EE11-2 PROPOSED BUILDING ENVELOPE CRITERIA FOR ASHRAE/IESNA STANDARD 90.1-2010

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ABSTRACT

In the United States, the 1992 Energy Policy Act (EPAct) established ASHRAE/IESNA Standard 90.1 as the baseline for State Energy Codes for commercial buildings. Standard 90.1 is updated every three years. The internal goal for the Standard 90.1 Project Committee for the 2010 version of Standard 90.1 is to achieve a 30% overall additional energy savings beyond that in Standard 90.1-2004.

In response, the Standard 90.1 Project Committee developed addenda to modify Standard 90.1-2004. Some revisions were adopted for Standard 90.1-2007, resulting in slight increases in energy-efficiency for opaque components and more significant improvements for fenestration, largely paralleling the 2006 ICC International Energy Conservation Code (IECC).

For Standard 90.1-2010, the Standard 90.1 Project Committee has proposed significant increases in stringency for insulation and for fenestration. The revised criteria were developed by the Standard 90.1 Project Committee using a combination of calculations and professional judgment. In addition, new analysis has been done on the insulating systems for metal buildings to better reflect the compression of insulation over purlins and sagging of insulation between purlins. For fenestration, lower U-factors reflect improved glass coatings and better thermal breaks in the frames. In addition, new criteria are specified for visible transmittance (VT) in terms of a minimum ratio of VT/SHGC (solar heat gain coefficient) so as to achieve good daylighting performance while minimizing solar gain.

The criteria for Portland, Oregon are presented as an example.

1. BACKGROUND

ASHRAE (the American Society of Heating, Refrigerating, and Air-Conditioning Engineers) first published Standard 90 in 1975 as *Energy Conservation in New Building Design*. The standard was republished in conjunction with IESNA (the Illuminating Engineering Society of North America) in 1980 with minor changes and in 1989 with significant revisions. In 1999, the standard was re-titled *Energy Standard for Buildings Except Low-Rise Residential Buildings* and written in code language so that it could be adopted as a code without modifications. The requirements were presented in a format so as to be easier to enforce, and the standard explicitly addressed existing buildings. Following 1999, the standard was updated in 2001, 2004, and 2007, and is now revised and republished every three years.

Standard 90.1 is on continuous maintenance, meaning that there is a standing project committee that considers modifications to the standard on an ongoing basis. The last modifications to be included in the 2010 version of the standard are expected to be approved by the ASHRAE Board of Directors at their Annual Meeting in June 2010.

2. OVERVIEW OF THE CRITERIA SETTING PROCESS

For the last ten years, the Standing Standards Project Committee (SSPC) has drafted the updates to Standard 90.1 with code compliance as a key guiding principle. For the SSPC 90.1 Envelope Panel, this meant continuing to develop the opaque envelope requirements based on typical construction assemblies for roofs, walls and floors. A broad range of classes of construction was identified, each of which has its own framing type and insulating issues resulting in different optimum performance levels. U-factors were then calculated for these assemblies, with the intent that these same values be included in Standard 90.1 and be used to demonstrate compliance so as to have a clear linkage from the development of Standard 90.1 through to the building permit process. For the fenestration, this has meant specifying the National Fenestration Rating Council (NFRC) rating and labeling procedures. Then, the energy performance was determined for a range of options using regression equations based on hourly DOE-2 analysis.

By establishing the requirements on an assembly-by-assembly basis, it also enables Standard 90.1 to be written to respond to the various degrees of sophistication in the building and code compliance industry. For that segment of the construction industry which is least knowledgeable about energy, there is a simple, true prescriptive compliance option, which specifies R-values for the insulation alone and U-factors, solar heat gain coefficient (SHGC), as well as a ratio of visible transmittance (VT) to SHGC for the fenestration. Note that, while the criteria for opaque assemblies has been set based on the performance of the complete assembly (e.g. roof, wall, floor), the R-value is specified for the insulation alone and does NOT include any building materials or air films. This will be easy to understand and allow a contractor to get the building permit fast and have the building inspector sign off on the construction. (This was one of the areas neglected in previous versions of Standard 90.1.)

