THE IMPLEMENTATION AND EFFECTIVENESS OF AIR INFILTRATION STANDARDS IN BUILDINGS

5th AIC Conference, October 1-4 1984, Reno, Nevada, USA

PAPER 8

AIR QUALITY ISSUES IN VENTILATION STANDARDS

A.V. Nero and D.T. Grimsrud

Building Ventilation and Indoor Air Quality Program
Applied Science Division
Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Building Systems Division, and by the Director, Office of Energy Research, Office of Health and Environmental Research, Human Health and Assessments Division, U.S. Department of Energy under Contract No. DE-Ac03-76SF00098.

SYNOPSIS

Ventilation standards in buildings are receiving increased attention because of energy conservation and indoor air quality. An important example of this is the current ASHRAE Standard 62-1981, "Ventilation for Acceptable Indoor Air Quality." This standard contains two distinct procedures that can be used to set ventilation rates. The first is a prescriptive specification that mandates ventilation rates for particular building types. The second is a performance specification that uses target concentrations of indoor contaminants as the basis for deciding the adequacy of ventilation rates. This paper comments on the latter procedure. Several issues are discussed: (1) the lack of a consistent basis for choosing concentration limits for indoor pollutants (2) the potential for adverse air quality if the performance specification is adopted in a building, and (3) the practical difficulties in implementing the second option. Several suggestions for improving the Standard are made.

1. INTRODUCTION

There are many questions and issues that must be considered when discussing ventilation standards. These range from the philosophical issue of regulating air quality in individuals' homes to the practical problem of measuring ventilation rates. This paper examines ventilation standards from the perspective of present knowledge of and current research efforts on indoor air quality. To focus on particular issues it examines a ventilation standard that is currently under review, Standard 62-1981 "Ventilation for Acceptable Air Quality", of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) [1]. This Standard is the first North American ventilation standard that has attempted to address the indoor air quality problem in any general way. While we do not agree with portions of 62-1981, we do recognize the importance of its attempt to treat indoor air quality explicitly in a ventilation standard.

Ventilation or indoor air quality standards for buildings can take many forms. The most straightforward is a standard that directly specifies required ventilation rates for particular building spaces, based on assumptions about occupant density and pollutant sources within the space. A second type, having the form more of an indoor air quality standard than a ventilation standard, specifies maximum concentrations of particular pollutants in a space, but does not mandate the control processes to be used to maintain concentrations below these targets. It may include also a baseline ventilation rate. This form allows innovation in indoor air quality control techniques. A third type of standard focuses directly on sources. Its form specifies the maximum emission rates of pollutant sources within the space. It assumes a nominal ventilation rate and standard environmental conditions in the space to assure that pollutant concentrations remain below some target value.

The present form of Standard 62 provides two options for assuring acceptable indoor air quality. The first, called the "Ventilation Rate Procedure", specifies minimum ventilation rates appropriate to a variety of building environments. The second type, called the "Indoor Air Quality Procedure", does not specify ventilation rates, but assures the acceptability of the indoor air directly based on measurements demonstrating that the air meets the limits specified for acceptable outdoor air, as well as additional limits associated with specific indoor-generated pollutants.

2. THE FORM OF ASHRAE STANDARD 62-1981

A useful summary of Standard 62-1981 and a description of the thinking that was used to cast it in its current form is presented by McNall[2]. The Ventilation Rate Procedure, referred to as the "Prescriptive Option" by McNall, has the following requirements:

a) The supply air must meet National Ambient Air Quality Standards [3]; if outdoor air, the source of supply air, does not meet these standards, it must be treated using a suitable air cleaner.

b) The air must be delivered at rates listed in the Standard's Table III which covers a multitude of types of interior occupied spaces.

McNall further notes that when the interior contamination is caused by human activity (cooking, smoking, exercise, etc.), the ventilation rates are specified per person, not per unit of floor area. A minimum of 2.5 L/s per person is necessary to dilute carbon dioxide produced by metabolism. On the other hand, when the interior contamination is produced by the building or its furnishings, ventilation per unit floor area, not per person, is used.

A recirculation option, to save energy, is allowed if air cleaning equipment is certified by the designer to operate at a specified efficiency on the important contaminants. The air-volume capacity of the space (theaters, office buildings, etc.) which can dilute contaminants is recognized for intermittent occupancy. This allows delayed start of ventilation for additional energy savings for human-generated pollutants but requires a lead time before occupancy in the case of space-generated contaminants.

