STANDARD

ANSI/ASHRAE/IES Standard 90.1-2019
(Supersedes ANSI/ASHRAE/IES Standard 90.1-2016)
Includes ANSI/ASHRAE/IES addenda listed in Appendix I

Energy Standard for Buildings Except Low-Rise Residential Buildings (I-P Edition)

See Appendix I for approval dates by ASHRAE, the Illuminating Engineering Society, and the American National Standards Institute.

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4.1.5 Other Laws

The provisions of this standard shall not be deemed to nullify any provisions of local, state, or federal law. Where there is a conflict between a requirement of this standard and such other law affecting *construction* of the *building*, precedence shall be determined by the *authority having jurisdiction*.

4.1.6 Referenced Standards

The standards referenced in this standard and listed in Section 12 shall be considered part of the requirements of this standard to the prescribed extent of such reference. Where differences occur between the provision of this standard and referenced standards, the provisions of this standard shall apply. Informative references are cited to acknowledge sources and are not part of this standard. They are identified in Informative Appendix E.

4.1.7 Normative Appendices

The normative appendices to this standard are considered to be integral parts of the mandatory requirements of this standard, which, for reasons of convenience, are placed apart from all other normative elements.

4.1.8 Informative Appendices

The informative appendices to this standard and informative notes located within this standard contain additional information and are not mandatory or part of this standard.

4.1.9 Reference Standard Reproduction Annexes

The reference standard reproduction annexes contain material that is cited in this standard but contained in another standard. The reference standard reproduction annexes are not part of this standard but are included in the publication of this standard to facilitate use of this standard.

4.2 Compliance

4.2.1 Compliance Paths

4.2.1.1 New Buildings

New *buildings* shall comply with Sections 4.2.2 through 4.2.5 and either the provisions of

a. Section 5, "*Building Envelope*"; Section 6, "Heating, Ventilating, and Air Conditioning"; Section 7, "*Service Water Heating*"; Section 8, "Power"; Section 9, "Lighting"; and Section 10, "Other *Equipment*," or

b. Section 11, "*Energy Cost Budget* Method," or

c. Normative Appendix G, "*Performance Rating Method*."

When using Normative Appendix G, the Performance Cost Index (PCI) of new *buildings*, *additions* to *existing buildings*, and/or *alterations* to *existing buildings* shall be less than or equal to the Performance Cost Index Target (PCI_t) when calculated in accordance with the following:

$$PCI_t = [BBUEC + (BPF \times BBREC)]/BBP$$

where

PCI = Performance Cost Index calculated in accordance with Section G1.2.

BBUEC = baseline *building* unregulated *energy* cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *unregulated energy use*.

BBREC = baseline *building* regulated *energy* cost, the portion of the annual *energy* cost of a *baseline building design* that is due to *regulated energy use*.

BPF = *building* performance factor from Table 4.2.1.1. For *building* area types not listed in Table 4.2.1.1 use "All others." Where a *building* has multiple *building* area types, the required BPF shall be equal to the area-weighted average of the *building* area types.

BBP = *baseline building performance*.

PNA = proposed renewable energy contribution not allowed for compliance.

topography at 9 a.m. and 3 p.m., respectively, on the summer solstice (June 21 in the northern hemisphere).

3. *Alterations* and additions with no increase in *vertical fenestration area.*
4. *Buildings* where the west-oriented and east-oriented *vertical fenestration area* (as defined in Section 5.5.4.5) does not exceed 20% of the *gross wall area* for each of those façades, and *SHGC* on those facades is no greater than 90% of the criteria in Tables 5.5-0 through 5.5-8.
5. *Buildings* in Climate Zone 8.

