

# Implications of ASHRAE's Guidance On Ventilation for Smoking-Permitted Areas

By **Stanton A. Glantz, Ph.D.**, and **Suzaynn Schick, Ph.D.**

**T**he issue of how to deal with secondhand smoke has been a subject of debate within ASHRAE for many years.<sup>1</sup> This debate has centered around ANSI ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*, whose stated purpose is to “specify minimum ventilation rates and indoor air quality that will be acceptable to human occupants and are intended to minimize the potential for adverse health effects.” Acceptable indoor air quality is defined 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.”

In 1981, ASHRAE first recognized that tobacco smoke posed problems inside buildings by revising indoor air quality Standard 62 to require ventilation rates two-to-five times higher in smoking areas than in non-smoking areas of buildings. Standard 62-1981 said, “higher ventilation rates are specified for spaces where smoking is permitted because tobacco smoke is one of the most difficult contaminants to control at the source” and

that the standard is developed so that indoor air quality does not “impair health.”

This approach alarmed the tobacco industry because, as Philip Morris noted, it “would effectively double the costs for heating and cooling in areas which allow smoking.”<sup>1</sup> This increased ventilation cost became a reason for building owners to make buildings smoke-free, and these smoke-free policies reduce cigarette consumption by 29% by making it easier for

people to cut down or stop smoking.<sup>2</sup> As a result, the tobacco industry, working both directly and through the hospitality and gaming industries,<sup>1,3</sup> has mounted a continuous campaign to have ASHRAE Standard 62 provide for smoking in buildings.

On June 26, 2002, the ASHRAE Board of Directors voted that “that the following sentence be added to the target title, purpose and scope of its ventilation and indoor air quality standard, Standard 62, ‘This standard does not address spaces where smoking is expected to occur.’”<sup>4</sup> This decision was based on a recommendation from the Board Policy Committee that recognized that “The title of Standard 62.1 is ‘Ventilation for Acceptable Indoor Air Quality.’ If supplemental guidance for spaces where smoking is permitted was included in the standard, such inclusion would be contrary to the title of the standard. There is evidence

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$$C_{RSP} = G(P/V)sr/Q$$

where

$C_{RSP}$  = respirable suspended particulates from second-hand smoke,

$G$  = effective RSP emissions per cigarette (adjusted to account for the effects of deposition),

$(P/V)$  = occupancy in people/volume,

$s$  = percentage of occupants who are smokers,

$r$  = rate of smoking (cigarette/smoker-time), and

$Q$  = ventilation rate (air changes/time).

This equation is the same steady state mass balance proposed and validated by Repace and Lowry<sup>6</sup> and Ott et al.<sup>7,8</sup> written in terms of the variables in Table I-3 of Appendix I.

Table 1 summarizes the results of these calculations of the increases in RSP due to secondhand smoke above any background levels that were present for other reasons, based on the information in Table I-3 of Appendix I (Occupancy, Proportion of Smokers, Smoking Rate, and Total Ventilation Rate).  $G = 11.4$  mg/cigarette.<sup>8,9</sup> The ceiling heights are assumed.

The equation assumes, as does Appendix I, that

there is perfect mixing.

These levels of RSP are well above the  $4.4 \mu\text{g}/\text{m}^3$  levels two-thirds of the healthy subjects Junker, et al.<sup>10</sup> found considered unacceptable air quality in a more recent, well-designed study than the 20-year-old study<sup>11</sup> ASHRAE relied upon to develop Appendix I.

#### Are these Levels “Comfortable?”

The “comfort” standard in Appendix I was based on a 1983 study by Cain et al.,<sup>11</sup> 92 participants of unspecified gender, 30% of whom were active smokers and were allowed to take smoking breaks during their evaluations, participated in the study. Air from a chamber, where people were smoking a controlled number of cigarettes under various ventilation conditions, was delivered to a “sniff box.” Before testing the smoke, participants first sniffed eight concentrations of 1-butanol to establish an intensity scale. Then they smelled varying concentrations of diluted cigarette smoke from the sniff box over the course of an hour, matching the apparent odor intensity to the remembered 1-butanol intensity scale. At the end of an hour of testing, the participants were asked to also describe the final condition as acceptable or unacceptable in a binary choice.