By contrast, McNall refers to the Indoor Air Quality Option as the "Performance Option". In this option:

a) The designer would meet the requirements of the Standard by certifying that the system provides an interior environment that meets or exceeds the air quality limits as specified in Tables I, II, and IV of the Standard. Table I is a summary of the National Ambient Air Quality Standards[3], while Table II includes additional ambient air guidelines that have been adopted by various states, provinces, and foreign countries. Table IV is a list of guidelines of pollutants of strictly indoor origin.

b) In addition, the air quality must be found acceptable by 80% or more of a panel of 20 untrained observers on the basis of odors or other subjective sensations.

Substantial differences of opinion exist on the suitability of the Indoor Air Quality Option as presently constituted. The option was developed for 62-1981 to allow innovative ventilation control strategies and because of the perceived importance of indoor air pollutants that were not necessarily those associated with earlier formulations of minimum ventilation rates. Difficulties with this formulation range from concerns about the inadequate knowledge of health risks associated with some of these pollutants to the practical difficulties of applying this form of the Standard.

This paper will discuss three major difficulties with the present form of the indoor air quality or performance procedure and make recommendations for revisions that serve to correct these problems.

3. DIFFICULTIES WITH THE "INDOOR AIR QUALITY PROCEDURE".

The most general issues arising from the current form of Standard 62, primarily in connection with the second option, are (1) the lack of a consistent basis for choosing concentration limits that apply indoors, (2) the potential that the second option, if used indiscriminately, may lead to poorer air quality than the ventilation option, and (3) the practical difficulty of using the second option, especially when interpreted to include a large number of measurements or even an odor panel.

The value of using a consistent basis for setting limits for a wide variety of pollutants is clear. In the absence of such consistency trade-offs can result that lead to the detriment of occupants or owners, rather than the converse. For example, by avoiding an exposure that is given too much weight (i.e., for which the specified limit is lower than it ought to be), one may cause some other exposure that is more harmful but that, relatively speaking, is not given enough weight (has too high a limit). An example is control of the concentration of pollutant A by removing its source. The guidelines for both pollutants A and B may now be met with reduced ventilation. However, if the guideline associated with pollutant B is too high, removing the source of pollutant A coupled with the ventilation reduction, will have caused an excess exposure to pollutant B. One simple criterion for consistency, then, is that numerical limits for the various pollutants correspond to equal health risks. Even this simple criterion is not met in the present formulation. Nor is it clear that this is the proper criterion in any case: the acceptability of specific risks might be weighted by the value of (or by the difficulty of avoiding) the exposure(s) in question. The general difficulty with the present Standard is that it is not based on a consistent philosophical basis and related criteria for development of specific standards. The concentration limits were not developed in the context of even a tentative set of criteria. It is certain that the present numerical limits are not consistent, derived as they are from several contexts, each of which had different criteria. An example of the kind of consideration that is necessary is given below, in the brief discussion of estimated health risk as one criterion for development of indoor standards.

4. ESTIMATED HEALTH RISK AS ONE CRITERION FOR INDOOR AIR QUALITY STANDARDS.

Several aspects of the use of risk as a criterion have already been mentioned, especially the difficulty of using even this criterion in a consistent way. Another perspective on the use of risk as a criterion is indicated by the following nominal (and very approximate) levels of risk associated with various situations. In each case, we cite approximate lifetime risks of mortality associated with the indicated situations and exposures. Risk of death is, of course, not the only risk criterion that could be used.

- Personal criteria for risk aversion tend to be in the range of 10^{-1} to 10^{-2} lifetime risk for risks under the control of the individual (as opposed to those imposed externally and discussed below). The larger number (10% or more) is associated with cigarette smoking and the smaller (about 1%) with automobile accidents. One percent lifetime risk appears, approximately, to be the level at which people begin to worry about chronic risk over which they have some control (and even at this level many people will not do anything about the corresponding exposure).

- Occupational criteria for exposures (over which individual workers have little control) tend to lie in the range of 10^{-2} to 10^{-3} for exposures that are specifically related to the type of work (e.g., exposures to a substance that arises from an industrial process). These must be distinguished from exposures that occur merely because a worker is in an indoor space (e.g., an office discussed below).

- Finally, environmental criteria for risks that arise externally to the people exposed, over which they have no control, and which are not directly related to a benefit to them, are typically less than 10^{-3} and often in the range of 10^{-5} (a number that the Environmental Protection Agency appears to use commonly as a criterion for such risks [4]).

Environmental risks are to be distinguished from the risks that individuals suffer in connection with situations of direct benefit to themselves, specifically in their own home and places of work. The current level of risk in homes appears to be in the range of 10^{-2} to 10^{-3}. (Some homes are as low as 10^{-4}, while a significant number exceed 10^{-2})[5]. This is the range arising from radon exposures alone, with other exposures adding to this. And, although it is possible in principle to reduce typical risks to lower values, it is probably not practical - again thinking even of radon alone - to reduce the level of risk much below 10^{-3} as a common matter.

