AN INDOOR AIR QUALITY PERFORMANCE STANDARD FOR SINGLE-FAMILY RESIDENTIAL BUILDINGS

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ABSTRACT

There is increasing interest worldwide in the use of performance standards for removing barriers to the acceptance of housing innovation. The use of performance standards can also improve communications between producers and consumers leading to enhanced housing quality and performance. A set of performance standard guides is being developed in the US within ASTM and internationally within ISO. The individual standards will address performance issues such as structural and fire safety, lighting, acoustics, and durability. This paper describes the initial attempt within ASTM to develop an indoor air quality performance standard for single-family residential buildings. Since we are not yet able to specify IAQ performance solely in terms of contaminant concentrations, the standard contains performance statements addressing building ventilation and ventilation rates as well as source control.

INTRODUCTION

Most building codes and standards employ a prescriptive approach based on minimum requirements for particular building components. In contrast, performance standards specify the desired results of how the component's performance, and not the manner in which that performance is to be obtained. An example from the structural realm is a requirement that walls be constructed of "2x4" wooden studs of a certain quality. A performance alternative to this prescriptive requirement would be that the wall must be able to withstand various types of loads, with a description of how this performance will be assessed but no details on how this performance must be achieved. Many see the current prescriptive system as a barrier to innovation that limits competition and constrains markets. In order to address some of these barriers, performance standards are being discussed and initial efforts are underway in their development.

ASTM Subcommittee E6.66 Performance Standards for Dwellings is in the process of developing a set of residential performance standard guides for one- and two-family dwellings. A related effort is also being pursued by ISO TC59/SC15, Performance Criteria for Single Family Attached and Detached Dwellings. Within ASTM, the current plan is to develop a standard to address sixteen different performance attributes, for example structural safety, fire safety, indoor air quality, acoustics, and durability.

These guides are organized around a hierarchy of building elements, the major components of which are: whole building, spaces, structure, exterior enclosure, interior space division, plumbing, HVAC, fire protection systems, electrical, communication and security systems, fuel networks, and fittings, furnishings and equipment. Within each building element, the standards contain a number of performance statements, each of which contains an objective, criteria, evaluation and optional commentary, referred to as the OCEC approach. The *objective* is a qualitative statement of what the product or assembly is intended to

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accomplish. The *criteria* are quantitative statements giving the level of performance required for the item being addressed. *Evaluation* sets forth the methods of tests and other information upon which a judgement of compliance with a criterion will be based. It states the standards, inspection methods, analysis, review procedures, historical documentation, test methods, and models that may be used in evaluating whether a criterion has been satisfied. Finally, the *commentary*, which is optional, provides background information and rationale behind each objective, criterion, and evaluation.

This paper describes the indoor air quality performance guide being developed within ASTM subcommittee E6.66. The description includes the scope of the guide and the way in which several performance issues are addressed. Being a guide within the ASTM standards development process, this standard will be a compendium of information rather than specifying a specific course of action. It will allow and facilitate communication between specifiers (buyers) and offerors (sellers) on a performance basis. As this standard is still under development, the version that is eventually approved could be significantly different from what is described here.

SCOPE

The indoor air quality performance guide being developed within ASTM contains performance statements for one and two-family residential buildings that address indoor air quality performance including indoor air pollution and thermal comfort. It does not address other aspects of the indoor environment such as lighting and acoustics, as these will be covered by other standards. While an indoor air quality performance standard would be based primarily on indoor contaminant limits, such limits are not yet available from the relevant health authorities. Therefore, the standard contains performance statements addressing building ventilation. Some of the performance statements are quantitative in nature, for example building air change rates. Other statements are more subjective, such as minimizing odors from outdoor sources. While it is difficult to make specific performance statements for some of these issues, the current thinking is that they are so important to indoor air quality that they need to be included in some form.

PERFORMANCE STATEMENTS

This section briefly summarizes the performance statements contained in the draft currently under development.

Whole Building

The performance statements under the whole building include the following: whole building ventilation; ventilation air distribution; kitchen, bath and toilet exhaust; thermal comfort; control of radon entry; odor control from indoor and outdoor sources; building design with respect to outdoor sources; airflow and pollutant transport from unconditioned spaces; pollutant sources in garage; and, pollutant sources in building.