\*Stanton Glantz, a coauthor of this paper, submitted a change proposal to SSPC 62.1 to delete Appendix I, with a rationale similar to that found in this article. The committee agreed to delete the appendix. However, the principle of “more ventilation” remains in Section 6.1.3.5, while the SSPC considers its deletion in forthcoming addenda, and work on the ETS design guide is continuing.

that acceptable air quality cannot be achieved where smoking is permitted.”<sup>5</sup> Nevertheless, the Board also voted to support the development of an “Informative Appendix,” Appendix I (part of Addendum 62o) that provides “Guidelines for Ventilation in Smoking-Permitted Areas.” While Appendix I was deleted from Standard 62 at ASHRAE’s Winter Meeting this January, the principle of “more ventilation” remains in Standard 62 Section 6.1.3.5, while the SSPC considers its deletion in forthcoming addenda.\* Despite this deletion, material similar to it can be expected to appear in the new ETS design guide being developed under contract to ASHRAE that can be expected to effectively define the procedures for ventilating smoking-permitted areas.

The stated purpose of former Appendix I (which was still available on ASHRAE’s Web site at the time of this writing) was to provide “satisfaction with respect to odor and sensory irritation,” not health. This paper examines the implications of Appendix I and the forthcoming ETS design guide for the odor, irritation and health aspects of indoor air quality due to the presence of tobacco smoke.

#### Pollution Levels Under Appendix I

It is possible to estimate the additional respirable suspended particulate load above background from secondhand smoke levels that will occur in each of the scenarios in Appendix I using the relationship

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In contrast to the real world situation that Standard 62 and Appendix I were designed to address, these assessments were not based on odor measured at the time cigarettes were actually being smoked. The measurements were recorded after smoking had ceased and the cigarettes had been extinguished. The study did not find any ventilation rates that met the requirement of 80% acceptability when smoking was actually occurring in the smoking chamber, even though smokers were over-represented in the study group. Moreover, Cain, et al. noted, “None of the (ventilation) conditions in the present study would satisfy even two-thirds of nonsmokers.”

A newer, more rigorous study published in 2001 by Junker, et al.,<sup>10</sup> reports the results of two sets of experiments. One set, using non-smoking women as subjects, establishes the odor threshold for sidestream smoke at 0.6–1.4  $\mu\text{g}/\text{m}^3$  SHS-PM2.25. The second set of experiments assayed odor acceptability, with 24 non-smoking women as participants. Each participant sat in a small Plexiglas exposure chamber and assessed four different diluted sidestream smoke concentrations presented in a random order alternating with clean air.

The assessment began with a clean air zero condition and during each of the eight conditions participants were given a startle stimulus test, followed by a questionnaire to fill out and an eye blink count. Acceptability was assessed by marking a line on a scale from –1 (unacceptable) to 1 (acceptable). Positive values greater were scored as acceptable and negative as unacceptable. Each set of secondhand smoke scores was compared to the values for the clean air condition preceding it. At the highest dilution tested, equivalent to 32,300  $\text{ft}^3$  (3000  $\text{m}^3$ ) clean air per cigarette, the air was judged acceptable by only 33% of the participants. (92% found the clean air condition that preceded the secondhand smoke condition acceptable.)

Junker, et al. report that “the detection of the arousing (secondhand smoke) odor alone was sufficient to create dissatisfaction.” These results indicate that sidestream cigarette smoke has one of the lowest odor thresholds of any known compound and causes sensory irritation at concentrations very near the threshold concentrations, 0.6–1.4  $\mu\text{g}/\text{m}^3$  SHS-PM2.25.

Thus, it appears that the guidance in Appendix I does not appear to meet its stated design objective of “satisfaction with respect to odor and sensory irritation.”

### Health Implications

While Appendix I was careful not to make any health claims, it is important to note that all the levels of RSP calculated using the methodology described above exceeded the 15  $\mu\text{g}/\text{m}^3$