However, there is also an alternate compliance option in the prescriptive approach that allows the user to show compliance for U-factor for the overall assembly. This overall assembly U-factor includes the insulation, plus the framing, any interior or exterior sheathing, and interior and exterior air films. The U-factor includes the thermal bridging of the various framing components, metal or wood. The U-factor for the overall assembly is NOT simply the inverse of the insulation R-value. However, these calculations can be complicated. To ensure that the calculations are done correctly, and for ease of use for those used to demonstrating compliance for overall assembly U-factors and desiring that flexibility, tables of pre-calculated values are included in Appendix A and cover the common options. The use of calculations will be limited more, with testing of assemblies as the preferred alternate, but where calculations are allowed, there will be clearer guidance. The original intent should be clearer, with more uniform and better implementation which means more energy savings, even though the criteria may be similar.

3. OPAQUE ENVELOPE ISSUES AND SOLUTIONS

Roofs, walls, floors, and opaque doors were subdivided into classes of construction.
- The roof types are: (1) roofs with insulation entirely above the deck, (2) metal building roofs, and (3) roofs with attics. (An exception addresses single-rafter roof/ceilings with wood joists).
- The above grade wall types are: (1) mass walls, (2) metal building walls, (3) steel-framed walls, and (4) wood-framed walls.
- There is one below grade wall type.
- The floor over unconditioned space types are: (1) mass floors, (2) steel joist floors, and (3) wood joist floors.
- The slab on grade floor types are:
(1) unheated slabs and (2) heated slabs.
- The opaque door types are: (1) swinging and (2) nonswinging.

Criteria were then established separately for each class of construction.

While a construction assembly may be common, the heat flow through it may be quite complex. Building officials are not trained in the nuances of U-factor calculations. Unfortunately, it appears that many designers also do not have that good an understanding of the science either. Even where there is an understanding, the complexity of calculation procedures, such as the zone method in Chapter 27 of the *2009 ASHRAE Handbook--Fundamentals*, may discourage their use. As a result, assumptions are made that don’t accurately reflect the heat flow.

Each of the general construction types presents its own problems. One of the most common errors, and most significant, is ignoring the metal stud in a steel frame wall. This may seem a reasonable assumption to both a designer and a building official because only a small, skinny element is being left out. The decision is also appealing because it also serves to simplify the calculations. Unfortunately, that thin piece of metal is such an excellent heat conductor that it reduces the effectiveness of the insulation roughly in half. Similarly, metal in roof and floor assemblies must <u>not</u> be neglected. For wood framing, there are similar inclinations to simplify the calculation process. It is easier (and one gets higher R-values) if the framing is neglected and the calculation only includes the insulated cavity. Even when framing is included, its contribution is often underestimated when only the primary framing is included, and plates, sills and headers are ignored. For metal buildings, there are further complexities with a metal skin being attached to a metal frame, and compression of insulation.

To respond to these problems, Standard 90.1 contains overall assembly U-factors for a wide variety of the most common assemblies with a range of insulation options. By providing pre-calculated U-factors, the designers and building officials will not need to make decisions about simplifying assumptions. For the designers, this means that they can evaluate more design options without doing calculations. For the building official, this means that the intent of the code requirements is clearer and compliance checking easier, thereby enabling fairer and more consistent treatment.

4. FENESTRATION ISSUES AND SOLUTIONS

Fenestration is subdivided into vertical fenestration and skylights.
- The vertical fenestration types, subdivided by frame material type and operator type, are: (1) nonmetal framing, (2) metal framing, fixed, (3) metal framing, operable, and (4) metal framing, entrance door.
- There is one category for all skylights.

To set the criteria, a range of frame, number of glass layers, low-e coatings, gas fills, and spacers were evaluated. For consistency, fenestration performance is based on the NFRC (National Fenestration Rating Council) rating procedures for U-factors, solar heat gain coefficient (SHGC) and visible transmittance (VT). The NFRC ratings are based on the entire fenestration product including glazing, sash, and frame. So as to ensure that low solar gain is achieved by products with good visible transmittance for daylighting, a minimum VT/SHGC ratio is specified. Products with very low VT/SHGC ratios, such as glass with mirror coatings, were removed from consideration. The analysis included the potential benefits of daylighting by assuming automatic daylighting controls to reduce electrical consumption for lighting (so that the full benefits of fenestration are considered when sizing windows and skylights).