For whole building ventilation, the objective is that the outdoor air ventilation rate of the building be adequate in terms of quantity and reliable in terms of availability. The whole building air change rate should be consistent with ASHRAE Standard 62 [1], that is 0.35 h^{-1} or 7.5 L/s (15 cfm) per person (whichever is greater). In terms of reliability, this rate should be achievable under all conditions of weather and building operation. Compliance can be demonstrated by measurements in the building using tracer gas techniques in accordance witl ASTM E741 [2]. Alternatively, it can be calculated using ASHRAE Standard 136 [3], which uses the results of a fan pressurization test of a building to estimate an average air change rat The air change rate may also be calculated with a single-zone or multizone airflow model. Th commentary section notes that ventilation may be provided by a combination of infiltration through envelope leakage, natural ventilation through open windows and other intentional openings, and mechanical ventilation. The guide omits the "building code" approach of specifying a window or vent area comprising 4% or 5% of the building floor area based on it prescriptive nature.

The performance statement on ventilation air distribution includes the objective that the outdoor ventilation air should be distributed throughout the occupied portions of the building. In mechanically or naturally ventilated buildings, there should be either an adequatel sized supply air vent in each room or in an adjacent space with a means for that air to reach the room in question. Alternatively, and in buildings ventilated via infiltration, outdoor airflo rates into each room should be measured or calculated. Operation of a forced-air distribution system can be used to meet this objective by mixing the ventilation air within the building. Tl commentary points out that it can be difficult to achieve this objective in buildings ventilated by infiltration, as the sites where air enters and leaves the building are uncontrolled and a strong function of weather conditions.

Kitchen, bath and toilet spaces should be provided with exhaust ventilation that reliably removes unwanted contaminants, moisture and odors. These criteria based on ASHRAE Standard 62 [1], state that the rates in kitchens should be 50 L/s (100 cfm) on an intermittent basis or 12 L/s (25 cfm) continuously. The rates in baths and toilets should be 25 L/s (50 cfm) on an intermittent basis or 10 L/s (20 cfm) continuously. These rates can be achieved via mechanical ventilation systems or engineered passive systems. For mechanical systems, evaluation can be based on equipment specifications or measured airflows. For engineered passive systems, the exhaust rates can be calculated using a multizone airflow model. These evaluations must address the issue of variability of exhaust airflow rates due to weather conditions and building operation.

An objective addressing thermal comfort is included and simply states that the conditioned spaces should be thermally comfortable as defined by ASHRAE Standard 55 [4] and ISO 7730 [5]. The criteria are based on the predicted mean vote in the space being between -0.5 and +0.5, corresponding to 80% of the building occupants being satisfied with the thermal environment. These standards are most commonly applied to commercial environments, where design approaches have been developed to meet these criteria. However, such design approaches do not exist for residential buildings. Therefore, thermal comfort may need to be assessed in residential buildings through measurement of the parameters used to calculate predicted mean vote. Alternatively, thermal comfort could be evaluated by interviewing the building occupants. This performance objective may not be extremely critical, in that the occupants can control the operation of heating and cooling systems based on their personal preferences. Nevertheless, it is important that the systems have sufficient capacity to provide thermal comfort, and that the system and the building be designed and constructed to avoid circumstances that can compromise thermal comfort.

The only contaminant-specific objective concerns radon. The criteria states that the building, particularly the foundation, should be designed to create a barrier between the soil and the building interior to prevent soil gas from entering the building. The means of doing so are described in ASTM Standard E1465 [6]. Alternatively, the indoor radon concentration can be measured in the building after construction, and the result should be less than 4 pCi/L (based on the U.S. EPA action level). A strong argument exists that measurement is the only way to verify that this performance objective has been adequately addressed.

The draft contains objectives related to odor control from indoor sources and outdoor sources. Such objectives are inherently subjective, and it is difficult to set clear performance criteria. The current draft states that there should be no objectionable odors from these sources, or the complaints that exist should be limited in frequency. The existence of objective odors can only be assessed after the building is built based on the reaction of the occupants, which can be formalized through the use of a questionnaire or a trained odor panel. While trained panels can be more rigorous, many odors are episodic and therefore the usefulness of such a panel can be limited.

