The Indoor Air Quality Procedure in the ASHRAE Ventilation Standard for Commercial Buildings: Is It Needed? Is It Ready?

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SUMMARY

The commercial building ventilation standard (62.1-2010) of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) contains alternate procedures: the prescriptive Ventilation Rate Procedure (VRP) and the rarely used Indoor Air Quality Procedure (IAQP). The IAQP allows lower ventilation rates (VRs) than the VRP, if additional contaminant reduction strategies help meet targets for indoor air concentrations and occupant acceptability. This paper reviews adequacy of the VRP, and potential benefits and limitations of the IAQP for use in California, which will soon require "net zero energy" buildings. Material reviewed suggests the current VRP provides neither sufficiently acceptable nor health-protective air quality. The IAQP offers multiple potential benefits over the VRP, but is limited by insufficient specifications and unavailable data. A VRP/IAQP hybrid might provide a practical intermediate strategy to save energy. Ultimately, energy-efficient VR standards that maintain adequate indoor air quality must consider contaminant control other than by ventilation alone.

IMPLICATIONS

Substantial limitations are evident in the ASHRAE IAQP, but also in the widely used VRP. To save energy while providing healthy and comfortable environments in commercial buildings, improved ventilation standards are needed, allowing multiple ways to reduce indoor contaminants in addition to ventilation, but more explicit than the current IAQP.

KEYWORDS

energy, indoor air contaminants

INTRODUCTION

The current commercial building ventilation standard (62.1-2010) of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) contains two alternate procedures: the widely used, prescriptive Ventilation Rate Procedure (VRP) and the rarely used Indoor Air Quality Procedure (IAQP) (ASHRAE, 2010). The VRP prescribes ventilation rates (VRs) for specific building uses, but does not explicitly consider knowledge on indoor emissions, indoor air quality, and health, and may not provide implied levels of health or satisfaction related to indoor air quality (IAQ). The IAQP, in contrast, is a performance-based design approach based on controlling concentrations of selected indoor contaminants of concern to specified health-linked concentration limits, and on a specified level of perceived indoor air acceptability. Neither the VRP nor the IAQP require verification in buildings over time. The IAQP potentially allows lower ventilation rates (VRs) than the VRP does, by allowing combined use of ventilation, source reduction, air cleaning, or other strategies to meet the specified targets for indoor air concentrations and occupant acceptability.

This paper summarizes a longer review on the potential benefits and limitations of the IAQP relative to the VRP, produced to assist the California Energy Commission (CEC) decide about inclusion of the ASHRAE IAQP in California Title 24 ventilation standards for commercial buildings. For more details see Mendell and Apte (2010). The specific focus was on "big box" retail stores, of greater than approximately 75,000 square feet, based on requests to CEC.

METHODS

We reviewed, not exhaustively, materials pertaining to ASHRAE 62.1-2010, relevant to adequacy of the VRP (e.g., on associations of prescribed VRs with health and satisfactory IAQ) and potential benefits and limitations of the IAQP. We included multiple sources such as the peer-reviewed literature, conference proceedings, ASHRAE journals, and the world-wide-web. We also reviewed information on indoor concentrations of contaminants in stores and other commercial buildings, indoor contaminants of potential concern for health or perceived indoor air quality (IAQ), and effects of commercial VRs on energy consumption. From these materials and commentary from a Technical Advisory Committee, we summarize briefly what is known about the VRP and IAQP, and lay out issues and questions raised. The focus is on data relevant to California.

RESULTS

Ventilation rates and human response in commercial buildings

Recent reviews on relationships between VRs in commercial buildings and health of occupants provide evidence on whether currently recommended ventilation rates adequately protect the health of occupants. Seppänen et al. (1999) found that significant improvements in health outcomes and in perceived air quality were associated with VRs increasing up to 10 L/s-person, and in many studies improvements continued with increases in VRs above 10 L/s-person, up to approximately 20 L/s-person. A recent meta-analysis of VRs and symptoms in commercial buildings confirmed that, based on a quantitative summary of eight available studies, symptoms in occupants were decreased at a VR of 10 L/s-person relative to lower VRs, and that as VRs increased from 10 up to 25 L/s-person, symptom prevalence decreased an additional 29% (Fisk et al., 2009). These findings agree in suggesting that VRs above the current VRP-prescribed level, and up to 20-30 L/s-person, would further improve health and environmental acceptability, although data are mostly from offices. In addition, there is a range of evidence suggesting that low ventilation rates in various types of buildings are associated with increased airborne transmission of some infectious diseases.

ASHRAE has defined acceptable (perceived) air quality as air considered acceptable by at least 80% of occupants. It is apparently often assumed, without any documentation, that VRs prescribed by the ASHRAE 62.1, (Ventilation for Acceptable Indoor Air Quality) VRP will produce "acceptable indoor air quality." The IAQP, in contrast, without the historical assumptions of adequacy behind it, comes with requirements to document successful initial achievement of both acceptability (surveys) and health (modeled contaminant concentrations) targets, whether it leads to lower or higher VRs than those specified in the VRP.

