Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings—Indoor Air Quality[1]

INTRODUCTION

This guide is part of a set which together presents a complete performance standard guide for specifying and evaluating single family attached and detached dwellings. The complete set in the series, when finished, is to include the attributes given in Table 1.

The series provides a framework for specifying and evaluating qualities of building products and systems to meet user needs without limiting ways and means. The format for this guide includes performance statements that consist of four components, Objectives-Criteria-Evaluation-Commentary (O-C-E-C), which together provide a systematic performance based approach for the intended purpose. These performance statements are presented in Section 8 against a Hierarchy of Building Elements as tabulated in Table 2.

The purpose of these standard guides is to provide a standardized system for describing performance parameters of single-family attached or detached dwellings. This system standardizes the descriptions of performance of a single-family dwelling, attached or detached, that can be expressed as performance statements (O-C-E-C) for a particular attribute, agent, and user need.

These standard guides are intended for use by those who need to prescribe required levels of performance and those who need to rate a product which forms a single-family dwelling or part thereof. The standard guides include examples of performance statements that may be used for the specification and evaluation of design, materials, products, components, subsystems, and systems.

1. Scope

1.1 This guide contains suggested performance statements for single family residential buildings (attached and detached) that address indoor air quality performance including indoor air pollution and thermal comfort. These performance statements are not presented as proposed requirements, but are written in permissive language as suggestions that can be used in developing specifications to satisfy user needs.

1.2 This guide does not address other aspects of the indoor environment such as lighting and acoustics.

1.3 Performance statements addressing building ventilation and ventilation rates are also included in the standard, since it is premature to base performance only on indoor air pollution, that is, airborne contaminant concentrations. When health authorities have established contaminant concentration limits for residential environments, it may be possible to define indoor air quality performance in terms of contaminant concentrations rather than ventilation.

1.4 This guide is one in a series of guides containing performance statements for residential buildings that are intended for use in the procurement, specification and evaluation of one- and two-family dwellings. These companion standard guides include those noted in the Introduction above.

1.5 This guide also addresses a number of residential indoor air quality issues that can not be expressed as performance statements at this time. However, they are important enough to include in this guide to at least raise the awareness of those

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TABLE 1 Attributes Addressed in the Series of Performance Standards for Single Family Attached and Detached Dwellings

A	Structural Safety and Serviceability
B	Fire Safety
C	Accident Safety
D	Health and Hygiene
E	Indoor Air Quality
F	Light
G	Acoustics
H	Durability
I	Accessibility
J	Security
K	Economics
L	Functionality
M	Aesthetics
N	Adaptability
O	Maintainability
P	Sustainability

involved in the process of procurement, specification and evaluation. These issues are addressed in 8.3.

1.6 This guide does not include site planning objectives. However, certain issues addressing the relationship of building to site have been covered, and it is important that these few objectives not be construed as a comprehensive site specification.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1356 Terminology Relating to Sampling and Analysis of Atmospheres

D5116 Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products

E241 Guide for Limiting Water-Induced Damage to Buildings

E631 Terminology of Building Constructions

E779 Test Method for Determining Air Leakage Rate by Fan Pressurization

E1465 Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings

E1554 Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization

E1998 Guide for Assessing Depressurization-Induced Backdrafting and Spillage from Vented Combustion Appliances

E2151 Terminology of Guides for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings

E2156 Guide for Evaluating Economic Performance of Alternative Designs, Systems, and Materials in Compliance with Performance Standard Guides for Single-Family

TABLE 2 Hierarchy of Building Elements Included in the Series of Performance Standards for Single Family Attached and Detached Dwellings

0. Whole Building System
  0.1 All Building Subsystems
  0.2 Groups of Building Subsystems
1. Spaces
  1.1 Entries
  1.2 Living Spaces
  1.3 Dining Spaces
  1.4 Kitchens
  1.5 Sleeping Spaces
  1.6 Bathrooms
  1.7 Water Closets
  1.8 Outdoor Living Spaces
  1.9 Storage Spaces
  1.10 Other
2. Structure
  2.1 Foundation
  2.2 Superstructure
3. Exterior Enclosure
  3.1 Grade Enclosure
    3.1.1 Floor on Grade
    3.1.2 Floor over Air Space
    3.1.3 Other
  3.2 Vertical and Sloped Enclosure
    3.2.1 Walls
    3.2.2 Windows
    3.2.3 Doors
    3.2.4 Other (e.g., railings, louvers, screens, etc.)
  3.3 Roofs
    3.3.1 Roof Coverings
    3.3.2 Skylights
    3.3.3 Other Roof Openings
  3.4 Joint Sealants
4. Interior Space Division
  4.1 Vertical Space Dividers
    4.1.1 Partitions
    4.1.2 Doors
    4.1.3 Other
  4.2 Horizontal Space Dividers
    4.2.1 Floors
    4.2.2 Ceilings
    4.2.3 Floor/Ceiling Openings
    4.2.4 Other
  4.3 Stairs and Ramps
5. Plumbing
  5.1 Plumbing Fixtures
  5.2 Domestic Water Distribution
  5.3 Sanitary Waste
  5.4 Rain Water Drainage
6. HVAC
  6.1 Heating
    6.1.1 Heating Generation
    6.1.2 Heating Distribution
    6.1.3 Heating Terminal and Package Units
    6.1.4 Heating Controls and Instrumentation
  6.2 Cooling
    6.2.1 Cooling Generation
    6.2.2 Cooling Distribution
    6.2.3 Cooling Terminal and Package Units
    6.2.4 Cooling Controls and Instrumentation
  6.3 Ventilation
    6.3.1 Ventilation Distribution
    6.3.2 Ventilation Terminal and Package Units
    6.3.4 Ventilation Controls and Instrumentation
7. Fire Protection Subsystems
  7.1 Suppression Systems
  7.2 Detection Systems
  7.3 Notification Systems
  7.4 Fire Protection Specialties
8. Electrical Network
  8.1 Electrical Service and Distribution
  8.2 Lighting and Branch Wiring

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

TABLE 2 *(continued)*

9. Communication and Security Networks
9.1 Telephone
9.2 Intercom
9.3 Television
9.4 Security
9.5 Other
10. Fuel Networks
10.1 Gas
10.2 Oil
10.3 Other
11. Fittings, Furnishings and Equipment

Attached and Detached Dwellings

2.2 *ASHRAE Standards:*[3]

ASHRAE Fundamentals Handbook 2001

ASHRAE Standard 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy

ASHRAE Standard 62 Ventilation for Acceptable Indoor Air Quality

ASHRAE Standard 111 Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems

ASHRAE Standard 129 Measuring Air Change Effectiveness

ASHRAE Standard 136 A Method of Determining Air Change Rates in Detached Dwellings

2.3 *Other Standards:*

ICC International Fuel Gas Code[4]

ISO 7730 Moderate Thermal Environments, Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort[5]

NFPA 54 National Fuel Gas Code[6]

NFPA 5000 Building Construction and Safety Code[6]

2.4 *Other References:*

Building for Environmental and Economic Sustainability (BEES) 3.0 [7]

EPA, 1992, Indoor Radon and Radon Decay Product Measurement Device Protocols EPA 402-R-92-004[8]

International Residential Code 2003[4]

Moisture Control in Buildings ASTM Manual Series, MNL 18, 1994[2]

MOIST A PC Program for Predicting Heat and Moisture Transfer in Building Envelopes. Version 3.0. NIST SP 917[7]

ORNL/CON-295 Builder's Foundation Handbook, 1991[9]

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide refer to Terminologies E631, D1356, and E2151.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *commentary, n*—the fourth part of a performance statement, consisting of an informative narrative explaining aspects of the performance statement.