| Smoking-Permitted Application      | Occupancy (People Per 100 m <sup>3</sup> ) | Ceiling Height | Proportion of Smokers, SM | Smoking Rate (Cigarettes/Smoker-h), SR | Total Ventilation Rate (L/s Per Adapted Person) | C <sub>RSP</sub>             |
|------------------------------------|--|----------------|---------------------------|--|---|------------------------------|
| Smoking Lounge                     | 70   | 3 m            | 1.00                      | 3.0                                    | 33  | 288 $\mu\text{g}/\text{m}^3$ |
| Heavy Smoking Lounge               | 70   | 3 m            | 1.00                      | 6.0                                    | 58  | 328 $\mu\text{g}/\text{m}^3$ |
| Bar, Cocktail Lounge               | 100  | 3 m            | 0.25                      | 1.0                                    | 16  | 59 $\mu\text{g}/\text{m}^3$  |
| Heavy Smoking Bar, Cocktail Lounge | 100  | 3 m            | 0.50                      | 2.0                                    | 29  | 109 $\mu\text{g}/\text{m}^3$ |
| Dining Room 1                      | 70   | 3 m            | 0.20                      | 0.6                                    | 13  | 29 $\mu\text{g}/\text{m}^3$  |
| Dining Room 2                      | 70   | 3 m            | 0.50                      | 0.6                                    | 16  | 59 $\mu\text{g}/\text{m}^3$  |
| Gambling Casino 1                  | 120  | 4 m            | 0.25                      | 1.5                                    | 19  | 63 $\mu\text{g}/\text{m}^3$  |
| Gambling Casino 2                  | 120  | 4 m            | 0.20                      | 1.5                                    | 18  | 53 $\mu\text{g}/\text{m}^3$  |
| Conference Room                    | 50   | 3 m            | 0.20                      | 1.1                                    | 14  | 50 $\mu\text{g}/\text{m}^3$  |
| Game Arcade                        | 70   | 2.5 m          | 0.20                      | 1.1                                    | 19  | 37 $\mu\text{g}/\text{m}^3$  |
| Bowling Alley (Seating Area)       | 70   | 4 m            | 0.20                      | 1.5                                    | 21  | 45 $\mu\text{g}/\text{m}^3$  |
| Office                             | 7  | 2.5 m          | 0.20                      | 0.6                                    | 13  | 29 $\mu\text{g}/\text{m}^3$  |

**Table 1: Respirable suspended particulate levels associated with Standard 62-2001, Appendix I.**

annual arithmetic mean level of PM2.5 specified by the U.S. EPA National Ambient Air Quality Standard.<sup>12</sup> (These size particles are similar to those generated by secondhand smoke.) These levels also are well above levels that would be considered to pose an acceptable risk for lung cancer based on federal standards.<sup>13</sup> It is appropriate to use the annual exposure levels for comparisons because people exposed to secondhand smoke in workplaces such as offices, restaurants, and bars are consistently exposed.

While most attention on secondhand smoke has been devoted to lung cancer, secondhand smoke also increases the risk of heart disease. Some of these changes, in particular effects on blood platelets and vascular endothelial function (which affects the ability of the arteries in the heart to expand and increase blood flow when the heart needs more blood) occur within less than 30 minutes of secondhand smoke exposure in realistic environments.<sup>14–16</sup> These changes both increase the immediate risk of a heart attack and do long term damage to the heart and blood vessels.

In addition, short term exposure to RSP in secondhand smoke reduces heart rate variability<sup>17</sup> (small random fluctuations in heart rate around the basic rate). While the precise mechanisms have not been elucidated, a reduction in heart rate variability

increases the risk of a heart attack. One experiment involved having volunteers sit in the smoking lounge (RSP = 78  $\mu\text{g}/\text{m}^3$ ) for two hours at the Salt Lake City airport.<sup>17</sup> This exposure to secondhand smoke RSP was associated with a consistent and significant reduction in heart rate variability associated with about a 10% increase in risk of a heart attack. No one yet has determined how quickly this effect occurs or how low a concentration of secondhand smoke is required to trigger this effect, but it will occur at some of the levels of RSP present in spaces designed in accordance with the guidelines in Appendix I, even under the assumptions that bias the results to low levels of RSP.

### The Assumptions Used in 62o for Comfort

Since the guidelines in Appendix I nominally sought to provide comfort, it is necessary to have some measure of the level of tobacco smoke pollution that will create discomfort. Appendix I was based on a 21-year-old study<sup>11</sup> (prepared by an individual who did consulting work for the tobacco industry<sup>18,19</sup>) that sought to identify the level that would be acceptable to 80% of experimental subjects in a chamber study. There are several problems with using this study as the basis for engineering decisions in 2004. First, one-third of the experimental subjects were smokers, much higher than the 23% of the adult population than smokes today.<sup>20</sup>

The fact that there was a high proportion of smokers in the test group biases the levels of ventilation necessary for “acceptable” air quality down. Indeed, this paper<sup>11</sup> also reported that “None of the conditions in the present investigation [including the level of ventilation used in Appendix I] would satisfy even two-thirds of nonsmokers.”<sup>11</sup>

