfur dioxide	80	0.03	1 yr	365	0.14	24 hr
Total particles	75	–	1 yr	260	–	24 hr
Carbon monoxide				40,000	35	1 hr
Carbon monoxide				10,000	9	8 hr
Oxidants (ozone)				235	0.12	1 hr
Nitrogen dioxide	100	0.055	1 yr			
Lead	1.5	–	3 mo			

Table 3. Guidelines for Selected Air Contaminants of Indoor Origin

Contaminant	Concentration/	ppm	Exposure Time
Carbon dioxide	1.8 g/m^3	1,000	Continuous
Chlordane	5 $\mu g/m^3$	0.0003	Continuous
Ozone	100 $\mu g/m^3$	0.05	Continuous
Radon	0.027 WL		Annual average

make this change in the standard. Users of the new standard are advised to be aware of this coming change. The rules of the ASHRAE Standards Committee did not permit this change without another public review, and the SPC did not believe it was advisable to delay the publication of the entire standard for this one item.

Table 3 presents guidelines for four other contaminants for which there is a reasonable consensus. EPA has recently adopted a guideline limit for radon gas of 4 pico Curie per liter (pCi/L), which is equivalent to about 0.02 working levels (WL). Although the working level unit is more directly related to health risk, the radon gas concentration in pCi/L is easier to measure. The conversion requires an assumption about the equilibrium among disintegrating radioactive species. This change is also being handled through the addenda process.

There are a number of other contaminants of concern whose limits have not been agreed to. The range of limits for these are discussed in Appendix C of the new standard. The user of the Air Quality Procedure must decide if any contaminants not listed in Table 1 or Table 3 of the 1989 Standard present a problem and then deal with the problem. This may include the use of a subjective odor panel to detect odorous contaminants. One type of odor panel is described in Appendix C. It is clear that the optional Air Quality Procedure puts more responsibility on the user. It does, however, offer the opportunity for innovative control of indoor air quality.

Control opportunities. The Air Quality Procedure was introduced in the 1981 standard to permit the use of advanced, energy-efficient means for controlling air quality. Air cleaning systems are included in this category when the outdoor air rate is reduced below the flow rates recommended under the Ventilation Rate Procedure. Most of the outdoor air flow rates recommended under the Ventilation Rate Procedure are presented as a volumetric flow rate per occupant. The minimum rate of 15 cfm (7.5 L/s) is based on CO_2 control. Thus, CO_2 sensing offers one means of controlling a ventilation system.

Figure 1 shows the CO_2 control point needed to achieve various specified ventilating rates. Thus, if an office space is to be ventilated at 20 cfm (10 L/s) per occupant, the CO_2 level in the space should be no higher than 825 ppm. *Figure 1* is a generally conservative curve since any increase in activity, increase in outdoor air CO_2 concentration, or increase in indoor CO_2 from unvented combustion sources including tobacco smoke would increase the ventilation rate per occupant.

There could be a problem, however, when the occupant density is low and other contaminant sources are present. It would appear that another sensor capable of sensing volatile organic hydrocarbons or some other family of common contaminants may be needed. Such a sensing system could provide new opportunities for control of the ventilating system under the Air Quality Procedure and thereby conserve energy.

Summary

ASHRAE Standard 62-1989, "Ventilation for acceptable indoor air quality," has now been published. It provides a minimum of 15 cfm (7.5 L/s) per person of outdoor air for ventilation. New opportunities for energy conservation have been added. It is expected that most ex-

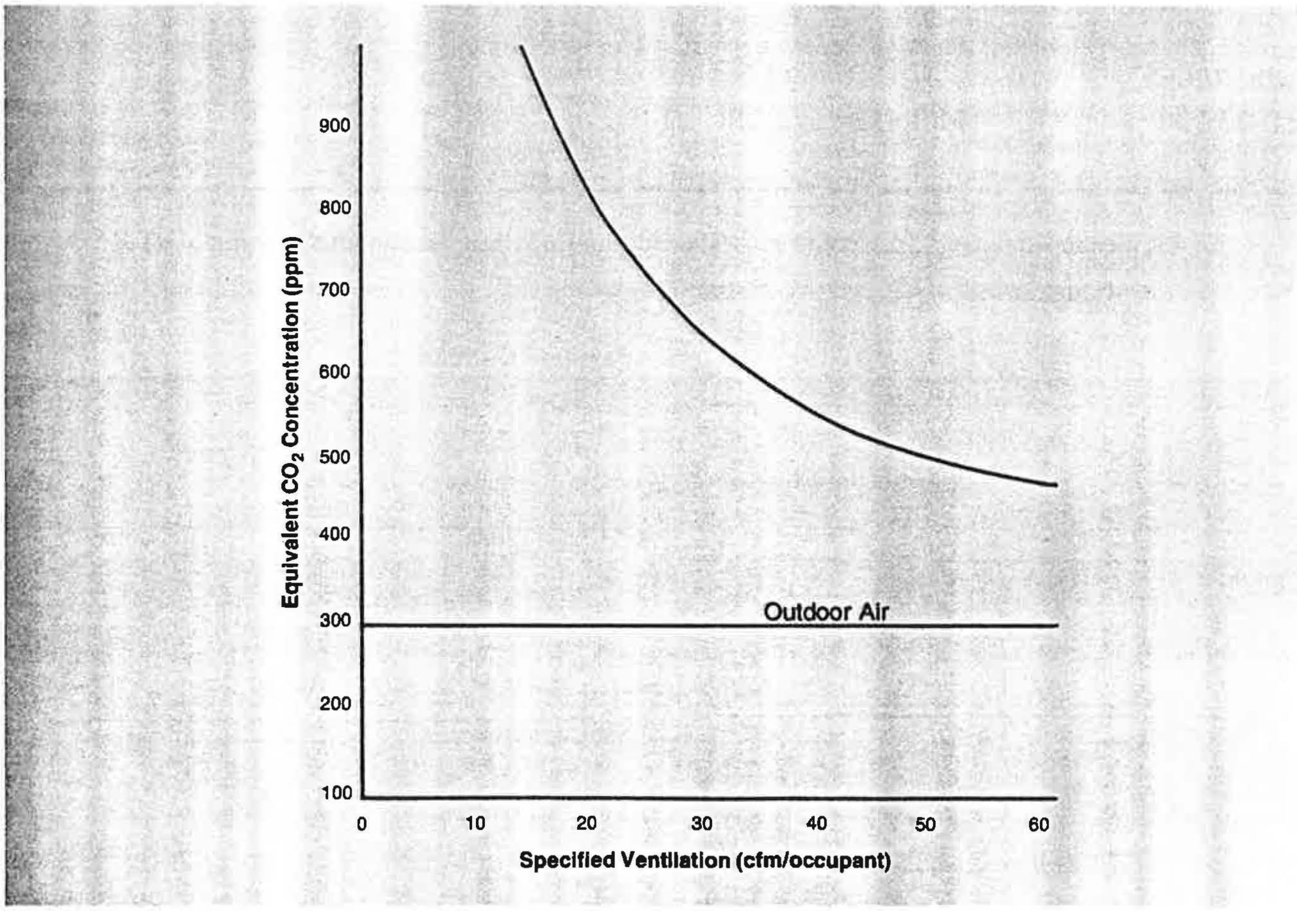

Figure 1. Room CO_2 concentration for equivalent ventilation 1.2 met physical activity

isting systems will be able to meet the conditions recommended in the revised standard by changes in operation rather than modifications to the system.

References

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