3.2.1.1 *Discussion*—A commentary may include one or more of the following: an explanation of how the objective relates to user needs in fields such as physiology, psychology, and culture or tradition; an explanation of how the criteria are established including guides for setting different levels of performance to meet various user needs; a discussion of the reliability of the evaluation method; and example solutions that may be deemed by the specifier to comply with the performance statement.

3.2.2 *criteria, n*—the second part of a performance statement, consisting of quantitative statements defining the level or range of performance necessary to meet an objective or, where such a level or range cannot be established, the units of measurement of the performance.

3.2.3 *evaluation, n*—the third part of a performance statement, consisting of the method(s) of assessing conformance of the element being addressed to the criteria.

3.2.3.1 *Discussion*—The evaluation states standards, inspection methods, review procedures, historical documentation, test methods, in-use performance, engineering analyses, models, or other means that may be used in assessing whether or not a criterion has been satisfied.

3.2.4 *indoor air pollution, n*—the level of air pollution in an enclosed environment.

3.2.4.1 *Discussion*—Based on the definition of air pollution in Terminology D1356, indoor air pollution relates to the concentrations of unwanted material in the air.

3.2.5 *indoor air quality, n*—the composition and characteristics of the air in an enclosed space that affect the occupants of that space.

3.2.5.1 *Discussion*—The indoor air quality of a space is determined by the level of indoor air pollution and other characteristics of the air, including those that impact thermal comfort such as air temperature, relative humidity, and air speed.

3.2.6 *specifier, n*—the individual or organization using the standard guides to create specifications and ultimately accept dwelling designs, materials, products, components, subsystems, or buildings to be provided by providers.

3.2.7 *thermal comfort, n*—the condition of mind that expresses satisfaction with the thermal environment; it requires subjective evaluation.

[3] Available from American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), 1791 Tullie Circle, NE, Atlanta, GA 30329, http://www.ashrae.org.

[4] Available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.

[5] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[6] Available from National Fire Protection Association (NFPA), 1 Batterymarch Park, Quincy, MA 02169-7471, http://www.nfpa.org.

[7] Available from National Institute of Standards and Technology (NIST), 100 Bureau Dr., Stop 1070, Gaithersburg, MD 20899-1070, http://www.nist.gov.

[8] Available from United States Environmental Protection Agency (EPA), Ariel Rios Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20004, http://www.epa.gov.

[9] Available from Oak Ridge National Laboratory (ORNL), Bethel Valley Rd., Oak Ridge, TN 37831, http://www.ornl.gov.

3.2.8 *user need, n*—a statement of the activities and behavior to be carried out in relation to the dwelling by its residents, or other users, defined in terms of motor, kinetic, physiological, psychological, emotional and other parameters of human behavior.

3.2.9 *ventilation, n*—the process of supplying outdoor air or removing indoor air by natural or mechanical means to or from any space.

4. Significance and Use

4.1 *General Purpose and Intent:*

4.1.1 This guide is to provide a standardized system for describing performance parameters of single-family attached and detached dwellings. The use of consensus performance standards for housing, can significantly contribute to the removal of barriers to the acceptance of traditional and innovative housing products and systems in the global marketplace. This guide in conjunction with the balance of the set of standard guides can also serve to improve communications between producers and consumers leading to enhanced quality and performance of housing.

4.1.2 This guide, in conjunction with the balance of the set of standard guides, will be useful to managers of housing procurement projects, homebuilders, designers, product manufacturers, and evaluation services.

4.2 *Indoor Air Quality Issues:*

4.2.1 The environment within a building impacts the health of the building occupants and their satisfaction with the space. While this guide only addresses indoor air quality, this aspect of the indoor environment is an important component of a performance approach to residential buildings.

4.2.2 The performance statements contained in this guide are relevant to the procurement of a range of built elements related to the indoor environment, including but not limited to the whole building, the exterior enclosure, HVAC subsystems, local exhaust subsystems, other ventilation subsystems and their components, filtration and air cleaning subsystems, and building materials and furnishings.

5. Aspects of Indoor Air Quality Performance

5.1 The quality of the air within a dwelling has multiple characteristics, including those described in this section.

5.2 *Indoor Air Pollution:*

5.2.1 Indoor concentrations of contaminants are important parameters of indoor air quality. However, few concentration guidelines have been issued to date that apply to nonindustrial environments, including residential buildings. Example guidelines are cited in Appendix B of ASHRAE Standard 62-2001, but these lists are not comprehensive in terms of the pollutants covered and are provided only for informational purposes.

5.2.2 Odors are another aspect of indoor air quality. Some odors can be readily associated with specific airborne contaminants, while many can not or are complex mixtures of contaminants. Because individuals vary greatly in their perceptions of and reactions to odors, the consideration of odor is necessarily a subjective issue.

5.2.3 Indoor moisture is important due to the association between high interior moisture levels and the potential for microbial growth. Liquid water from plumbing leaks or rain penetration can also be associated with microbial growth. Such growth indoors can lead to the generation of bioaerosols, which can seriously degrade indoor air quality. In addition, low levels of indoor humidity can lead to discomfort and health concerns based on drying of mucous membranes. Therefore, moisture issues are covered in this guide.

5.3 *Thermal Comfort:*

5.3.1 The thermal environment within a space is another important aspect of indoor air quality. The thermal conditions in a space, and the reaction of building occupants to these conditions, are determined by a combination of physical and personal factors. The physical factors include the air temperature, relative humidity, air speed, and radiant temperatures of indoor surfaces. The personal factors include clothing levels, physical activity and personal preference.

5.4 *Energy Use:*

5.4.1 Energy use is an important consideration in the provision of adequate indoor air quality. Some approaches to ventilating for indoor air quality can lead to a net increase in outdoor air entry, leading to increased energy consumption. In addition, approaches that employ fans for ventilation are associated with the energy used to power those fans. Compliance with the performance statements in this guide can be achieved with alternative designs and elements proposed by providers that very in the costs of components. These alternatives will also very in their energy use, and consequently in energy costs to be incurred over the design life of the dwellings. The evaluation of energy costs will be an important consideration for specifiers in making the selections among alternative proposals by providers.

5.4.2 Some performance specifications have included some form of energy budget, but that is not the approach taken in this guide. Economics is addressed in a separate standard guide of this suite: Standard Guide for Evaluating Economic Performance of Alternative Designs, Systems, and Materials in Compliance With Performance Standard Guides for Single-Family Attached and Detached Dwellings. An appendix to this latter document will include an example of the use of life-cycle costing to evaluate alternative solutions with varying energy costs. Providers should provide all the necessary information on the energy use entailed by their proposals. Specifiers shall provide information on the methods to be used for estimating the costs of various energy sources, as well as predicting the ambient thermal conditions affecting the dwelling.

6. Site Considerations Affecting Indoor Air Quality

6.1 *Outdoor Sources:*

6.1.1 Indoor air quality can be impacted by contaminant sources outside a building in addition to those indoors. Outdoor air pollution sources can be characterized as regional, local or immediate. Examples of regional sources include a high density of heavy industry and other industrial pollution sources, farming and other agricultural activities, and natural sources of dust or pollen. Local sources would include a specific agricultural or industrial source (such as a factory) located near the building, or proximity to a road with heavy traffic. An immediate source might be an exhaust vent from an adjacent building, idling motor vehicles at a nearby loading dock, landscaping activities, or a trash dumpster in an adjoining alley.

6.1.2 Information on regional, local or immediate contaminant sources of sufficient detail is important to the design of the building so as to provide a specified level of indoor air quality. Outdoor or other contaminant sources should be determined in conjunction with the site design, so that methods for controlling contaminant sources may be established.