Appendix I did not reflect a much newer (2001) and more carefully done study,<sup>10</sup> which concludes that “Odor thresholds of sets obtained from the olfactory experiments showed that a median odor sensation was perceived at very low concentrations equivalent to an ETS-PM<sub>2.5</sub> concentration of approximately 0.6–1.4  $\mu\text{g}/\text{m}^3$ .”<sup>10</sup> At about 4.4  $\mu\text{g}/\text{m}^3$  only one-third of subjects found the quality of the air acceptable.<sup>10</sup> All the experimental subjects were healthy nonsmokers; including individuals with medical conditions such as asthma would have lowered further the level of acceptability.

Appendix I also included other assumptions that bias the recommended ventilation rates toward lower values. The assumed smoking prevalence (proportion of smokers) is low in several cases. Appendix I assumes that only 25% of occupants are smokers in a Bar Cocktail Lounge and Gambling Casino 1 (Table 1). Several of the other environments (Din-

| Smoking-Permitted Application      | Occupancy (People Per 100 m <sup>3</sup> ) | Ceiling Height | Proportion of Smokers, SM | Smoking Rate (Cigarettes/Smoker-h), SR | Total Ventilation Rate |            |
|------------------------------------|--|----------------|---------------------------|--|------------------------|------------|
|                                    |  |                |                           |  | L/s-Person             | cfm/person |
| Smoking Lounge                     | 70   | 3 m            | 1.000                     | 3.0                                    | 9,500                  | 20,127     |
| Heavy Smoking Lounge               | 70   | 3 m            | 1.000                     | 6.0                                    | 19,000                 | 40,253     |
| Bar, Cocktail Lounge               | 100  | 3 m            | 0.300                     | 3.0                                    | 2,850                  | 6,038      |
| Heavy Smoking Bar, Cocktail Lounge | 100  | 3 m            | 0.500                     | 4.0                                    | 6,333                  | 13,418     |
| Dining Room 1                      | 70   | 3 m            | 0.255                     | 2.5                                    | 2,019                  | 4,277      |
| Dining Room 2                      | 70   | 3 m            | 0.255                     | 2.0                                    | 1,615                  | 3,422      |
| Gambling Casino 1                  | 120  | 4 m            | 0.300                     | 4.0                                    | 3,800                  | 8,051      |
| Gambling Casino 2                  | 120  | 4 m            | 0.300                     | 3.0                                    | 2,850                  | 6,038      |
| Conference Room                    | 50   | 3 m            | 0.255                     | 2.0                                    | 1,615                  | 3,422      |
| Game Arcade                        | 70   | 2.5 m          | 0.255                     | 2.0                                    | 1,615                  | 3,422      |
| Bowling Alley (Seating Area)       | 70   | 4 m            | 0.255                     | 2.0                                    | 1,615                  | 3,422      |
| Office                             | 7  | 2.5 m          | 0.255                     | 2.0                                    | 1,615                  | 3,422      |

**Table 2: Additional ventilation rates required to obtain a secondhand smoke respirable suspended particulate level ( $C_{RSP}$ ) of 0.6  $\mu\text{g}/\text{m}^3$  using conservative engineering assumptions.**

ing Room 1, Gambling Casino 2, Conference Room, Game Arcade, Bowling Alley, and Office) assume that only 20% of people smoke, less than the prevalence of smoking in the adult population (23%).<sup>20</sup>

The assumed smoking rates are low. For example, they assume only one cigarette smoked per hour per smokers in a bar or cocktail lounge, 1.5 cigarettes per hour in casinos. These are environments where smokers would be expected to smoke more than average, yet no objective data are presented to support this assumption. The assumed level of 0.6 cigarettes/hour in workplaces also is low.

While designers relying on Appendix I and the anticipated ETS design guide could and should adjust the percentage of smokers and cigarette consumption rate to the correct values for the space that they are designing, there is a strong likelihood that designers — who are not tobacco-use epidemiologists — will simply assume that the numbers there are typical and follow the examples given there.

In addition, acceptable ventilation levels in smoking lounges and heavy smoking bars are based on “adapted” people only, who have acclimatized to the pollution due to the secondhand smoke, which hides the higher ventilation quantities that would

be required in these places even if one accepts the other assumptions in Appendix I.