A second difficulty with the indoor air quality option is the potential that, by meeting limits for specified pollutants, concentrations of unspecified (and unmeasured) pollutants might rise to levels that would be unacceptable if they were identified. As an example, suppose that in a residence, instead of providing the 0.3 to 0.6 ach that corresponds to the ventilation rate option, the designer reduced the ventilation rate substantially and provided assurance that CO_2, radon, and formaldehyde levels were not excessive. If that residence had normal sources of other pollutants, then, in first order, the lower than normal ventilation rates would result in higher than normal concentrations of these pollutants. It would appear that this option ought to have a baseline ventilation rate, which depends on the size of the space rather than the occupancy, to provide for the possibility of unknown or uncharacterized indoor sources. (This same difficulty arises in connection with the specification of ventilation rates on an occupancy basis when the occupancy is low. Thus, in this sense, the ventilation rate option, except for specialized buildings, does not take account of pollutant sources that exist independent of the occupants. This would seem to suggest the provision of a lower limit for the ventilation rate per unit volume, even in the ventilation rate option. However, the need is more acute in the second option, where the entire orientation of the approach is to assure adequate air quality directly, permitting a reduction of ventilation rates.)

A third broad difficulty is that of implementation, specifically how a ventilation engineer is to ascertain what measurements ought to be performed under the Standard and in what way they are to be carried out. At the extreme, i.e., the interpretation that measurements are made of all the pollutants found in the three tables of the Standard (a literal reading of the Standard), the difficulty is clearly prohibitive. But even with a softer reading, how can the engineer know which pollutants to measure and how they are to be measured? The Standard provides no guidance on estimating pollutant levels or on measurement techniques and protocols, nor does it indicate where the engineer might go for help. Thus from a practical point of view, the present formulation merely raises the issue of indoor air quality in a way that the designer and the code writer cannot handle effectively.

The criterion for <u>commercial</u> buildings, including office buildings, ought to take account of this general picture. As a possible extrapolation from the situation in employees' homes, where the risk will probably remain in the vicinty of 10^{-3}, one might use this as a criterion applicable to offices and other workplaces. If a stricter criterion were adopted, this would mean pushing employers or building owners beyond the usual concept that "excessive" risk should be avoided in connection with work situations. What is acceptable (or unavoidable) in homes might be a reasonable criterion for what is acceptable in the workplace.

This discussion only suggests one of the perspectives that has to be developed in trying to formulate the risk aspect of an overall basis for choosing indoor air quality standards. Closely related is the development of a consistent basis for actually estimating the risks associated with the various pollutants appearing indoors. This, too, is a complex and difficult question, both from the point of view of the dose-response data base and from the difficulty of deciding what population groups ought to be considered in evaluating risks.

5. PROPOSED CHANGES TO ASHRAE STANDARD 62-1981.

On the whole, considerations such as those given above suggest that an approach to revising 62-1981 ought to 1) retain the ventilation rate procedure much as it is and 2) modify the second procedure to correct the difficulties with its present form, preferably while still providing effective guidance on the question of indoor air quality. An approach consistent with these objectives is given below. Undoubtedly it is not the only possibility, but most other suggestions have either neglected indoor air quality, specifically by dropping the second option entirely, or have retained the present difficulties, by retaining the basic formulation of the second option and modifying it only in detail (rather than concept). The formulation given below is an intermediate possibility that does not include indoor air quality as a second option but, for the present, adds such considerations as a specific form of guidance as part of the more traditional procedure. It asks the ventilation engineer for a statement of design assumptions that would continue to be associated with the building after its construction and occupancy. The assumptions would have several practical implications for the designer of the building, including providing a way of handling the question of indoor air pollutants.

The proposal is:

1. RETAIN the bulk of the 62-1981 language, particularly the section on the ventilation rate procedure, with modest changes - e.g., re-examining specific ventilation rates on the basis of new information, and perhaps specifying a minimum ventilation rate per unit volume, thereby coping with low occupancy situations and the presence of unidentified sources.

2. REPLACE the second procedure with a continuation of the ventilation rate procedure that:

   a. notes that innovative ventilation techniques may be employed (e.g., controlling on CO_2), provided that:

   - makeup air continues to meet the usual conditions;

   - a minimum ventilation rate is provided to avoid difficulties with unspecificed pollutants that are building- rather than occupant- related;

   - explicit consideration is given to the pollutant classes specified as part of the standard (as indicated below).

   b. specifies that certain pollutants that do not originate with occupants can be of concern. This section would be for the information of the user and would specify pollutant classes that are reasonably well defined (e.g., radon and its decay products, formaldehyde, combustion emissions), indicating situations when they could be a problem, as judged by provisional indoor air quality guidelines. The following section would indicate explicitly an approach for the designer to handle these possibilities, as they occur for each of the pollutant classes specified.