6.2 *Climate:*

6.2.1 The climate in which a building is located can impact indoor air quality. The relevant climatic variables are air temperature, insolation, relative humidity, wind speed and direction, and precipitation.

6.2.2 Air temperature, insolation, relative humidity, and wind speed and direction impact thermal comfort through the shading, insulation and thermal storage capabilities of the building enclosure elements, through the thermal storage capability of the building interior elements, and through the placement of operable windows.

6.2.3 Outdoor air temperature and wind speed and direction also impact building infiltration rates, which determine the rate of dilution of pollutants generated indoors and the rates at which outdoor pollutants enter a building. These weather conditions are particularly relevant to natural ventilation strategies in buildings.

6.2.4 Outdoor temperature and humidity levels impact moisture migration into and through the building envelope and the potential for condensation in the envelope and within the building. Excessive condensation and accumulation can lead to microbial growth and deterioration of indoor air quality.

6.2.5 Wind speed and direction relate to the transport of contaminants from outdoor sources to the building and moisture penetration into and possibly through the building envelope. Prevailing winds and the location of outdoor pollutant sources is a consideration when locating operable windows and ventilation system inlets, as are local site conditions that impact airflow in the vicinity of the building (for example, trees, bushes, berms, other buildings, etc.). Wind-driven moisture should also be considered in designing the building envelope.

6.2.6 Air temperature, solar insolation and relative humidity can impact the emission rates of some organic materials due to temperature and humidity effects.

6.2.7 The level of precipitation at a site, in combination with wind conditions, is another climatic consideration. Exterior envelope design, rain runoff control and ventilation of unconditioned spaces such as crawl spaces are important factors to consider, particularly in climates with heavy precipitation, as they will impact water penetration and therefore the potential for indoor microbial growth.

6.2.8 Information on local climatic conditions of sufficient detail is important to the design of the building so as to provide a specified level of indoor air quality. Climatic conditions should be determined in conjunction with the site design, so that methods for controlling these contaminant sources may be established.

6.3 *Soil Conditions:*

6.3.1 The level of moisture in soil can impact indoor moisture levels and needs to be considered in foundation and floor design and construction.

6.3.2 The soil can also be a source of contaminants such as radon, bioaerosols, pesticides or other organic compounds associated with past site conditions and events. These factors need to be considered when selecting a site, preparing it for construction and designing the foundation system.

6.3.3 Information on the soil conditions at the local site of sufficient detail is important to the design of the building so as to provide a specified level of indoor air quality. Soil conditions should be determined in conjunction with the site design, so that methods for controlling contaminant sources may be established.

7. Evaluation Methods

7.1 *Contaminant Measurement*—While the guide does not contain many criteria based on indoor contaminant concentrations, the evaluation of concentration requires the use of appropriate measurement methods. Currently, there is not a comprehensive set of standard test methods for measuring the indoor concentrations of relevant contaminants at levels appropriate to non-industrial environments. When measuring indoor contaminant concentrations, the measurement method must be selected based on accuracy, minimum detection limits, expected indoor concentrations, noise associated with the measurement equipment, and cost.

7.2 *Ventilation and Airflow Measurement*—The guide contains criteria related to building ventilation and airflow rates. Standard test methods exist for such quantities. They are cited in the specific performance statements, and some of them are discussed in Appendix X2.

7.3 *Inspection*—Several of the criteria are associated with evaluations based on inspections of building design and of the constructed building. These are not standardized procedures, but are based on the specific item being examined and the relevant criteria.

7.4 *Life Cycle Costing*—Alternative proposals, each of which may comply with all the performance specifications based on the performance statements in this guide, are likely to have differing first costs as well as differing energy and other operating costs. A life cycle cost analysis of each of the alternatives may be performed in order to be able to complete the evaluation and select from among the alternative proposals. Such an analysis should be based on an agreed upon methodology that accounts for the energy and other costs needed to operate the proposed solutions. Life cycle cost analysis that includes energy use can be found in Guide E2156. In addition to these economic analyses, specifiers may also employ life cycle assessment methodologies that consider environmental impacts including resource consumption, pollution emitted and other issues such as those employed within the BEES methodology.

8. Performance Statements

8.1 Illustrative examples of performance statements for building materials, products, components, assemblies, and subsystems are given in Appendix X1 in O-C-E-C format.

8.2 *Hierarchy of Building Elements:*

8.2.1 The example performance statements given in Appendix X1 are presented against the Hierarchy of Building Elements tabulated in Table 2. The order of presentation begins with "0. Whole Building System" followed in order by each of the subsystems. Within each subsystem, the example performance statements follow in order down to the lowest levels of the hierarchy as needed.

8.2.2 To some extent the Hierarchy of Building Elements reflects the structure of the housing industry, and therefore, the organization of the provider teams. For example, a homebuilder or developer is likely to be the systems integrator responsible for "0. Whole Building System." The provider teams may include separate subcontractors for "5. Plumbing," "6. HVAC," "8. Electrical Network" and the like, and separate suppliers for components such as "3.2.2 Windows," "3.2.3 Doors," "3.4 Joint Sealants," and so forth.

8.2.3 The Evaluation part of the performance statements includes the identification of the types of information (for example, drawings, samples, test reports, and so forth) that might be developed to allow comparison with the Criteria. The responsibility for making available this information is dependent upon the contractual relationship that exists between provider, specifier and user. For performance statements at higher levels of the Hierarchy of Building Elements such as "0. Whole Building System," the technical information documenting compliance must be provided by the systems integrator. The systems integrator, for example, may assemble portions of this information from members of the provider's team, such as subcontractors or suppliers. In some cases, the systems integrator may develop a performance specification for one or more products, components, or assemblies at lower levels of the Hierarchy of Buildings Elements in order to obtain this information.

8.2.4 For performance statements at lower levels of the Hierarchy of Building Elements, the information documenting compliance may be provided directly by a subcontractor or supplier member of the provider's team.

8.3 *Other Performance Issues:*

8.3.1 There are a number of residential indoor air quality issues that are important, but that may not yet be appropriate for performance statements due to the current lack of recognized performance criteria or evaluation methods. This section identifies some of those issues.

8.3.2 *Odors:*

8.3.2.1 When occupying a building, the occupants should not experience objectionable odors generated within the building that are not created by the user. The occupants themselves may be responsible for odors due to their activities. Examples of such activities include some hobbies and cooking, while odorous sources might include some furnishings and pets.

8.3.2.2 Standardized methodologies for predicting odor levels that might occur due to materials and furnishings do not currently exist Therefore the ability to address these odors is limited within the context of this guide. Some work has been done that allows one to relate the emissions from some materials in chambers to expected odor levels, but the capability does not yet exist to perform such predictions on a whole building basis for the wide variety of sources that might be present.

8.3.2.3 Consideration of odors could focus on the unoccupied building, which would avoid the influences of occupant activities and furnishings. However, the methodological problems for predicting and evaluating odor levels would remain.

8.3.3 *Pollutant Sources in Garages:*

8.3.3.1 Indoor air quality can be impacted by contaminant sources in attached parking garages. Although the homeowner has control over the existence of noxious or odorous substances in a garage, the airtightness of the boundary between the garage and the occupied space can help to reduce the likelihood of such pollutant transport. In addition, they might want to consider the airtightness of air handling equipment and ductwork that is located in the garage, given the potentialimpact of duct leakage on pollutant transport between the garage and the living space.

9. Keywords

9.1 building performance; indoor air pollution; indoor air quality; residential; ventilation

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLES OF INDOOR AIR QUALITY PERFORMANCE STATEMENTS

X1.1 Whole Building System

X1.1.1 Whole Building Ventilation. See Table X1.1.

X1.1.2 Ventilation Air Distribution. See Table X1.2.

X1.1.3 Occupant Control of Whole Building Ventilation. See Table X1.3.