Limited data are available on occupant satisfaction with the indoor environment in commercial buildings in the U.S. A large database of survey information has been collected from 34,169 occupants in 215 office buildings, mostly larger government office buildings in the U.S. Consequently, this sample may not fully represent the general population of office buildings. In almost three quarters (74%) of the buildings sampled, fewer than 80% of occupants were satisfied (votes of 0 or higher on a scale from -3.5 to +3.5) with their indoor air quality (Huizenga et al., 2006). Ventilation rates were not measured. The European Audit Study reported that 27% of occupants in 56 buildings studied reported the IAQ to be not acceptable (Bluyssen et al., 1996). This was despite the high average measured VRs of 25 L/s-person, far above existing standards. Even among the 44 buildings providing at least the minimum VR in ASHRAE 62, 64% of the buildings did not meet the 80% satisfaction criterion. The authors concluded that meeting existing ASHRAE VRP standards was no guarantee of adequate acceptability of indoor air quality (Bluyssen et al., 1996).

Ventilation rates in commercial buildings

One problem with any VR standard is the difficulty of verifying adequate VRs. Limited information is available from commercial buildings in California on current outdoor air VRs estimated accurately with tracer gases. Lagus Applied Technologies (1995) measured VRs with tracer gases when systems were at minimum damper settings, in multiple building types and multiple climate zones. Using an assumed occupant density, median measured ventilation rates in both offices and retail exceeded the minimum current ventilation guidelines (ASHRAE 62.1, 2010) by over 50%. In the BASE study, a large study of U.S. office buildings, the California buildings had median VRs (24-70 L/sec-person) substantially higher than those in the U.S. generally (18-31 L/sec-person), due at least in part to mild weather conditions in California allowing more economizer use (Persily et al., 2008). All median VRs were substantially higher than the default VRP standard of 8 L/sec-person. However, among U.S. buildings assumed to be operating at minimum intake conditions, presumably in very hot or cold weather, a substantial proportion failed to meet ASHRAE VRP requirements (Persily et al., 2008). In European buildings in the European Audit Study, average outdoor VR was 25 L/s-person, substantially higher than the ASHRAE minimum levels (Bluyssen et al., 1996).

Ventilation rates and energy consumption

Simulations performed by the National Renewable Energy Laboratory provide the best estimates available of the energy impact of outside air ventilation on total whole building energy use (Benne et al., 2009; Griffith et al., 2008). For the full commercial building stock, entirely eliminating the observed minimum mechanical ventilation would (in theory) decrease whole building energy use by 6.6%; the natural gas Energy Use Intensity (EUI) would decrease by 21.4%, with a 0.0% change to the electricity EUI. Considering just the national retail sector, the total EUI would decrease by 8.6% on average, with the gas EUI decreasing by 27.8%. In the climate zones of the most populated areas in California, the models estimated that eliminating the minimum observed levels of mechanical ventilation in the full commercial building stock year-round would produce net decreases in energy use (gas and electricity) of only 0.2 and 1.4%. If these predictions are accurate, even substantial reductions in the minimum outside air ventilation rate in commercial buildings in California, if implemented throughout the year, would not produce substantial reductions in overall energy use. However, reductions in minimum mechanical ventilation rates during only the heating season in California would significantly decrease gas energy consumption (data not shown).

The IAQP

Applying the IAQP requires the designer to perform and document the following tasks:

- Identify *contaminants (*or mixtures*) of concern* (COCs).
- Identify *indoor sources* (occupants and materials) and *outdoor sources* of each COC.
- Determine the *emission rate* of each COC from each source.
- Specify an indoor *concentration limit*, with a corresponding *exposure period* for each COC, with appropriate reference to a *cognizant authority* as the source.

- Specify a *design level* of (subjective) *indoor air acceptability*, as a percentage of *occupants or visitors* expressing satisfaction with perceived IAQ.
- Determine *for each zone* the minimum required ventilation rates that will achieve *both*
    - the *specified concentration limit for each COC*, as estimated in a mass balance analysis, and
    - the *specified indoor air acceptability*, based on either occupant evaluation of the completed building, or prior determination in a very similar building.

The IAQP does not specify how COCs are chosen; require post-construction verification for specified COCs, their source strengths, or the resulting concentrations; nor require IAQ sampling prior to occupancy. The system thus might be "gamed" to allow undesirable levels.

The IAQP offers potential benefits of two types, relative to the VRP:
- The IAQP *allows lower VRs* to save energy, operation costs, and possibly construction costs, and reduced problems with very polluted outdoor air, while providing at least equivalent IAQ. These benefits *require lower VRs* than allowed by the current VRP.
- The IAQP *allows improved IAQ, health, and satisfaction* in buildings through setting of explicit health-based and acceptability-based concentration limits which can be achieved through a combination of strategies in addition to ventilation. These benefits could also be obtained under the current VRP, although incentives for the extra effort and cost may be absent for building owners and designers if reduced VRs were not allowed.