5.5.4.6 Visible Transmittance/SHGC Ratio

Where *automatic* daylighting *controls* are required in accordance with Section 9.4.1.1(e) or (f), *fenestration* shall have a ratio of *VT* divided by *SHGC* not less than that specified in Tables 5.5-0 through 5.5-8 for the appropriate *fenestration area.*

Exceptions to Section 5.5.4.6

1. A *light-to-solar-gain ratio* (*LSG*) of not less than 1.25 is allowed to be used as an alternative to *VT/SHGC*. When using this option, the center-of-glass *VT* and the center-of-glass *SHGC* shall be determined in accordance with NFRC 300 and NFRC 301, determined by an independent laboratory or included in a database published by a government agency, and certified by the *manufacturer*.
2. *Fenestration* not covered in the scope of the NFRC 200.
3. *Enclosed spaces* where the *daylight area under roof monitors* is greater than 50% of the *enclosed space* floor area.
4. *Enclosed spaces* with *skylights* that comply with Section 5.5.4.2.3.
5. *Enclosed spaces* where the *sidelighting effective aperture* is greater than or equal to 0.15.
6. For *dynamic glazing*, the *VT/SHGC* ratio and the *LSG* shall be determined using the maximum *VT* and maximum *SHGC*. *Dynamic glazing* shall be considered separately from other *fenestration*, and area-weighted averaging with other *fenestration* that is not *dynamic glazing* shall not be permitted.

5.6 Building Envelope Trade-Off Compliance Path

5.6.1

The *building envelope* complies with the standard if

a. the *proposed design* satisfies the provisions of Sections 5.1, 5.4, 5.7, 5.8, and 5.9 and
b. the *proposed envelope performance factor* of the *proposed design* is less than or equal to the *proposed envelope performance factor* of the *base design.*

5.6.1.1

All components of the *building envelope* shown on architectural drawings or installed in *existing buildings* shall be modeled in the *proposed design.* The *simulation program* model *fenestration* and *opaque building* envelope types and area shall be consistent with the *construction documents.* Any *building envelope* assembly that covers less than 5% of the total area of that assembly type (e.g., *exterior walls*) need not be separately described, provided it is similar to an assembly being modeled. If not separately described, the area of a *building envelope* assembly shall be added to the area of an assembly of that same type with the same *orientation* and thermal properties.

5.6.1.2 Trade-Offs Limited to Building Permit

When the *building* permit being sought applies to less than the whole *building*, parameters relating to unmodified existing conditions or to future *building* components shall be identical for both the *proposed envelope performance factor* and the *base envelope performance factor*. Future *building* components shall meet the prescriptive requirements of Section 5.5.

5.6.1.3

Envelope performance factor shall be calculated using the procedures of Normative Appendix C.

This is a normative appendix and is part of this standard.

Normative Appendix C

Methodology for Building Envelope Trade-Off Option in Section 5.6

C1 MINIMUM INFORMATION

The following minimum information shall be specified for the *proposed design*.

C1.1 At the Building Level

The *floor* area, broken down by *space conditioning categories* and *building* area type, shall be specified. Each *building* area type shall be chosen from Table 9.5.1.

C1.2 At the Exterior and Semiexterior Surface Level

The *building envelope* assembly type, gross area, *orientation*, tilt, and associated *space conditioning category* and *building* area type shall be specified. The surface shall be designated as exterior or semiexterior. A semiexterior surface separating a *conditioned space* from a *semiheated space* shall be specified with two associated *space conditioning categories*. A semiexterior surface separating a *conditioned space* from an *unconditioned space* shall be specified with an associated *space conditioning category* and with an adjacency to an *unconditioned space*. Exterior surfaces with the same *building envelope* assembly type and associated *space conditioning category* and *building* area type whose orientations differ by no more than 22.5 degrees and whose tilts differ by no more than 22.5 degrees are allowed to be described as a single surface.

C1.2.1 For Roofs

The *class of construction*, *opaque* area, *U-factor*, *HC*, and insulation position shall be specified. Where three-year-aged test data for the solar *reflectance* and three-year-aged thermal *emittance* of the exterior *roof* surface are available, the three-year-aged solar *reflectance* and three-year-aged thermal *emittance* shall be specified.

C1.2.2 For Above-Grade Walls

The *class of construction*, *opaque* area, *U-factor*, *HC*, and insulation position shall be specified.

C1.2.3 For Below-Grade Walls

The *opaque* area, average depth to the bottom of the *wall*, *C-factor*, *HC*, and insulation position shall be specified.

C1.2.4 For Floors

The *class of construction*, *opaque* area, *U-factor*, *HC*, and insulation position shall be specified.