X1.1.4 Thermal Comfort. See Table X1.4.

X1.1.5 Indoor Radon Concentrations. See Table X1.5.

X1.1.6 Design with Respect to Outdoor Sources. See Table X1.6.

X1.1.7 Indoor Pollutant Sources. See Table X1.7.

X1.2 Spaces

X1.2.1 Whole Building Kitchen, Bath and Toilet Exhaust. See Table X1.8.

TABLE X1.1 Whole Building Ventilation

		E INDOOR AIR QUALITY
0.1. WHOLE BUILDING SYSTEM—All Building Subsystems		
A. Whole Building Ventilation		
Objective		The outdoor air ventilation rate of the building should be adequate, in terms of quantity, and reliable, in terms of availability under a range of weather and building operation conditions, to provide occupant comfort and health.
Criteria	C-1:	The whole building air change rate, either measured or calculated, should be consistent with an appropriate standard in units of air changes per hour (h^{-1}) or L/s (cfm) per occupant.
Evaluation Methods		Compliance with the criteria can be demonstrated in a number of different ways. However, any of these evaluation methods must address the issue of variability of ventilation rates due to weather and building operation conditions.
	E-1:	The ventilation rate can be measured in the building using tracer gas techniques in accordance with ASTM E741.
	E-2:	The airflow rate into the building can be measured directly at intake vents.
	E-3:	The ventilation rate can be calculated using ASHRAE Standard 136, which requires a fan pressurization test of the building.
	E-4:	The ventilation rate may also be calculated using engineering methods, such as single-zone or multizone airflow models (see Appendix X2).
Commentary		The actual air change rate used in the criteria can be based on a local building code or on a national or international ventilation standard. For example, ASHRAE Standard 62 requires 0.35 h^{-1} or 7.5 L/s (15 cfm) per person (whichever is greater). The outdoor air ventilation criteria may be achieved through a combination of infiltration through envelope leakage, natural ventilation through open windows and other intentional openings (for example, through-the-wall vents, window inlets and similar devices), and mechanical ventilation. Many building codes require operable windows and other openings to be sized as a fraction of floor area, for example the International Residential Code requires these openings to be 4 % of the floor area. The objective stated above notes that the building ventilation rate needs to be achievable under a range of conditions. This is important because infiltration and natural ventilation rates can be quite low under mild weather conditions, even in very leaky buildings. Mechanical ventilation has its own reliability issues based on system sizing and the ability of the control approach to provide sufficient ventilation. Also, the rate needs to be achievable under these conditions, but need not be maintained under all conditions, especially when the building is not occupied. Modeling approaches may be acceptable for evaluation, but their accuracy is limited by the availability of accurate input data for the models.

TABLE X1.2 Whole Building Ventilation Air Distribution

		E INDOOR AIR QUALITY
0.1. WHOLE BUILDING SYSTEM—All Building Subsystems		
B. Ventilation Air Distribution		
Objective		The outdoor ventilation air should be distributed throughout the occupied portions of the building to provide adequate ventilation to all occupied spaces.
Criteria	C-1:	There should be an identifiable means of providing outdoor air to each occupiable room, with the means depending on the approach taken to ventilating the building.
	C-2:	In mechanically or naturally ventilated buildings, there should be either an adequately-sized supply air device in each room or in an adjacent space with a means for that air to reach the room in question.
	C-3:	Alternatively, and in buildings ventilated via infiltration, measured or calculated outdoor airflow rates into the room should correspond to a specific air change rate in units of air changes per hour or L/s (cfm) per occupant.
Evaluation Methods		Compliance with the criteria can be demonstrated in three different ways: measurement, modeling or design review.
	E-1:	Outdoor airflow rates can be measured for individual rooms using multizone tracer gas techniques.
	E-2:	Similarly, age of air measurements using tracer gas (based on ASHRAE Standard 129) could be used.
	E-3:	Multizone airflow modeling can be used to calculate outdoor airflow rates into zone, as well as age of air for individual rooms.
	E-4:	Alternatively, the building design can be reviewed to determine whether it will result in adequate outdoor air distribution throughout the building.
Commentary		For both measurements and modeling, the criteria can be based on a local building code or on a national or international ventilation standard. For example, ASHRAE Standard 62 requires 0.35 h^{-1} or 7.5 L/s (15 cfm) per person (whichever is greater). Note that evaluation methods based on measurements or modeling need to address the issue of variability of airflow rates due to weather conditions and building operation. Also, it can be difficult to achieve this objective in buildings ventilated by infiltration, as the points where air enters and leaves the building are uncontrolled and a strong function of weather conditions. The existence of a forced-air distribution system, designed to operate continuously, can be used to meet this objective by mixing the ventilation air within the building. However, if the system operates only when there is a demand for heating or cooling, its effectiveness will be limited. And while such a system can be operated more frequently, such operation can carry a significant energy cost. Also, the ability of a system to distribute ventilation air as intended is impacted by installation and maintenance, including but not limited to system balancing and changes in damper position over time. Note that mulitzone tracer gas techniques (E-1) have not been standardized and are generally used only in research, and age at air measurement (E-2) are still in the realm of research. Given the difficulty of the measurements needed to assess the criteria, and the limitations of modeling due to a lack of input data, the most common means of evaluation is inspection of the design. This inspection would involve establishing the existence of those features needed to provide outdoor air to each room or to enable its mixing within the building. Until detailed guidelines are written for use in such inspections, the reliability will depend to a large degree on the experience of the individual conducting the inspection.

X1.2.2 Airflow and Pollutant Transport from Unconditioned Spaces. See Table X1.9.

TABLE X1.3 Control of Whole Building Ventilation

E INDOOR AIR QUALITY		
0.1. WHOLE BUILDING SYSTEM—All Building Subsystems		
C. Occupant Control of Ventilation Components		
Objective		Occupants should be able to turn ventilation components on and off, or control positions of ventilation openings such as vents or windows, in order to obtain amounts of ventilation that meet their needs.
Criteria	C-1:	All ventilation fans and system components, including those associated with natural ventilation systems should have conveniently located on-off switches or positioning controls.
Evaluation Methods	E-1:	The HVAC design and ventilation system component product information can be inspected. In addition, the building can be inspected once completed.
Commentary		There are conditions when additional ventilation may be undesirable, for example when the outdoor air is particularly polluted or when the house may be unoccupied for an extended period of time. There may also be conditions when the occupants desire additional ventilation, beyond what may be provided under a given set of circumstances. The occupant should have the option of reducing or increasing the ventilation as they desire, within the capabilities of the ventilation approach(es) being employed in the building.

TABLE X1.4 Thermal Comfort

E INDOOR AIR QUALITY		
0.1. WHOLE BUILDING SYSTEM—All Building Subsystems		
D. Thermal Comfort		
Objective		The conditioned spaces within the dwelling should be thermally comfortable to the occupants of these spaces.
Criteria	C-1:	The indoor air temperature and relative humidity should both be in a range that leads to thermally neutral conditions for a high percentage of the building occupants. In addition, the air speed and radiant temperature should also be in a range that maintains thermal comfort.
Evaluation Methods	E-1:	The only means available for assessing thermal comfort in residential buildings is through measurement of the parameters referred to in the criteria, which are based on calculation methods in ISO 7730 and ASHRAE Standard 55. Another option for evaluating thermal comfort is by interviewing the building occupants. Whatever evaluation method is used, it needs to address the full range of outdoor weather conditions and space-conditioning system operation.
Commentary		As described in ASHRAE Standard 55 and ISO 7730, thermal comfort is determined by air temperature, relative humidity, air speed and radiant temperature. In addition, as pointed out in these documents, the activity and clothing levels of the occupants are also important. These documents contain ranges of air temperature and relative humidity that lead to acceptable thermal comfort for certain assumptions of activity and clothing levels, as well as for different seasons of the year. In the context of these documents, thermally neutral means the predicted mean vote in the space should be between -0.5 and +0.5, corresponding to 80 % of the building occupants being satisfied with the thermal environment. The ASTM Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings. Functionality also contains ranges of air temperature and relative humidity for achieving thermal comfort. Regardless of the specific criteria employed, the important issue is that the heating and cooling systems have sufficient capacity to provide thermally comfortable conditions, and that the system and the rest of the building are designed and constructed to avoid circumstances that may compromise thermal comfort. Such circumstances can include hot or cold exterior wall and window surfaces, and drafts due to cold wall surfaces and poor system configuration.