Key limitations of the current IAQP can be grouped in four categories:
- It may not adequately protect occupants or IAQ, either initially or in the future.
- It is too subjective and imprecise, and can lead to a wide range of VRs.
- Engineers/designers are reluctant to use the IAQP, as it fits poorly with their knowledge, experience, and skills.
- Enforcement (e.g., monitoring many contaminants) would be difficult.

Note that the VRP has many of these same limitations, including lack of guarantee that compliance provides adequate IAQ, lack of provision for increased indoor emissions from later construction; and difficulty in enforcement; however, it has a history of use.

Indoor chemical concentrations and effects of VRs on indoor contaminants
Few available studies provide recent data on indoor concentrations of VOCs in U.S. retail stores or other commercial buildings (e.g., Loh et al., 2006; Hotchi et al., 2006; Hodgson and Levin, 2003). Multiple chemical compounds at relatively high levels (e.g., trichloroethene. 1-4-dichlorobenze, methylene chloride) or of potential health concerns (i.e., formaldehyde at above California chronic reference exposure levels (CRELS) were identified in some buildings. Published data on indoor concentrations in retail stores, and in big box stores in particular, were very limited, and were available for only a fraction of the VOCs that are known or suspected to occur in indoor air. Unmeasured compounds are likely to include a number with important effects on health, sensory irritation, and odor, but inadequately characterized by conventional collection or analysis methods.

It is important, when considering requirements for an improved IAQP approach, to focus only on indoor air contaminants for which increased general ventilation could effectively reduce indoor concentrations. Other contaminants should not influence required VRs, but should be controlled using alternate strategies. Consideration of indoor air contaminants for which acceptable levels can be maintained through adequate ventilation should focus on VOCs (and, pending future research findings, possibly CO_2), as long as particle filtration efficiency is maintained as adequate to control indoor generated bioaerosols and other particles.

The influence of VRs in buildings on indoor concentrations of VOCs emitted by buildings, their contents, and occupants are often assumed to be readily estimated with mass balance models. Limited research is available on these relationships in real buildings, as opposed to from chamber studies or mathematical models. Findings of several field intervention studies suggest, however, that effectively limiting VOC concentrations in office buildings requires source control in addition to adequate ventilation (e.g., Hodgson et al. 2003).

DISCUSSION

Material reviewed suggests that revision of the current ventilation standard is necessary, because the VRP in use provides air quality that is not sufficiently acceptable or health-protective. Increasing prescribed VRs is not a feasible solution for three reasons: the need to reduce rather than increase energy use, the polluted outdoor air in many cities, and the limited ability of increased VRs to reduce all indoor airborne contaminants of concern. A solution must include other methods of pollutant reduction., California buildings must by State law use zero net energy by 2030, yet cannot just reduce VRs to achieve this, as this would lead to indoor air even less acceptable and healthy. Other methods to reduce ventilation energy will need to be considered. And for any VR standard, practical VR measurements are needed.

Any feasible solution to these problems is likely to require methods of pollutant reduction in addition to outdoor air ventilation, so that VRs lower than those prescribed today can produce adequate IAQ. The current IAQP – requiring control of COCs to specified health- and acceptability-related limits with strategies that may include source control, air cleaning, and outdoor air ventilation – allows movement in this direction, whereas the VRP does not. With the IAQP, outdoor air ventilation would be *just one of multiple tools* for achieving adequate IAQ. Ventilation rate standards linked to achieving specified levels of indoor pollutants and acceptability could document healthful indoor environments, and also reward owners who control indoor pollutants by allowing lower energy costs from reduced outdoor air ventilation.

Although the current IAQP offers multiple potential benefits over the VRP, it is too limited by insufficient specifications and inadequate data to sufficiently protect occupants. Ventilation engineers rarely use it, finding it too arbitrary and requiring non-engineering judgment and unavailable data. Revising the current IAQP could reduce its limitations, but would make it more complex and prescriptive and require substantial research. Arguably, an IAQP need only deal with VOCs, not, given adequate particle filtration, with particulate contaminants. A practical intermediate strategy to save energy would be an alternate VRP, allowing VRs lower than currently prescribed, if indoor VOC concentrations were documented to be no higher than with current VRP-prescribed VRs. Problems with this approach include apparently unacceptable IAQ with the current VRP, unknown VOC levels, and possible adverse effects at these levels. An initial hybrid could develop into a full IAQP. Ultimately, VR standards must evolve to include other contaminant controls as in the IAQP.

CONCLUSIONS

Given the current limitations of the IAQP in ASHRAE 62.1 (2010), in combination with the lack of information and expertise needed to use and enforce it, implementation for big box and other commercial buildings in California would not save energy while providing reliably acceptable and healthy indoor environments. Ultimately, ventilation standards considering contaminant control other than by ventilation alone seem necessary to achieve these goals. .

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