The innovation that has occurred in the fenestration industry over the past two decades has been astonishing: low-emissivity coatings and films, inert gas fills, low-conductivity spacers, and advanced frame materials and designs. These innovations responded to a demand for more energy efficient products, but presented a difficulty as manufacturers sought to take credit for the new technologies towards compliance with Energy Codes. Several problem areas were quickly identified. First, there needed to be a better rating system as the simple calculations of the past did not and could not adequately address the complexities of the present. Second, the new technologies did not lend themselves to visual inspection so there needed to be some way for the technologies to be verified.

The National Fenestration Rating Council (NFRC) has developed a comprehensive response to these issues. The National Fenestration Rating Council (NFRC) was formed in 1989 to respond to a need for fair, accurate, and credible ratings for fenestration products. Fenestration products include all types of windows, skylights, and doors, both glazed and opaque: vertical sliders, horizontal sliders, casements, projecting (awning), fixed (includes non-standard shapes), single door with frame, double and multiple doors with frames, glazed wall systems (site-built windows), skylights and sloped glazings, greenhouse/garden, dual action, and pivoted windows. NFRC has adopted and updated rating procedures for U-factor (*NFRC 100*), solar heat gain coefficient and visible transmittance (*NFRC 200*), and air leakage (*NFRC 400*).

This process has a number of noteworthy features that make it superior to previous fenestration energy rating systems and correct past problems.

- First, the procedures provide a means for manufacturers to take credit for all the nuances and refinement to their product design, and a common basis for others to compare product claims.
- Second, the involvement of independent laboratories and the inspection agency provides architects, engineers, designers, contractors, consumers, building officials, and utility representatives with greater confidence that the information is unbiased.
- Third, by requiring simulation and testing, there is an automatic check on accuracy. This also remedies a shortcoming of previous State Energy Code requirements that relied on testing alone, which allowed manufacturers to perform several tests and then use the best one for code purposes.
- Fourth, the certification process indicates that the manufacturer is consistently producing the product that was rated. This also corrects a past problem where manufacturers were able to make an exceptionally high quality sample and obtain a good rating in a test, but not consistently produce that product.
- Fifth, there is now a readily visible temporary label that can be used by the building inspector to quickly verify compliance with the Energy Code. (For site-built products, there is an NFRC Label Certificate for each fenestration operator type.)
- Sixth, there is now a permanent label that enables future access to energy rating information.

5. PRESENTATION OF THE REQUIREMENTS

To simplify use of the document, all of the key Building Envelope requirements for all space-conditioning categories are presented in a single table for a particular climate. Generally, criteria are specified in two ways: prescriptive (such as the R-value for the insulation alone without building materials or airfilms) and component performance (the U-factor, C-factor, or F-factor for the entire assembly and including the thermal bridging effects of framing members).

Building envelope requirements vary by the three space-conditioning categories: nonresidential conditioned space (daytime use, higher internal loads), residential conditioned space (24-hour occupancy, shell-dominated due to lower internal loads), and both nonresidential and residential semiheated space (heating to a lower level).

Climates are grouped into eight broad ranges of heating degree-days (HDD) base 18 C (65°F) and cooling degree-days (CDD) base 10 C (50°F). Grouping into ranges (rather than having a graph that varies by degree days) allows the user to more easily determine requirements. This also results in adjacent locales generally having the same requirements, simplifying Energy Code compliance. HDD base 18 C (65°F) was chosen for heating as most heating occurs during unoccupied hours when internal loads are low. CDD base 10 C (50°F) was chosen for cooling as most cooling occurs during occupied hours when loads from people, lights, equipment, and solar gains are higher.

To simplify compliance for climates within the United States, each county has been assigned to a climate zone as shown in Appendix B Figure B-1. The counties are also listed by name for each state in Table B-1. For Canada, the climate zones are listed for major cities in Table B-2. For international locations, the climate zones are listed for major cities in Table B-3.