TABLE X1.5 Indoor Radon Concentrations

E INDOOR AIR QUALITY		
0.1. WHOLE BUILDING SYSTEM—All Building Subsystems		
E. Indoor Radon Concentrations		
Objective		Exposure of building occupants to radon should be controlled by minimizing radon entry into the building from the surrounding soil.
Criteria	C-1:	The building, particularly the foundation, should be designed to to prevent soil gas from entering the building interior
	C-2:	Alternatively, the indoor radon concentration can be measured in the building after construction, and a process developed and implemented to reduce the concentration to less than a specific value established by an appropriate authority.
Evaluation Methods	E-1:	Analysis of the building design and on-site inspection of construction can be used to assess its ability to prevent soil gas entry through strategies including barriers between the soil and the building interior and the creation of pressure relationships that limit the entry of soil gas.
	E-2:	Compliance with a radon concentration guideline can be assessed using measurement techniques that are consistent with existing standards and guidelines (for example, EPA 1992). Measurement-based evaluation must address the issue of variability of radon concentrations due to ventilation rates, weather conditions and building operation.
Commentary		Specific design guidance for limiting radon entry is contained in Practice E1465, NFPA Standard 5000 and the International Residential Code (appendix F on Radon Control Methods) The radon criteria can be based on a standard or guideline issued by a relevant organization, such as the U.S. EPA action level of 0.15 Bq/L (4 pCi/L). While radon resistant design can be effective in maintaining low indoor concentrations, concentration measurement is the only way to be certain that the concentrations are sufficiently low.

TABLE X1.6 Design with Respect to Outdoor Sources

E INDOOR AIR QUALITY

0.1. WHOLE BUILDING SYSTEM—All Building Subsystems

G. Design with Respect to Outdoor Sources

Objective		Nearby pollutant sources should not reduce the acceptability of the air to the building occupants.
Criteria	C-1:	The building should be located, oriented and designed to limit the impact of nearby pollutant sources on the indoor air in the building.
Evaluation Methods	E-1:	This objective can be evaluated through inspection of the site and the building plans. The site would be examined in terms of the nature and location of nearby pollutant sources, such as heavily-used roads and industrial facilities. The building design would be examined in terms of the orientation of locations where outdoor air would be expected to enter the building such as windows and vents. In performing this evaluation, prevailing wind directions needs to be considered. Wind roses (charts depicting prevalent wind speeds as a function of wind direction) are available for many localities and can be useful in this respect.
Commentary		This objective and evaluation to assess achievement of this objective, are necessarily subjective and require experienced personnel to do both.

TABLE X1.7 Indoor Pollutant Sources

E INDOOR AIR QUALITY

0.1. WHOLE BUILDING SYSTEM—All Building Subsystems

H. Indoor Pollutant Sources

Objective		The strength of pollutant sources in the building should be limited to specified concentration levels.
Criteria	C-1:	Materials and furnishings should be selected with source strengths of air pollutants consistent with achieving the specified concentrations.
Evaluation Methods	E-1:	Compliance with this criterion can be based on consideration of the materials and furnishings that will be used in the building. Information on these items that relate to source strengths includes Material Safety Data Sheets (MSDS's) and actual emissions test data.
Commentary		Source control is a fundamental approach to providing good indoor air quality. By using lower emitting sources, indoor air quality can be improved. However, test methods and emission rate guidelines are not available. Also, emissions test data on potential sources are not always available and must be used with an understanding of its accuracy and relevance. MSDS's can provide information on the compounds associated with a given product, but do not provide actual emission rates. Guide D5116 provides guidance on emission rate measurement, but it is not a test method and the issue of what constitutes acceptable or low emission rates remains. Nordtest Method N.T. Build 438 is another procedure for quantifying contaminant emissions from materials. Users can, and do, have products tested per the guidance in Guide D5116 or N.T. Build 438 and then use indoor pollution models to predict indoor pollutant concentrations (see Appendix X2 for a discussion of these models). However, while these predicted concentrations can serve as a performance parameter, they must still be compared with an acceptable indoor pollutant concentration and exposure. Such concentration and exposure guidelines are not available for the residential environment.

TABLE X1.8 Whole Building Kitchen, Bath and Toilet Exhaust

E INDOOR AIR QUALITY

1.0. SPACES

A. Kitchen, Bath and Toilet Exhaust

Objective		Kitchens, baths and toilets shall be designed and constructed to provide for removal of unwanted contaminants, moisture and odors.
Criteria	C-1:	The exhaust ventilation rates in kitchens should be consistent with an appropriate standard in units of L/s (cfm).
	C-2:	The rates in baths and toilets should be consistent with an appropriate standard in units of L/s (cfm).
Evaluation Methods		These rates can be achieved via mechanical ventilation systems or engineered passive systems. The latter approach is any combination of unpowered vents (including open windows) or stacks that provides exhaust airflow out of the room allude to temperature and wind induced pressures.
	E-1:	For mechanical systems, the equipment specifications can be compared to the stated criteria. In addition, the installed airflows can be measured using standard testing and balancing procedures (ASHRAE Standard 111 or equivalent).
	E-2:	For engineered passive systems, the exhaust rates can be calculated, for example using a multizone airflow model (see Appendix X2) or some other airflow analysis approach. It may also be possible to measure the airflows in some passive systems using standard testing and balancing procedures.
Commentary		The actual exhaust ventilation rates used in the criteria can be based on a local building code or on a national or international ventilation standard. For example, ASHRAE Standard 62 requires 50 L/s (100 cfm) on an intermittent basis or 12 L/s (25 cfm) continuously for kitchens and 25 L/s (50 cfm) on an intermittent basis or 10 L/s (20 cfm) continuously for baths and toilets. While fan specifications can be useful in evaluating exhaust airflow rates, installed systems do not always provide the rated flows due to the configuration of the installed system. Therefore, evaluation based on measurements is generally more reliable than the use of fan specifications, unless the fan manufacturer provides detailed installation guidelines to ensure rated airflows. Any of these evaluation should address the issue of variability of exhaust airflow rates due to weather conditions and building operation. While engineered passive systems may be adequate, no standards currently exist for their evaluation. Note that the 2003 International Residential Code requires that these spaces have not less that 0.28 m2 (3 ft2) of glazing, one-half of which must be openable.