The next performance objective states that the building should be located, oriented and designed to minimize the impact of nearby pollutant sources on the acceptability of the air in the building. This objective involves the inspection of the site and the building design relative to nearby pollutant sources, such as heavily used roads and industrial facilities. Specifically consideration needs to be given to the orientation of elements where outdoor air would be expected to enter the building such as windows and vents. Compliance with this objective, and the evaluation to assess compliance, are necessarily subjective. Another source-related objective concerns airflow and pollutant transport from unconditioned spaces such as crawl spaces and attached garages. This objective can be achieved through an evaluation of the design in terms of the barriers between conditioned and unconditioned spaces and the ability to maintain lower air pressures in unconditioned spaces. On-site inspection of these barriers and evaluation of the installed ventilation system can supplement the design analysis.

The last two objectives under the Whole Building relate to pollutant sources in attached garages and in the building itself. In both cases, a subjective objective is included that the existence and strength of such sources should be limited. Obviously, compliance with these objectives can only be evaluated after the building is built and occupied. Compliance with the criteria related to indoor sources can be based on consideration of the materials and furnishings that will be used in the building. Relevant information includes information on the sources, such as emissions test data, however such information may not always be available. Test methods for quantifying indoor source strengths and emission rate guidelines are still under development. ASTM D5116 [7] provides guidance on emission rate measurement, but it is not a test method and the issue of acceptable emission rates remains. Users can, and do, have products tested per the guidance in D5116 and then use indoor pollution models to predict indoor pollutant concentrations. While these predicted concentrations can serve as a performance parameter, they must still be compared with an indoor pollutant guideline and such guidelines are not available for the residential environment.

Subsystems, Exterior Enclosure and Roofs

Under the building subsystems classification, the draft standard addresses a number of issues related to moisture. These include the foundation, crawl spaces, grade enclosures, roofs, and exterior walls, windows and doors. In all cases, the respective component should be designed and constructed to minimize water entry. Compliance involves a pre-construction inspection of the plans, followed by a post-construction inspection of the building. ASTM E241 [8] and the ASTM Manual Moisture Control in Buildings [9] are referenced as providing useful design guidance for controlling water entry.

Another objective is included to avoid excessive condensation within exterior wall construction. The criteria are based on analysis of the design, followed by a lack of evidence of condensation after construction. The commentary section mentions the existence of calculation methods for analyzing the potential for condensation in exterior walls, and notes that the ASHRAE Fundamentals Handbook chapter 23 [10], ASTM E241 [8] and the ASTM Manual Moisture Control in Buildings [9] provide useful design guidance.

Plumbing and HVAC Systems

A number of criteria exist in the category of plumbing and HVAC systems, including the control of plumbing leaks, venting of atmospherically ventilated water heating appliances, accessibility of HVAC equipment, filtration, venting of atmospherically ventilated combustion heating appliances, unvented heating appliances, condensate from air conditioning equipment, and venting of clothes dryers.

In the case of atmospherically vented combustion water and space heating appliances, the appliance should vent to the outdoors such that entry of combustion products to the living space is effectively eliminated. The criteria states that the venting system should be designed and installed in compliance with applicable codes and standards, and that the installed system should pass at least one of the induced-conditions tests contained in ASTM E1998 [11]. These include house depressurization, downdrafting, appliance backdrafting or cold vent establishment pressure. ASTM E1998 is only a guide, and therefore does not contain definitive test procedures for assessing a water heater installation in terms of this objective. Nonetheless, spillage of combustion products is of sufficient concern that some attention is merited. Inspecting the installation relative to applicable codes is not considered adequate, because these codes do not consider factors related to building pressures induced by weather and the operation of exhaust ventilation equipment.

Another objective states that the HVAC equipment should be designed and installed to ensure that it is accessible for inspection, maintenance and cleaning. A performance objective related to filtration states that adequate particulate filtration should be provided in forced-air heating and cooling systems in order to control particulate levels in the indoor air and to maintain the cleanliness of HVAC components. An additional objective states that condensate from air conditioning equipment should be able to drain freely and completely. The last equipment-related objective states that exhaust air from clothes dryers should be vented to the outdoors to prevent water vapor and dust from entering the building interior.

DISCUSSION

While there is a desire to develop an indoor air quality performance standard, the draft being developed within ASTM has revealed some of the difficulties in producing such a document. The primary difficulty is the establishment of quantitative performance criteria for many of the issues that are important to residential indoor air quality. However, the process of attempting to develop this standard will reveal some of the critical gaps and could help to focus future research activities. The effort within ASTM needs to be considered a preliminary step in the development a true indoor air quality performance standard based on contaminant concentrations and other quantitative criteria.

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