None of the calculations in Appendix I allow for particularly sensitive people, such as people with asthma, allergies, lung or heart disease, or children, even though such people are likely to be in rooms with secondhand smoke designed according to the recommendations in Appendix I.

All these assumptions bias the results to lower the ventilation rates (and higher levels of secondhand smoke pollution) that will be deemed “acceptable.” In addition, the results are strongly dependent on the assumptions that are made. For example, using an average smoking prevalence of 23%<sup>20</sup> (rather than the low 20% assumed in Appendix I) and a smoking rate of two cigarettes/hour per smoker<sup>6,11</sup> (rather than the very low rate of 0.6 cigarettes/hour assumed in Appendix I) raises the RSP levels for Dining Room 1 and Office from 29  $\mu\text{g}/\text{m}^3$  to 112  $\mu\text{g}/\text{m}^3$ .

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Thus, none of the pollution levels achieved meet comfort, much less health, design objectives. This procedure is not consistent with good engineering design principles; normally any assumed values are selected to represent “high end” inputs to ensure that the system will respond effectively in real world conditions and be suitable for sensitive people. Even as a minimum ventilation recommendation, it is not good practice to bias all of the assumptions toward the lower end.

### **An Alternative Approach**

Appendix I did not purport to develop its recommendations based on health considerations, but rather “comfort (odor control).”<sup>21</sup> If one accepts this design goal of “comfort” rather than health, a more direct way to approach specification of ventilation requirements would be to make conservative assumptions about smoking levels and rates, then compute the ventilation levels necessary to achieve the design objective level of RSP.

For example, suppose we set a design objective at the odor threshold of 0.6  $\mu\text{g}/\text{m}^3$  based on the newest available information on sensory perception of secondhand smoke.<sup>10</sup> Note that, in terms of odor, even this level only represents the lower end of the median odor threshold, meaning that half the population would detect odors below this level. (Even this design objective does not reach *de minimus* levels of cancer,<sup>13</sup> but it comes much closer than Appendix I.) We assume 25.5% smoking prevalence, the 75th percentile of smoking prevalence among the 50 states.<sup>20</sup> (The highest prevalence is 30.9%, in Kentucky.<sup>20</sup>) The smoking rates are also adjusted upward to more reasonable estimates.

The resulting ventilation levels (*Table 2*) are much higher than in Appendix I (*Table 1*), ranging from 3,400 to 40,200 cfm/person (1615 to 19 000 L/s per person). These levels are so high that it might be argued that they put ASHRAE in the uncomfortable position of recommending unfeasible solutions to the problem of secondhand smoke. These values, however, follow from conservative engi-

neering assumptions and procedures combined with mass balance.

### **Conclusion**

Given the high levels of ventilation required to meet even a “comfort” design goal based on modern evidence, combined with the demand for “guidance” encouraged by the tobacco industry and its allies,<sup>1</sup> what is ASHRAE to do?

There are two broad ASHRAE policies that are relevant: On June 9, 2002, “The Board of Directors affirm[ed] the implied policy that ASHRAE standards shall consider health impacts where appropriate” (100-117-006 & 520-166-013) and the ASHRAE Code of Ethics states in part: “Our efforts shall be directed at all times to the enhancement of the public health, safety and welfare.”<sup>22</sup> As noted, spaces designed in accordance with the guidelines in Standard 62-2001 Appendix I can lead to levels of RSP that are not consistent with “public health, safety, and welfare.”

These policies would seem at odds with recommendations in Standard 62-2001 Appendix I, which are based on unrealistic assumptions, which bias recommendations to lower ventilation rates. In many ways, Appendix I was similar to a civil engineering society developing recommendations for bridge construction based on liberal assumptions about strength of building materials, while assuming that the number of vehicles on the bridge was low. While such guidance might serve economic needs of contractors who wish to cut corners, it could be viewed as violating basic engineering principles and ethics.

Since ASHRAE seems unwilling to develop a standard based on *de minimus* risk,<sup>1,13</sup> perhaps it would be best to simply include a statement in Standard 62, as the Board Policy Committee did in its report to the ASHRAE Board of Directors on June 25, 2002, that “There is evidence that acceptable air quality cannot be achieved where smoking is permitted;”<sup>5</sup> delete Section 6.1.3.5, the statement in the standard about the need for additional ventilation or air cleaning when smoking is permitted, drop the forthcoming ETS design guide, and leave it at that.

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