TABLE X1.9 Airflow and Pollutant Transport from Unconditioned Spaces

		E INDOOR AIR QUALITY
1.0. SPACES		
B. Airflow and Pollutant Transport from Unconditioned Spaces		
Objective		Airflow from unconditioned spaces, such as crawl spaces and garages, to living spaces should be limited to control indoor contaminant levels.
Criteria	C-1:	The airtightness of the boundary between conditioned and unconditioned spaces should be within stated limits.The transfer rates of airflow from unconditioned spaces to living spaces should be consistent with a specified level unit of L/s (cfm).
Evaluation Methods	E-1:	Compliance with this objective can be achieved through an evaluation of the design in terms of the necessary barriers and pressure control. Consideration of the barriers involves their existence, adequacy and constructability. Evaluation of the building pressures involves consideration of the all ventilation system components in terms of the pressures that will be established between the conditioned and unconditioned spaces. On-site inspection of these barriers and evaluation of the installed ventilation system can supplement the design analysis.
Commentary		This objective can be achieved through tight physical separation of conditioned and unconditioned spaces. Also, lower air pressures in unconditioned spaces relative to conditioned spaces will reduce undesirable airflows. Unconditioned spaces, primarily crawl spaces and garages, are potential sources of contaminants, and it is desirable to keep air and those contaminants from entering the conditioned space. Crawl space air can contain high levels of moisture, radon and other ground source contaminants. Garage air can contain pollutants from substances stored in the garage. Measurements of pressure differences between conditioned and unconditioned spaces after the dwelling is constructed can be useful. Such pressure measurements must address the issue of variability of these pressure differences due to weather conditions and building operation.

X1.3 Structures

X1.3.1 Control of Groundwater and Rain Runoff. See Table X1.10.

X1.3.2 Control of Crawl Space Moisture. See Table X1.11.

X1.4 Exterior Enclosure

X1.4.1 Control of Water Penetration. See Table X1.12.

X1.4.2 Control of Groundwater and Rain Runoff. See Table X1.13.

X1.4.3 Control of Water Vapor within Wall Construction. See Table X1.14.

X1.4.4 Roofs

X1.4.4.1 Control of Water Leakage. See Table X1.15.

X1.5 Plumbing

X1.5.1 Control of Plumbing Leaks. See Table X1.16.

X1.5.2 Venting of Atmospherically-Vented Combustion Water Heating Appliances. See Table X1.17.

X1.6 HVAC

X1.6.1 Accessibility of HVAC Equipment. See Table X1.18.

X1.6.2 Filtration. See Table X1.19.

X1.6.3 Air Distribution Duct Leakage. See Table X1.20.

X1.6.4 Heating

X1.6.4.1 Venting of Atmospherically-Vented Combustion Heating Appliances. See Table X1.21.

X1.6.4.2 Unvented Heating Appliances. See Table X1.22.

X1.6.5 Cooling

X1.6.5.1 Condensation Drainage. See Table X1.23.

X1.7 Fittings, Furnishings and Equipment

X1.7.1 Removal of Clothes Dryer Exhaust. See Table X1.24.

TABLE X1.10 Control of Groundwater and Rain Runoff

		E INDOOR AIR QUALITY
2.1. STRUCTURES—Foundation		
A. Control of Groundwater and Rain Runoff		
Objective		Groundwater and rain runoff (including snow melt) should be prevented from entering the building in order to prevent occupant exposure related to moisture problems in buildings.
Criteria	C-1:	The foundation should be designed and constructed for subsurface water control and water resistance to prevent water from entering and/or accumulating in the foundation in amounts that are hazardous or detrimental.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection of the plans and specifications. A post-construction inspection of the building is needed to evaluate the actual extent of water entry, and the results of this inspection must be interpreted with consideration of recent levels of precipitation.
Commentary		After construction, there should be no water entry, or symptoms thereof, associated with the foundation. Excessive entry of liquid water can lead to microbial growth and associated indoor air quality problems associated with allergies and other health effects due to molds and fungi. Guide E241, the ASTM manual titled Moisture Control in Buildings (ASTM MNL 18), the ORNL Foundation Handbook and some local building codes, among other sources, provide useful design guidance for controlling water entry at foundations. Note that the ASTM Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings - Functionality also contains some guidance on this subject.

TABLE X1.11 Control of Crawl Space Moisture

E INDOOR AIR QUALITY		
2.1. STRUCTURES—Foundation		
B. Control of Crawl Space Moisture		
Objective		Groundwater and rain runoff (including snow melt) should be prevented from entering the crawl space in order to prevent occupant exposure related to moisture problems in buildings, and the transport of significant quantitites of water vapor from the soil to the crawl space should be prevented.
Criteria	C-1:	The crawl space should be designed and constructed for subsurface water control, and water resistance to prevent water from entering and/or accumulating in the foundation in amounts that are hazardous or detrimental. It should also be designed and constructed to limit water vapor transport from the soil.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection of the plans and specifications. A post-construction inspection of the building can also be used to determine if the building and foundation were constructed per the design and to inspect the integrity of any waterproofing or vapor barriers employed. A post-construction inspection is also needed to evaluate the actual extent of liquid and vapor water entry, but the results of this inspection must be interpreted with consideration of recent levels of precipitation.
Commentary		After construction, there should be no liquid water entry and limited water vapor entry, or symptoms thereof, associated with the crawl space. Excessive moisture in the crawl space can lead to microbial growth and associated indoor air quality problems associated with allergies and other health effects due to molds and fungi. Even though the crawl space is outside the conditioned volume of the building, contaminants can often find their way into the conditioned space through air leakage sites and via ductwork that might pass through the crawl space. It is therefore important to keep the crawl space as dry as possible. Guide E241, the ASTM manual titled Moisture Control in Buildings (ASTM MNL 18), the ORNL Foundation Handbook and some local building codes, among other sources, provide useful design guidance for controlling water entry at foundations including crawl spaces.

TABLE X1.12 Control of Rain Penetration

E INDOOR AIR QUALITY		
3.0. EXTERIOR ENCLOSURES—Exterior Walls, Windows and Doors		
A. Control of Water Penetration		
Objective		The exterior envelope shall be designed and constructed to efficiently manage and control moisture in order to prevent occupant exposure related to moisture problems in buildings.
Criteria	C-1:	Exterior walls, windows and doors should be designed and constructed to prevent rain penetration into portions of the building envelope not designed to drain liquid water and dissipate water vapor below levels that are hazardous.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection of the plans. A post-construction inspection of the flashings, sealants and water entry routes is needed to evaluate the actual extent of rain penetration, and the results of this inspection must be interpreted with consideration of recent levels of precipitation.
Commentary		Excessive entry of liquid water can lead to microbial growth and associated indoor air quality problems associated with allergies and other health effects due to molds and fungi. After construction, there should be no unintended water entry, or symptoms thereof, associated with rain penetration of the facade. The building codes require flashing of doors, windows, and roofs, and other design features to address other possible water entry points, and reference standards on siding and masonry installation. Guide E241, the ASTM manual titled Moisture Control in Buildings (ASTM MNL 18), and some local building codes, among other sources, provide useful design guidance for controlling rain penetration. Some wall systems are designed to allow water to penetrate the facade, but then to drain to the outdoors. These wall systems still require evaluation per their design. Note that the ASTM Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings - Functionality also contains some guidance on this subject.

TABLE X1.13 Control of Groundwater and Rain Runoff

E INDOOR AIR QUALITY		
3.1. EXTERIOR ENCLOSURES—Grade Enclosure		
A. Control of Groundwater and Rain Runoff		
Objective		Groundwater and rain runoff should be prevented from entering the building at grade in order to prevent occupant exposure related to moisture problems in buildings.
Criteria	C-1:	The grade enclosure should be designed and constructed to prevent groundwater and runoff from entering the building at grade and provide for for sufficient drainage to remove water from the grade enclosure.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection of the plans. A post-construction inspection of the building is needed to evaluate the actual extent of water entry, and the results of this inspection must be interpreted with consideration of recent levels of precipitation.
Commentary		Excessive entry of liquid water can lead to microbial growth and associated indoor air quality problems associated with allergies and other health effects due to molds and fungi. After construction, there should be no unintended water entry, or symptoms thereof, associated with rain penetration of the facade Guide E241, the ASTM manual titled Moisture Control in Buildings (ASTM MNL 18), the ORNL Foundation Handbook and some local building codes, among other sources, provide useful design guidance for controlling rain penetration. Note that the ASTM Standard Guide for Specifying and Evaluating Performance of Single Family Attached and Detached Dwellings. Functionality also contains some guidance on this subject.