C1.2.5 For Slab-on-Grade Floors

The *class of construction*, perimeter length, *F-factor*, and *HC* shall be specified.

C1.2.6 For Uninsulated Assemblies

All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate *floor* slabs, concrete *floor* beams over parking garages, *roof* parapet) shall be separately modeled.

C1.3 For Opaque Doors

The *class of construction*, area, and *U-factor* shall be specified. Each *opaque door* shall be associated with a surface as described in Section C1.2 and shall have the *orientation* of that surface.

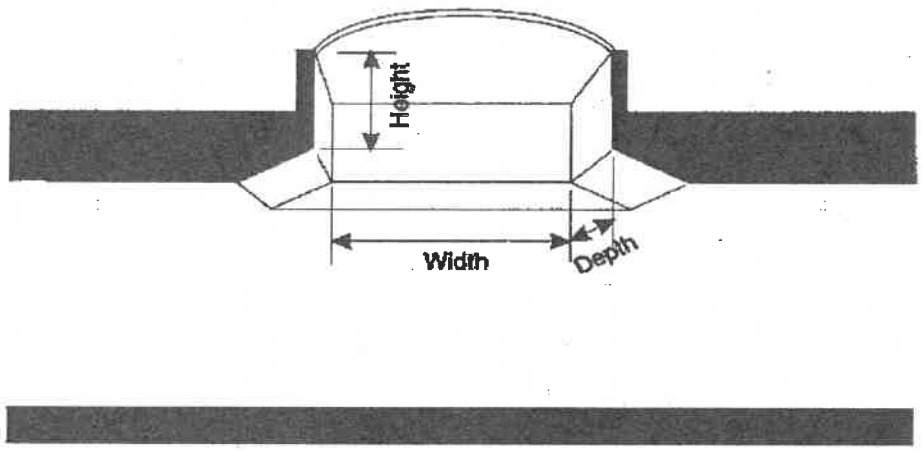

Figure C1.4 ***Skylight well*** **dimensions.**

C1.4 For Fenestration

The *class of construction*, area, assembly *U-factor*, assembly *SHGC*, *VT*, and *PF* shall be specified for *fenestration*. Each *fenestration* element shall be associated with a surface as defined in Section C1.2 and shall have the *orientation* of that surface.

C2 OUTPUT REQUIREMENTS

Output reports shall contain the following information.

C2.1

Name and contact information of the entity executing the simulation, and date of report.

C2.2

Location of the *building*, including street address and climate zone.

C2.3

Location corresponding to the weather data used to perform the simulation.

C2.4

Simulation program used to perform the simulation.

C2.5

Tables summarizing the minimum information described in Section C1.

C2.6

All differences between the *proposed envelope performance factor* and the *base envelope performance factor*.

C2.7

Peak heating and cooling loads for *building classes of constructions*.

C2.8

The version of the software and the link to the website that contains the ASHRAE Standard 140 results for the version used in accordance with Section C3.1.4.

C3 SIMULATION GENERAL REQUIREMENTS

C3.1 Simulation Program

The *simulation program* shall be a computer-based software program for the analysis of *energy* consumption in *buildings*. The *simulation program* shall include calculation methodologies for the *building* components being modeled.

Informative Note
Examples of simulation programs include, but are not limited to, EnergyPlus and DOE-2.

C3.1.1

The *simulation program* shall be approved by the *adopting authority* and shall, at minimum, have the ability to explicitly model all of the following:

a. The *base envelope performance factor*, using only the input for the *proposed envelope performance factor*. The calculation procedure shall not allow the user to directly modify the *building* component characteristics of the base design.

b. 8760 hours per year.

c. Hourly variations in occupancy, lighting power, miscellaneous *equipment* power, *thermostat set points*, and *HVAC system* operation, defined separately for each day of the week and holidays.

d. Thermal mass effects.

e. The number of thermal zones in the *proposed design* or nine thermal zones, whichever is greater.

f. *Air economizers* with integrated *control*.

g. *Continuous daylight dimming controls* and *photosensors*.

