INDOOR AIR POLLUTION AND VENTILATION STANDARDS

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ABSTRACT

In this brief report we make some suggestions to the ASHRAE standards committee on some items that we believe should be considered in setting ventilation standards.

After revewing the past and recent history of attempts to set air-pollution standards for buildings and indoor spaces, we consider alternative future standards to achieve not only adequate comfort, as was the intention of past standards, but health protection, an area almost entirely neglected previously. We find that the ventilation requirements to achieve acceptable health protection would lead to unacceptable energy costs in many situations. We therefore recommend standards for heat-exchanger systems, for filters that can control particulates, hydrocarbons, and radon gas, and for such important details as flow direction and system maintenance. Finally, we recommend the setting of standards that would encourage what we terms "pollustat" systems, analogous to thermostat systems governing temperature levels, by which four surrogate pollutant levels would be kept below suggested threshold levels in all conditions of building use and occupancy.

CONTENTS

INTRODUCTION

IMPORTANCE OF THE STANDARD

THE PURPOSE OF AIR-POLLUTION REDUCTION

--to improve comfort

--to improve health

acute risk

chronic risk--cancer, lung problems

POSSIBLE VENTILATION STANDARD OPTIONS

the measure of odor

the fixed standard option

variable standard--various alternatives

standards for carcinogens and chronic effects

Filtering and precipitation

Flow direction

Ventilation control by concentration measurement

Introduction

In the last century people have become aware of the importance of reducing air-pollution. Although Edward I of England ordered that the makers of kilns of Southwork stop using coal (Plantaganet, 1307) and the diarist John Evelyn wrote a pamphlet about air-pollution (Evelyn, 1661), it was only in the 20th century that active steps have been taken to curb air pollution in the major industrial cities.

In the period 1400-1700, people thought diseases were caused by crowds--and refused to get together in large rooms. When they did get together in churches they used incense to mask other odors. The idea of indoor air-pollution did not, of itself, seem important.

There were, as recently as 1952, high concentrations of SO_2 and particulates in an air-pollution incident in London. On subsequent occasions (January 1956, for example) residents of London, particularly asthmatics and the aged, were encouraged to stay indoors, where the air was assumed to be, and probably was often purer.

This perception that indoor air is likely to be purer, in general than outdoor air remained until the middle of the last decade. One of the first air pollutants to be discussed by public-health experts was radon gas (and its daughter products) (Moeller, 1976). Since then cigarette smoke, formaldehyde, and organic compounds generally, have been brought forward as potential public-health hazards.

The simple twin facts that urban people spend more time indoors than out-of-doors, and that in the late 20th century the indoor sources of pollution are often more numerous and in total more important than outdoor sources, have spurred intense study. Three recent international conferences on indoor air-pollution, and should spur re-examination of the purpose as well as the detail of ASHRAE's ventilation standards.

Importance of the Standard

In the 19th century standards were vastly different from today. There were no mechanical fans, and air circulation was accomplished by designing proper buildings to ensure natural circulation.

Before 1973, it was easy to specify that air should circulate freely in large quantities. However, the rise in cost of fuel in 1973, followed by the larger rise in 1979, makes a re-examination of this concept mandatory. In domestic homes it has been estimated that half the heat escapes through walls and windows by thermal conduction and half goes to heat up the air which enters by infiltration. Recent fuel-saving measures do not greatly alter this ratio: as much has been spent on improved insulation in houses as has been spent on plugging leaks.

In commercial office and industrial buildings the energy used to heat incoming air is often five times the amounted needed to supply losses through windows and walls.

Over the last ten years there have been many studies of saving fuel through more efficient insulation and ventilation reduction. Those who have stridently advocated such measures, whether to avoid the environmental degradation of coal burning or the unknown dangers of nuclear power, have often done so with heedless disregard for the risks. No pamphlet from DOE's department of energy conservation discusses these risks. It is therefore important that professional organizations such as ASHRAE do so loudly, clearly, and with erudition.