TABLE X1.14 Condensation within Wall Construction

E INDOOR AIR QUALITY		
3.2. EXTERIOR ENCLOSURES—Vertical and Sloped Enclosures		
A. Control of Water Vapor within Wall Construction		
Objective		Excessive levels of water vapor within exterior wall construction should be avoided in order to prevent occupant exposure related to moisture problems in buildings.
Criteria	C-1:	Exterior walls should be designed and constructed to limit levels of water vapor from indoors and outdoors, and to dissipate any excessive water vapor that might occur.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection and analysis of the wall construction. Calculation methods exist to quantify the potential for condensation as discussed in the Commentary section. A post-construction inspection of the building can also be used to assess the existence of such condensation, but either the inspection must involve some destructive techniques or it will reveal only the grossest of failures. The timing and interpretation of such an inspection must reflect the current and recent weather conditions.
Commentary		Excessive condensation can lead to microbial growth and associated indoor air quality problems associated with allergies and other health effects due to molds and fungi. After construction, there should be no evidence or symptoms of uncontrolled condensation. In addressing moisture transport and condensation, it is important to consider both diffusion and transfer through convection or air leakage. While both can be important, air leakage is generally the dominant mechanism by which moisture moves through walls. The ASHRAE Fundamentals Handbook chapter 23, Guide E241, the ASTM manual titled Moisture Control in Buildings (ASTM MNL 18) and some local building codes provide useful design guidance for controlling condensation within walls. One calculation tool for analyzing the potential for condensation within a wall the computer program MOIST (Burch and Chi, 1997).

TABLE X1.15 Control of Water Leakage

E INDOOR AIR QUALITY		
3.3. EXTERIOR ENCLOSURES—Roofs		
A. Control of Water Leakage		
Objective		Rain and melting snow should be prevented from entering the building at the roof in order to prevent occupant exposure related to moisture problems in buildings.
Criteria	C-1:	The roof system should be designed and constructed for adequate deflection and drainage of rain and melting snow in order to prevent water penetration into the attic or building interior.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection of the plans. A post-construction inspection of the building is needed to evaluate the actual extent of water entry, and the results of this inspection must be interpreted with consideration of recent levels of precipitation.
Commentary		Excessive entry of liquid water can lead to microbial growth and associated indoor air quality problems associated with allergies and other health effects due to molds and fungi. After construction, there should be no water entry, or symptoms thereof, associated with the roof. Guide E241 and the ASTM manual titled Moisture Control in Buildings (ASTM MNL 18) provide useful design guidance for controlling water entry at roofs. Information on rainfall and snowfall amounts is available for most localities, and this information can be useful in developing criteria and specifications.

TABLE X1.16 Control of Plumbing Leaks

E INDOOR AIR QUALITY		
5.0. PLUMBING		
A. Control of Plumbing Leaks		
Objective		Plumbing leaks should be avoided in order to prevent occupant exposure related to moisture problems in buildings.
Criteria	C-1:	The plumbing system should be designed and the system components installed such that the potential for plumbing leaks is minimized.
Evaluation Methods	E-1:	Compliance with these criteria can be based on a pre-construction inspection of the plans. A post-construction inspection of the building is needed to evaluate the actual existence of any plumbing leaks.
Commentary		Plumbing leaks can be one of the major sources of indoor moisture problems and the negative indoor air quality impacts that can result. After construction, there should be no evidence of plumbing leaks.

TABLE X1.17 Venting of Atmospherically-Vented Combustion Water Heating Appliances

		E INDOOR AIR QUALITY
5.0. PLUMBING		
B. Venting of Atmospherically-Vented Combustion Water Heating Appliances		
Objective		Atmospherically vented combustion water heating appliances should vent to the outdoors such that occupant exposure to combustion products is effectively eliminated.
Criteria	C-1:	The venting system should be designed and installed in compliance with applicable codes and standards (for example, National Fuel Gas Code).
	C-2:	The installed system should be evaluated using an accepted test for backdrafting and spillage.
Evaluation Methods	E-1:	The compliance of the system with applicable codes and standards can be evaluated by analysis of the design and visual inspection of the installed system.
	E-2:	Guide E1998 describes short term and continuous tests for assessment of appliance backdrafting and spillage.
Commentary		Guide E1998 is a guide that describes alternative test procedures for assessing a water heater installationThis guide does not recommend a specific procedure but does summarize the requirements for different tests along with the basis for interpretation of test results and important distinctions between the tests.

TABLE X1.18 Accessibility of HVAC Equipment

		E INDOOR AIR QUALITY
6.0. HVAC		
A. Accessibility of HVAC Equipment		
Objective		The HVAC equipment should be designed and installed to ensure that it is accessible for inspection, maintenance and cleaning so that it is able to provide environmental conditions acceptable to the occupants and does not become a source of airborne contaminants that negatively impact the health and comfort of the occupants.
Criteria	C-1:	The HVAC system should be designed and constructed to provide sufficient space around the system and its major components for inspection, servicing, including cleaning, in order to prevent environmental conditions that negatively impact the health and comfort of the occupants.
Evaluation Methods	E-1:	Compliance with these criteria can be evaluated by inspecting the plans, specifications and installed system.
Commentary		It is critical that HVAC equipment can be inspected and serviced without extraordinary efforts and special tools. Otherwise, it may not get done.

TABLE X1.19 Filtration

		E INDOOR AIR QUALITY
6.0. HVAC		
B. Filtration		
Objective		Adequate particulate filtration should be provided in forced-air heating and cooling systems in order to reduce particulate exposure of building occupants, from both indoor and outdoor sources, and to maintain the cleanliness of HVAC components.
Criteria	C-1:	Particulate filtration should be adequate to prevent dirt buildup in and on HVAC system components including coils and ductwork. This filtration should also be adequate to control any unusual particle sources, indoors or outdoors, such as those associated with heavy motor vehicle traffic. The filtration system should be installed such that there is minimal bypass (unintentional) around the filter within the HVAC system, and should not reduce airflows in HVAC equipment.
Evaluation Methods	E-1:	The installation of the filtration system can be inspected as soon as it is installed for bypass, though it is valuable to reinspect the installation periodically throughout the life of the system. The effectiveness of the filtration system at controlling dirt buildup in the system can only be assessed visually after the building has been occupied and the system operated for several months. Reinspections for such buildup should be performed periodically throughout the life of the system. The effectiveness of the filtration system at controlling airborne particle concentrations in the building can be assessed by visual inspection of building surfaces, but there are many other factors affecting building cleanliness.
Commentary		Filtration can help to reduce the concentrations of particulates within the HVAC and air distribution systems. In turn, this will lessen indoor particulate concentrations and reduce the potential for microbial growth in these systems by limiting the availability of nutrients. In most situations, a filter rated as MERV 6 in accordance with ASHRAE Standard 52.2 should be adequate, but in some environments a more efficient filter may be needed.