C3.1.2

The *simulation program* shall have the ability to determine the *proposed envelope performance factor* and *base envelope performance factor* by calculating annual *energy* costs.

Informative Note

Neither the *proposed envelope performance factor* nor the *base envelope performance factor* are predictions of actual energy consumption or costs for the proposed design after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this procedure, changes in energy rates between design of the building and occupancy, and the precision of the calculation tool.

C3.1.3

The *simulation program* shall be capable of performing design load calculations to determine required HVAC *equipment* capacities and airflow rates in accordance with Section 6.4.2 for both the *proposed design building envelope* and the *base design building envelope*.

C3.1.4

The *simulation program* shall be tested according to ASHRAE Standard 140, except for Sections 7 and 8, of Standard 140. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program along with the results of the other simulation programs included in ASHRAE Standard 140, Annexes B8 and B16. The modeler report in Standard 140, Annex A2, Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values or for missing results.

Informative Note

There are no pass/fail criteria established by this requirement.

C3.2 Climatic Data

The *simulation program* shall perform the simulation using hourly values of climatic data, including temperature, humidity, solar radiation, and wind speed and direction from representative climatic data, for the *proposed design building envelope* location. For cities or urban regions for which several climatic data sources are available and for locations for which weather data are not available, the designer shall select available

weather data that represent the climate at the *construction* site. Selected weather data shall be approved by the *authority having jurisdiction*.

C3.2.1 Surface Exposure

Semiexterior surfaces separating *conditioned spaces* from *unconditioned spaces* shall be simulated as exterior surfaces with no exposure to wind or solar radiation.

C3.3 Purchased Energy Rates

The following rates for *purchased energy* shall be used to determine the *proposed envelope performance factor* and the *base envelope performance factor*:

a. Electricity: $0.1063/kWh

b. Heating: $0.98/therm

Exception to C3.3

Where approved by the *authority having jurisdiction*, actual annual rates for *purchased energy* or state average *energy* prices published by the Department of Energy's Energy Information Administration shall be permitted. The same rates shall be used for both the *proposed envelope performance factor* and the *base envelope performance factor*.

C3.4 Compliance Calculations

The *proposed envelope performance factor* and *base envelope performance factor* shall be calculated using the same

a. *simulation program*,

b. climatic data, and

c. *purchased energy rates*.

C3.5 Calculation of Proposed Envelope Performance Factor

The simulation model for calculating the *proposed envelope performance factor* shall be developed in accordance with Sections C3.5.1 through C3.5.11.

C3.5.1 Space Conditioning

All *conditioned spaces* in the *proposed design* shall be simulated as being both heated and cooled, even if no cooling or heating *system* is being installed. Temperature *control set points* and schedules shall be consistent with those in the *building envelope trade-off schedules and loads* for the applicable *building* area type. All *semiheated spaces* shall be simulated as being heated and not cooled. The heating temperature *control set point* shall be 50°F for all hours.

C3.5.2 Model Geometry and Thermal Zones

The *building* model shall be divided into thermal zones described as follows:

a. Determine the ratio (R_c) of the *floor* area to the *gross wall area* for each unique combination of *space conditioning category* and *building* area type. The index "c" refers to a combination of *space conditioning category* and *building* area type as defined for each surface.

b. Create a perimeter zone for each unique combination of *building* area type, *above-grade-wall orientation*, and *space conditioning category*. If there is more than one *above-grade-wall* assembly for a *building* area type and *orientation*, each *above-grade-wall* assembly shall be placed end-to-end in the order it is defined. The area of each perimeter zone shall be the *gross wall area* of the zone times R_c or 1.25, whichever is smaller.

c. For each unique combination of *space conditioning category* and *building* area type with R_c greater than 1.25, interior zones shall be created and used in the trade-off procedure. The area of the interior zone shall be the total area for the unique combination of *space conditioning category* and *building* area type less

the area of the perimeter zones for that combination of *space conditioning category* and *building* area type.

d. Create a below-*grade* zone for each unique combination of *space conditioning category* and *building* area type associated with *below-grade walls*. If there is more than one *below-grade-wall* assembly for a *building* area type, each below-*grade-wall* assembly shall be placed end-to-end in the order it is defined. The area of each below-*grade* zone shall be the *gross wall area* of the zone times R_c or 1.25, whichever is smaller.