The Purpose of Air-Pollution Reduction

The most obvious sign of industrial air-pollution is visual--"this horrid smoke, which obscures our churches and makes our palaces look old," (Evelyn, 1661). The effects on public health are less obvious, much harder to define and prove, but in the long run more important. Thus the U.S. Senate declared in 1970 that "the health of the people is more important than the question of whether the early achievement of ambient air-quality standards is technically feasible" (U.S. Senate, 1970). Even now, industrial smoke is still often controlled by visual methods.

Likewise the first public concern of indoor air-pollution has not been that of public-health per se, but of "comfort." It is easy to ask a group of people if they feel comfortable at certain temperature, luminosity, and ventilation levels; it is sophisticated to quantify the health risks of air-pollution, for it presupposes a method of defining and measuring these risks. Nonetheless, we feel that the time has come to address these issues quantatively and to state categorically that the purpose of regulations is to reduce risk, and that the levels must be set so that the risks are reasonably low.

As we identify the risks which we are discussing, we can distinguish two distinct general types: acute risks and chronic risks. High carbon-monoxide levels pose an acute risk. A person exposed to high levels of carbon-monoxide can be killed in a short time--an hour or so. Some pollutants, while not posing an acute risk of death, pose an acute risk of illness.

Chronic health effects are less often noticed but may be more serious. It has been noted, for example, that children brought up in homes where one parent smokes cigarettes have a reduced rate of growth in lung function compared with those who live in less-polluted homes (Berkey, 1985). Although reduced lung function is not, in itself, an ailment, the reduction may well be irreversible and may lead to a host of problems later in life.

A more well-known chronic effect is cancer. Indoor air pollution can contribute to cancer incidence by at least three known pollutants: cigarette smoke; formaldehyde and radon gas. Risk analyses can be performed for each of these pollutants and the effects on public-health estimated. Once this has been done, it is possible to compare the effects of different indoor-pollutant concentration levels, and hence of different ventilation standards.

It is our considered opinion that the time has come for the ASHRAE ventilation standard committee, SPC62-1981R would be shirking its duty to the public if it failed to address the carcinogenic potential of indoor air-pollution.

Possible Ventilation-Standard Options

Historically, ventilation standards have been set at either fixed levels, or levels which vary with room type and occupancy. It is, for example, common to discuss a standard for ventilation of, perhaps, 20 cubic feet per minute per occupant, without regard to air-pollution sources. This is logical if, and only if, the dominant sources of air-pollution are people themselves, or are directly proportional to occupancy. This might be true for odors and for CO_2; however people do not emit radon, formaldehyde or benzopyrene. Therefore we we maintain that it is logical and, as we will discuss below, necessary to consider ventilation requirements that depend upon sources as well as occupancy. Ideally, of course, the requirements would depend upon measured concentrations, But there are many pollutants in indoor air and they cannot all be measured. Therefore, we revert below to a discussion of a choice of surrogate concentration measure.

<u>The Measure of Odor</u>

As noted above, the standard method for choosing a ventilation standard has been based on the measurements of odor. The classic measurements of Yaglow (1936) dominated the field for many years. He found that levels of air changes varying from 5 cfm (2.4 l/sec) to 25 cfm (11.8 l/sec) per person were needed to reduce odor.

The best studies in the modern era are probably those of Cain and Leaderer (1982) at Yale University. They found that 70-80% of persons failed to discern any odor with ventilation rates of about 7.5 cfm (3.8 l/sec) per occupant for rooms with moderate humidity and no cigarette smoking regardless of crowding. However when smokers are present, five times the ventilation rate (37.5 cfm or 19 l/sec) is needed to reduced discomfort.

The requirement that 70%-80% of persons notice no discomfort seems to us to be marginal. Over the years the public has become more and more cognizant of the "sensitive individual" and attentive to his/her needs. Thus the FDA in its regulations often demands that less than 1% of persons be adversely affected. The EPA has taken a strong position also. We feel that ASHRAE should consider moving with the times. It should recognize that sensitive individuals exist and formulate more stringent standards to protect these individuals.

The Fixed-Standard Option

There are those who propose that ventilation standards be set independent of sources of pollution, even when these sources are known and controllable, but are in fact not controlled. (Cigarette smoking is an obvious one, but not the only one.) In our view this would be an acceptable option if, and only if, the ventilation standard is set high enough--at least 40 cfm per person. The fuel-conservation measures alluded to in section 2 would prevent serious consideration of this as a viable alternative.