TABLE X1.20 Air Distribution Duct Leakage

		E INDOOR AIR QUALITY
6.0. HVAC		
C. Air Distribution Duct Leakage		
Objective		Air distribution ductwork should be designed and installed to minimize air leakage, particularly to unconditioned spaces, such that the system is able to effectively maintain an indoor environment that is acceptable to the building occupants.
Criteria	C-1:	The measured amount of duct leakage, expressed as an airflow rate at 25 Pa, should be no more than a fixed percentage of the total system airflow rate. Alternatively, the effective leakage area associated with duct leakage should be no more than a fixed percentage of the effective leakage area of the whole house (as measured using Test Method E779).
Evaluation Methods	E-1:	Duct leakage is measured using Test Methods E1554.
Commentary		The percentage of duct leakage, relative to either the system airflow rate or the whole house ELA, may be based on state or national guidelines as they become available. It is important to minimize duct leakage as it impacts the performance of forced-air heating and cooling systems to properly condition the occupied space. In addition, return leaks can drawn air and potentially contaminants into the building from crawl spaces and garages. Supply leaks tend to depressurize the building interiors, which can interfere with the proper operation of vented combustion appliances and which can drawn air and contaminants into the building from unconditioned spaces. Pressurization due to return leaks and depressurization due to supply leaks can also lead to undesirable moisture transport through the building envelope.

TABLE X1.21 Venting of Atmospherically-Vented Combustion Heating Appliances

		E INDOOR AIR QUALITY
6.1. HVAC—Heating		
A. Venting of Atmospherically-Vented Combustion Heating Appliances		
Objective		Atmospherically vented combustion heating appliances should vent to the outdoors such that occupant exposure to combustion products is effectively eliminated.
Criteria	C-1:	The venting system should be designed and installed in compliance with applicable codes and standards (for example, National Fuel Gas Code or International Fuel Gas Code).
	C-2:	The installed system should be evaluated using an accepted test for backdrafting and spillage.
Evaluation Methods	E-1:	The compliance of the system with applicable codes and standards can be evaluated by analysis of the design and visual inspection of the installed system.
	E-2:	Guide E1998 describes short term and continuous tests for assessment of appliance backdrafting and spillage.
Commentary		Guide E1998 is a guide that describes alternative test procedures for assessing a heating system installation.. This guide does not recommend a specific procedure but does summarize the requirements for different tests along with the basis for interpretation of test results and important distinctions between the tests.

TABLE X1.22 Unvented Heating Appliances

		E INDOOR AIR QUALITY
6.1. HVAC—Heating		
B. Unvented Heating Appliances		
Objective		Unvented, combustion heating appliances should be operated and maintained properly in order to minimize occupant exposure to hazardous products of combustion.
Criteria	C-1:	There should be no excessive emissions of nitrogen oxides, carbon monoxide or water vapor by these devices to the indoor air.
Evaluation Methods	E-1:	Operation and maintenance of these appliances according to the manufacturer instructions should help to meet these criteria. In some cases, these instructions will involve limiting the time of operation, opening a window or door during operation, or not operating the appliance indoors.
Commentary		It should be noted that some jurisdictions do not allow such appliances. If they are allowed, it is critical that they are installed and function properly since the combustion products from these appliances are released directly into the occupied space. Ideally this issues would be addressed by numerical limits on emission rates for these substances and a standardized test method for obtaining these rates for an individual piece of equipment. However, such limits and standards do not currently exist.

TABLE X1.23 Condensation Drainage

E INDOOR AIR QUALITY		
6.2. HVAC—Cooling		
A. Condensate Drainage		
Objective		Condensate from air conditioning equipment should be able to drain freely and completely to minimize the potential for microbial growth in the equipment and subsequent exposure of building occupants to bioaerosols.
Criteria	C-1:	There should be no standing water in air conditioning units, including both central systems and window units.
Evaluation Methods	E-1:	Compliance with these criteria can be assessed by visual inspection of the installed system.
Commentary		Standing water in these systems, or overflow from condensate drain pans, can contribute to microbial growth within air conditioning units or nearby areas.

TABLE X1.24 Removal of Clothes Dryer Exhaust

E INDOOR AIR QUALITY		
11.1. Fittings, Furnishings and Equipment		
A. Removal of Clothes Dryer Exhaust		
Objective		Exhaust air from clothes dryers should be managaed to avoid excessive indoor moisture levels and particulate and the associated deterioration of indoor air quality.
Criteria	C-1:	A duct should be installed to convey dryer exhaust to the exterior of the building. The size and length of the duct should comply with applicable industry codes and standards or dryer manufacturer instructions.
Evaluation Methods	E-1:	Compliance with these criteria can be assessed by comparing code and standard requirements with manufacturers installation instructions, and by visual inspection of the installed system.
Commentary		This objective is included to prevent water vapor and lint from entering the building interior.

X2. MODELING TECHNIQUES FOR PREDICTING BUILDING VENTILATION RATES

X2.1 Building ventilation rates can be predicted using approaches that range in complexity from single-zone approaches to multizone airflow models. These predictive methods use information on the building in question including size and some information on airtightness, ventilation system airflow rates, the exposure of the building to wind, and the weather conditions to predict the rate at which outdoor air enters the building. The various methods differ in the degree of detail they consider and in their ease of use. Chapter 26 Ventilation and Infiltration of the ASHRAE Fundamentals Handbook(**1**)[10] contains brief descriptions of these predictive methods, and presents two widely-used single zone methods referred to as the LBL and AIM-2 models. Additional information on airflow modeling is available (**2**).

X2.2 Single-zone approaches to predicting building air change rates are based on an assumption that the building in question can be represented by a single zone at a constant temperature with the interior pressure being only a function of height. It is a valid assumption for many single-family dwellings, but may not work as well for two-family dwellings. These models generally use a single parameter to characterize the airtightness of the building, most often based on the results of a fan pressurization test conducted in accordance with Test Method E779. Most single zone methods use simple algebraic expressions to predict building air change rate from envelope leakage parameters and weather. To characterize the magnitude of envelope leakage, the LBL model uses an effective leakage area of 4 Pa and AIM-2 uses the envelope leakage coefficient and pressure exponent. Additional information required to perform these calculations includes the distribution of this leakage over the surface of the building and wind shelter.

X2.3 Multizone models represent buildings as a number of interconnected zones (often corresponding to rooms), with the pressure in each room being only a function of height. These models are based on a mass balance of air in each zone, which is used to solve the static pressure in each zone. The user of such a model is required to input the location and magnitude of the leaks in the building envelope and in interior partitions, wind pressure coefficients for the exterior surface of the building, airflow rates associated with any mechanical ventilation system, air temperatures in each zone, wind speed and direction, and outdoor temperature. The multizone models that exist can easily be run on today's personal computers. Examples of such models include COMIS (**3**) developed by an International Energy Agency annex and CONTAMW (**4**) developed at NIST.

[10] The boldface numbers in parentheses refer to a list of references at the end of this standard.

X3. MODELING TECHNIQUES FOR PREDICTING INDOOR POLLUTANT CONCENTRATIONS

X3.1 A number of models exist for predicting indoor contaminant concentrations. Some of them require the user to input building airflow rates, such as EXPOSURE (**5**) and MCCEM (**6**). Others, including CONTAMW (**7**) calculate these airflow rates as described in Appendix X2.

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(1) ASHRAE, *Fundamentals Handbook*, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, GA, 2001.

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(4) Dols, W. S., Walton, G. N., and Denton, K. R., *CONTAMW 1.0 User Manual*, NISTIR 6476, National Institute of Standards and Technology, Gaithersburg, MD, 2000.

(5) Sparks, L. E., Tichenor, B. A., and White, J. B., "Modeling Individual Exposure from Indoor Sources," *Modeling of Indoor Air Quality and Exposure, ASTM STP 1205*, N. L. Nagda, ed., American Society for Testing Materials, Philadelphia, PA, 1993, pp. 245-256.

(6) Koontz, M. D. and Nagda, N. L., "A Multichamber Model for Assessing Consumer Inhalation Exposure," *Indoor Air*, 4, 1991, pp. 593-605.

(7) Dols, W. S. and Walton, G. N., *CONTAMW 2.0 User Manual*, NISTIR 6921, National Institute of Standards and Technology, Gaithersburg, MD, 2002.