e. The *wall* height and the height of each thermal zone shall be 15 ft.

f. *Roof* area and *floor* area associated with each *building* area type shall be prorated among all zones of the corresponding *building* area type in proportion to the zone area of each zone. *Roof* area and *floor* area in each zone shall be centered in the horizontal plane of the zone with the same aspect ratio as the horizontal plane of the zone.

g. *Slab-on-grade floor* perimeter associated with each *building* area type shall be prorated among perimeter zones of the corresponding *building* area type in proportion to the area of each zone.

h. *Vertical fenestration area* shall be assigned to the associated surface as described in Section C1.4. *Vertical fenestration* shall be centered on the associated surface with the same aspect ratio as the associated surface. Windows with equivalent *U-factor*, *SHGC*, and *VT* that do not include fins may be combined into a single window on the associated surface.

i. *Skylight* area shall be assigned to the associated surface as described in Section C1.4, prorated among interior zones containing the *roof* area with which the *skylight* area is associated, in proportion to the associated *roof* area. If the total *skylight* area exceeds the associated *roof* area in interior zones, the remaining *skylight* area shall be prorated among perimeter zones containing the *roof* area with which the *skylight* area is associated, in proportion to the associated *roof* area.

j. Each zone shall be modeled as being fully enclosed. Zone boundaries not created as described above shall be modeled as adiabatic interior surfaces.

C3.5.3 Daylight Area and Photosensor Location

Daylight areas and *photosensors* shall not be modeled in *residential* zones. In each *nonresidential* zone, *daylight areas* and *photosensor* locations shall be modeled in accordance with the following:

a. For each *nonresidential* zone associated with *vertical fenestration*, the *daylight area* shall be modeled as directly adjacent to the *vertical fenestration* with a width equal to the width of the *vertical fenestration* and a depth equal to the head height of the *vertical fenestration*.

b. In each *nonresidential* zone associated with *skylights*, the *daylight area under skylights* shall be modeled as bounded, in each direction, by the edge of the *skylight* area plus 10 ft or the distance to the edge of the zone, whichever is less.

c. For each *daylight area* associated with *vertical fenestration*, a *photosensor* shall be modeled as located at the center of the width of the *daylight area*, at the depth of the *daylight area* and at a height of 3 ft.

d. For each *daylight area* associated with a *skylight*, a *photosensor* shall be modeled as located at the center of the horizontal plane of the *skylight* and at a height of 5 ft.

C3.5.4 Schedules

The schedule types listed in Section C3.1.1(c) shall be required input. The schedules shall be consistent with those in the *building envelope trade-off schedules and loads*[2] for the applicable *building* area type.

C3.5.5.3.1 Infiltration Schedule

Infiltration shall be adjusted in accordance with the *infiltration* schedule in the *building envelope trade-off schedules and loads* for the applicable *building* area type.

C3.5.6 Interior Surfaces

Interior surfaces shall be modeled with visible light reflectances of 0.80 for ceilings, 0.50 for *walls*, and 0.20 for *floors*. Interior surfaces shall be modeled with a thermal *emittance* of 0.90.

C3.5.7 Lighting

The modeled lighting power shall be determined using the *lighting power density* allowances in Table 9.5.1 for the applicable *building* area type. The modeled lighting power shall be adjusted in accordance with the lighting schedule in the *building envelope trade-off schedules and loads* for the applicable *building* area type. Fifty percent (50%) of lighting in *daylight areas* shall be modeled with *continuous daylight dimming controls* such that when sufficient daylight is available at the corresponding *photosensor*, lighting power is reduced to maintain a minimum 50 fc for *conditioned spaces* and 30 fc for *semiheated spaces*. The minimum light output for the *continuous daylight dimming* shall be 6% of peak light output. Power input shall be modeled as 20% of lighting power at the minimum light output and scaled linearly to 100% of lighting power at peak light output.