The Variable Standard--Various Alternatives

The problem and expense of maintaining a high ventilation rate in a era of high fuel costs leads to a suggestion that ventilation vary, not merely with the occupancy by people, but also with the occupancy of any pollution sources they bring with them. It seem important to us that this variable standard concept not, in itself, single out a particular pollutant. Although cigarette smoke seems now to be the most frequent pollutant, others may at a later time be seen to be more important. Nonetheless a dual standard seems a good start. This could be based on the measurements of Cain and Leaderer.

8 cfm (3.8 l/sec) per nonsmoker

40 cfm (19 l/sec) per smoker

It might be sensible to add a fixed amount perhaps of 2 cfm per 100 square foot of floor area, to allow for carpets glues and so forth (needed only when people are present to inhale the pollutant!) This additional amount per floor area should be increased for new apartments (when a floor has just been glued or when new fabrics have been installed).

Of course this level is adjusted so that 20% of non-smokers would not notice the cigarette odor. It is therefore a minimum level and should be increased to take into account sensitive individuals.

There is one--and only one--circumstance in which we believe that a ventilation rate of 35 cfm per smoker could be reduced. This is when all persons present in the room are smokers and are presumably voluntarily accepting the air-pollution (we leave aside the thorny question of involuntary addiction here) or any non-smokers who have voluntarily and explicitly accepted the pollution. We would add that the smokers present would be well advised, for legal reasons, to get such a waiver in writing.

Standards for Carcinogens and Chronic Effects

The minimal standards suggested above are based entirely upon odor and comfort requirements with no consideration for carcinogens. We suggest that the levels for indoor carcinogens be set in a similar way to that in which EPA and FDA set standards for air and water. These standards follow general principles as outlined in, for example, the regulations of the State Board of Health of the Commonwealth of Massachusetts in 1869 where it is stated: "We believe that all citizens have an inherent right to the enjoyment of pure and uncontaminated air and water, and soil; that this right should be regarded as belonging to the whole community; and that no one should be allowed to trespass upon it by his carelessness or his avarice or even by his ignorance. This right is in a great measure recognized by the State, as appears by the General Statutes."

The EPA and FDA have discussed an acceptable risk level of 1 in 10^6 per lifetime (1.4 in 10^8 per year) although levels up to 1 in 10^6 per year are discussed by others (Pochin, 1975; Crouch and Wilson, 1982). These levels are to be calculated "conservatively", a term which usually includes straight-line extrapolation from observed levels at high exposures, and a conservative animal-to-man comparison. Zeise, Crouch and Wilson (1983) have noted that in spite of the EPA's claims that some specific chemicals which are 100 times more stringent, 1 in 10^6 per year is barely met for many sources of drinking water. We argue that a level of cigarette smoke leading to a risk of 1 in 10^6 per year might be acceptable but any more would need attention. The risk is not acute, and therefore the attention can be such as to keep the average low over a period as long as a year.

Repace and Lowrey (1980, 1982) have discussed this problem and their calculations have been presented to this committee. They find that 2700 l/sec per person is needed to reduce the level to a 1.3 x 10^{-7} annual risk. Even for a 10^{-6} annual risk this is 330 l/sec per person--about 20 times the level suggested above. We note that this is roughly consistent with an observation by Wilson (1977) that the risk suffered by a non-smoker living with smokers is 10^{-5} per year, and OSHA standards on carcinogenic risk must take cognizance of this fact.

Repace has been criticized as being somewhat pessimistic in his calculations--perhaps even by a factor of 10. Moreover we observe here the averaging concept in any chronic effect. If the suggested level of 40 cfm per smoker is strictly maintained to guard against acute effects, there will be many occasions when smokers are not present; few non-smokers live all their lives among smokers. For these reasons we consider that a level of 40 cfm per smoker is just acceptable for general public policy, subject to the comments below.

The above allows for the carcinogenic properties of cigarette smoke and demands increased ventilation when it is present. But there must also be a procedure for appropriate ventilation for reducing radon and formaldehyde to acceptable levels. This is not proportional to occupancy, but depends on the room and on its floor area. Since sources are so variable, there seems to be no alternative to measuring these levels or installing large ventilation systems in public buildings in order to ensure safety.