3. ADD specifications for a one-page statement of source assumptions used in the design. This would include assumptions related to the occupants, as well as aspects of the building structure that are related to indoor pollutants. As elements in this statement, examples are:

   a. The number of occupants assumed in area __________ is __________.

   b. The percentage of smokers assumed in area __________ is __________.

   c. The limit on the area of material emitting _____gm of formaldehyde per hour to meet the tentative IAQ guideline of (cite) is _____ m^2 per m^3 of volume.

   d. The limit on radon entry rate needed to meet the (e.g., NCRP limit of 8 pCi/l) is _______ pCi l^{-1} h^{-1}.

There may be some version of the source statement for combustion emissions. However, a statement of this kind would probably only be appropriate for building projects of a certain scale, i.e., largely to commercial buildings, which tend not to have combustion sources in the occupied spaces. On the other hand, most residences are now built as large-scale projects - called developments, apartments, etc.

Eventually, other classes than those mentioned might be added. For example, a specification might be added for organics as a class, with the practical implication that some standard must be developed. However, like the formaldehyde formulation given, this might be source-oriented, albeit different in concept. For example, an initial material-oriented measure might be odor as perceived in a test chamber. (This might be a more practical utilization of the odor-panel approach than that presently specified in the indoor air quality procedure.) Hence, the ASHRAE language might ultimately simply state the assumption that materials employed in the interior meet a materials standard, which might be developed separately.

Note that this source statement would tend to solve another important difficulty with the ventilation rate procedure. That is, although the designer may size systems for a certain number of occupants with a certain proportion of smokers, this information does not necessarily affect how the building is used or occupied. In this suggested approach, the builder and designer can choose design assumptions on ocupancy and smoking, complete the design, then include the assumptions in the source statement -- which would continue to be available.

ASHRAE could recommend that this "statement of source assumptions" be incorporated with the legal documents conveying ownership of the structure, so that it could always be referred to if necessary; the knowledge that this is available would provide an incentive for the building to be operated in a manner that is consistent with the design assumptions. And regardless of the association with deeds of ownership, the statement of source assumptions, if completed, solves the present difficulty of conveying basic information to, at a minimum, the initial operators of the buildings. Moreover, it provides the ventilation system designer with an easy and practical way of handling the IAQ question and of conveying essential information to those who design the furnishings and have influence over other potential sources. (It would also be appropriate for similarly straightforward procedures to be included in the ventilation rate procedures, indicating how the ventilation engineer ought to handle the pollutant limits specified in the first two tables of concentration limits. As a general rule, whenever a number is given, even if it is a national outdoor air quality standard, a way of using it ought to be specified.)

6. CONCLUSION

The three elements given above constitute an approach to revising Standard 62-1981 to meet the objectives indicated earlier. Although this is certainly not the only approach, it is straightforward and gives examples of some considerations in formulating a revised approach to the question of controlling pollutant concentrations.

As a final note, these brief comments cannot adequately explore the variety of considerations pertaining to revising the Standard, nor can they indicate a practical approach in any detail. They may provide some useful thoughts on some of the considerations and, if developed more fully, could lead to a specific and generally satisfactory result. To a significant degree, the approach suggested avoids the overwhelming difficulty inherent in ASHRAE formulating a consistent rationale for indoor air quality standards. Instead, we suggest that a simple approach be adopted that retains the Standard's present emphasis on ventilation rates, while giving the designer practical means to handle the question of indoor air quality.

7. ACKNOWLEDGEMENTS

The authors thank Peter Cleary, John Girman, and Frances Offermann, Jr. for perceptive reviews of the paper. This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Building Systems Division, and by the Director, Office of Energy Research, Office of Health and Environmental Research, Human Health and Assessments Division, U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

8. REFERENCES

[1] ASHRAE Standard 62-1981.
"Ventilation for Acceptable Indoor Air Quality",
The American Society of Heating, Refrigeting, and
Air-Conditioning Engineers, Inc., Atlanta, GA, 1981.

[2] MCNALL, P.E.
"Building Ventilation Measurements, Predictions, and Standards"
Bull. NY Acad. Med. 57, 1981, pp 1027-1046.

[3] U.S. Environmental Protection Agency
"National Primary and Secondary Ambient Air Quality Standards"
Code of Federal Regulations, Title 40 Part 50 (40 CFR 50).

[4] ALBERT, Roy E.
"Critical Review Discussion"
JAPCA 33, 1983, pp 836-837.

[5] NERO, A.V.
"Indoor Radiation Exposures rom ^{222}Rn and Its Daughters:
A View of the Issue"
Health Physics 45, 1983, pp 277-288.