C3.5.8 HVAC Systems

One *HVAC system* shall be provided for each thermal zone and shall have the following characteristics:

a. Constant-volume fan *control*.

b. Electrically provided cooling with EER from Table 6.8.1-1, based on requirements for split-system air conditioners with heating section type "all other" between 65,000 Btu/h and 135,000 Btu/h. The EER shall be adjusted to remove the fan power in accordance with Section 11.5.2(c).

c. Gas furnace with constant thermal *efficiency* equal to the minimum *AFUE* allowed for gas-fired warm-air furnaces with maximum capacity <225,000 Btu/h, in accordance with Table 6.8.1-5.

d. The *ventilation* rate for each *building* area type shall be consistent with the *ventilation* rate in the *building envelope trade-off schedules and loads* for the applicable *building* area type.

e. *Air economizers*, except in Climate Zones 0 and 1. The high-limit shutoff shall be "Fixed Dry Bulb" type as described in Table 6.5.1.1.3.

f. *System* design supply air rates shall be based on a supply-air-to-room-air temperature difference of 20°F in cooling.

g. *System* capacities used in the annual simulation shall be 1.5 times the capacities determined by the sizing simulations.

h. Fans shall cycle ON whenever the *space* calls for heating or cooling. The fan power shall be 0.3 W/cfm, and the fan *energy* shall be modeled explicitly.

C3.5.9 Miscellaneous Loads

Miscellaneous loads shall be modeled as included in the *building envelope trade-off schedules and loads* for the applicable *building* area type.

C3.5.10 Occupant Density

The occupant density shall be modeled according to the peak occupant density and the occupancy rate schedule in the *building envelope trade-off schedules and loads* for the applicable *building* area type.

C3.5.11 Heat Gain from Occupants

The sensible and latent heat gain due to occupants shall be modeled as included in the *building envelope trade-off schedules and loads* for the applicable *building* area type.

C3.6 Calculation of Base Envelope Performance Factor

The simulation model for calculating the *base envelope performance factor* shall modify the simulation model for calculating the *proposed envelope performance factor* as follows:

a. All *opaque* assemblies shall be modeled with the maximum *U-factor* required in Section 5.5.3 for the appropriate *class of construction*, *space conditioning category*, and climate zone. *Mass walls* and *mass floors* shall be modeled with *HC* equal to 7.2 Btu/ft^2·°F. All other *opaque* assemblies shall be modeled with the same *HC* as the *proposed design*. *Mass walls* shall be modeled with equal mass on each side of the insulation. All other *opaque* assemblies shall be modeled with insulation on the exterior.

b. The exterior *roof* surfaces shall be modeled with a solar *reflectance* and thermal *emittance* as required in Section 5.5.3.1.1(a). All other *roofs*, including *roofs* exempted from the requirements in Section 5.5.3.1.1, shall be modeled the same as in the *proposed design*.

c. *Fenestration* shall be assumed to be flush with the *wall* or *roof*. If the *fenestration area* for new *buildings* or *additions* exceeds the maximum allowed by Section 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in Section 5.5.4.2 is met. If the *fenestration area* facing west or east of the *proposed design* exceeds the area limit set in Section 5.5.4.5, the *baseline building performance* shall be generated by simulating the *building* with its actual *orientation* and again after rotating the entire *building* 90, 180, and 270 degrees, then averaging the results of the four simulations. *Fenestration U-factor* and *SHGC* shall be the maximum allowed for the appropriate *class of construction*, *space conditioning category*, and climate zone in accordance with Section 5.5.4. Where there is no *SHGC* requirement, the *SHGC* shall be equal to 0.40 for all *vertical fenestration* and 0.55 for *skylights*. The *VT* for *fenestration* in the base envelope design shall be equal to 1.10 times the *SHGC*.

d. Manually operated interior shades shall be modeled on all *vertical fenestration* as described in Section C3.5.5.1. Permanent shading devices, such as fins and overhangs, shall not be modeled.

e. *Daylight areas* and *photosensor* locations shall be modeled as described in Section C3.5.3 after reducing the *fenestration area* as described in Section C3.6(c).

Informative Appendix D

(Retained for Future Use)

Climatic data are no longer contained in this appendix. See Section 5.1.4 for requirements. Annex 1 of this standard contains extracts of material from ASHRAE Standard 169.