Filtering and Precipation

In the days before 1973 when indoor air was not often recycled, and outside air was the normal source for air changes, the question of whether the air was adequately cleaned or filtered arose less often. Now, however, that the fuel requirements for heating the air seem excessively expensive and it is becoming common to recirculate indoor air.

We would, from the standpoint of air quality, prefer the use of heat exchangers, whereby outside air is circulated and the ejected air warms up the incoming stream of nominally pure air. We believe ASHRAE should recommend this as a standard.

However, we recognize that this is not always possible and that air is often recirculated through filters. We call upon ASHRAE to recognize the fact, noted over 20 years ago, that although some filters take out particulates and and carcinogenic hydrocarbons, most remove neither the "musty" odor nor the carcinogens formaldehyde and benzopyrene. An activated charcoal trap following the filter seems necessary.

We also call attention to the fact, widely neglected even though it is obvious, that fibers and traps must be maintained, and that in many public buildings the maintenance is neglected. ASHRAE should call attention to the necessity of there being adequate maintenance so that the standard is met at all times and not merely when the installation is new.

Although we regard filters as very important, we do call attention to the fact that in some circumstances the circulation of <u>outside</u> air can be reduced by the use of electrostatic precipitators and negative-ion generators, and the diffusion of ions by <u>local</u> circulation fans. This has been shown (Moeller, 1984) to give excellent control of radon and its daughters (a reduction by a factor of 10 or 20) and <u>may</u> serve to reduce cigarette smoke also. However, we suggest that ASHRAE not allow this to be a substitute for a 40 cfm-per-smoker standard but simply a permissible way of achieving the standard on a local basis.

<u>Flow Direction</u>

An important feature of indoor-air-pollution control is the direction of air flow. This is obvious--but often neglected. A kitchen stove will have an extraction fan to remove odors, and if a gas stove, nitrogen oxides. Yet all too often air flow in ventilated spaces flows, e.g., from a restaurant kitchen to the customers. There are many restaurants which purportedly attend to the needs of their customers by establishing separate smoking and non-smoking areas, yet place the non-smoking area near the <u>air-extraction fan</u>, not near the input of clean air.

We feel that the ASHRAE committee on ventilation would do well both to mention, and condemn, the scandalous occasions when extraction fans merely take air to another inhabited space, and the more common occasions when the air flow is in the wrong direction.

<u>Ventilation Control By Concentration Measurement</u>

We have mentioned that numerous buildings are known to us in which the maintenance of air-circulation devices has been so faulty that the air has become stagnant. This will obviously be worse if any attempt is made to manually control circulation fans in accordance with room occupancy or smoking habits.

This has led to the suggestion made by several people that circulation be automatically controlled to reduce some measure of air-pollution to an adequately low level, analogous to the use of thermostats to control temperature levels.

This seems to be such a good idea, that any standards that are now set must recognize this as a possible desirable future control system for public buildings. The ventilation standards can then be changed to satisfy air-quality standards that can then be set at a definite concentration level of certain surrogate pollutants.

This topic clearly needs extensive discussion. We suggest that the following pollutants be used as surrogates, and controlled to the proposed concentration levels. We suggest that the concentrations be set simultaneously at or below the following levels:

carbon dioxide (CO_2)	$<$ 1000 ppm
fine particulates	$<$ 5 micrograms/m^3
radon and daughter products	$<$ 10 pc/l
total hydrocarbons	$<$ 11 ppm

CO_2 will be proportional to occupancy; fine particulates to cigarette smoke; radon and total 'hydrocarbons' are a surrogate for those of the hydrocarbons that are carcinogenic. If one or another of these are not measured, and excluded, a fixed amount of ventilation should be added to compensate. Instruments to measure these pollutants are, however, readily available, and, in analogy to thermostats, a "pollustat" system of maintaining indoor-air quality is now feasible. ASHRAE should set standards to permit the high-volume low-cost production of such systems and to put this country in the leadership position in this area, as it was earlier with thermostatic control.

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