6. SAMPLE CRITERIA - PORTLAND OREGON

Per Appendix B, Portland Oregon in Multnomah County is assigned to Climate Zone 4 Marine. The applicable criteria are in Table 5.5-4. The values are shown in table format at the end of the document, for both the proposed 2010 version and the 2007 version, with the SI table first, followed by the I-P table. Within the text below, the proposed criteria for the 2010 version of Standard 90.1 are shown first and then compared with the 2007 version in SI units (with the I-P comparison shown in parentheses). R-values are expressed in units of $m^2 \cdot K/W$ ($h \cdot ft^2 \cdot °F/Btu$). U-factors are expressed in units of $W/m^2 \cdot K$ ($Btu/h \cdot ft^2 \cdot °F$). The solar heat gain coefficient (SHGC) and visible transmittance (VT) in SHGC and VT/SHGC are dimensionless numbers.

The first column in each table contains the criteria for nonresidential conditioned spaces. The middle column contains the criteria for residential conditioned spaces in buildings more than three stories tall. In a number of cases, the requirements are a notch higher, reflecting the fact that residential buildings are envelope load dominated. The right-hand column contains the criteria for semi-heated spaces such as warehouses with very minimal heating for freeze protection only. Required insulation levels are lower and there are no SHGC requirements.

6.1 Nonresidential Conditioned Spaces

For roofs with insulation above the roof deck (a typical flat roof), the user can comply either by installing R-5.3 vs. R-3.5 (R-30 vs. R-20) insulation in a continuous manner uninterrupted by framing or by any other method that will achieve a maximum U-factor of 0.184 vs. U-0.273 (U-factor of 0.032 vs. U-0.048). Note that the maximum U-factor for a metal building roof is higher at U-0.199 vs. U-0.369 (U-0.039 vs. U-0.065), even though the insulation requirements are comparable at R-3.3 + R-1.9 liner system vs. previously R-3.3 cavity insulation only (R-19 + R-11 liner system vs. previously R-19 cavity insulation only) reflecting the compression of insulation and thermal bridging by the metal that is typical in metal buildings. For attics, the U-factor of U-0.119 vs. U-0.153 (U-0.021 vs. U-0.027) is the lowest and the insulation requirement of R-8.6 vs. R-6.7 (R-49 vs. R-38) is the highest of the roof types.

For walls above grade in nonresidential conditioned spaces, the highest U-factor of U-0.592 vs. U-0.592 (U-0.104 vs. U-0.104) and the lowest insulation requirements are for mass walls at R-1.7 continuous insulation uninterrupted by framing vs. R-1.7 c.i. (R-9.5 continuous insulation uninterrupted by framing vs. R-9.5 c.i.) thereby providing a credit for thermal mass. For metal building walls, the U-factor criteria of U-0.341 vs. U-0.142 (U-0.060 vs. U-0.113) now rely upon continuous insulation of R-2.8 vs. previously R-2.3 cavity insulation (continuous insulation of R-15.8 vs. previously R-13 cavity insulation) to avoid the thermal bridging of the metal studs. Steel stud walls need R-2.3 cavity insulation plus R-1.8 insulation which is continuous over the framing vs. R-2.3 + R-1.3 c.i. (R-13 cavity insulation plus R-10 insulation which is continuous over the framing vs. R-13 + R-7.5 c.i.) or to achieve a U-0.315 vs. U-0.365 (U-0.055 vs. U-0.064). Wood stud walls need R-2.3 cavity insulation plus R-1.3 insulation which is continuous over the framing vs. previously R-2.3 cavity insulation only (R-13 cavity insulation plus R-7.5 insulation which is continuous over the framing vs. previously R-13 cavity insulation only) or to achieve a U-0.291 vs. U-0.504 (U-0.051 vs. U-0.089).

For walls below grade in nonresidential conditioned spaces, the requirement is C-0.678 vs. C-6.473 (C-0.119 vs. C-1.140) and the insulation requirements are R-1.3 continuous insulation uninterrupted by framing vs. previously no insulation required (R-7.5 continuous insulation uninterrupted by framing vs. previously no insulation required). Note that the overall assembly requirement is expressed in terms of a C-factor which only includes the components of the wall assembly itself, and does not include air films or soil. (The air films and soil were considered in developing the criteria, but have been removed from the values in the table to simplify the compliance process.)

For floors in nonresidential conditioned spaces, the highest U-factor of U-0.321 vs. U-0.496 (U-0.057 vs. U-0.087) and the lowest insulation requirements are for mass floors at R-2.6 vs. R-1.5 (R-14.6 vs. R-8.3) thereby providing a credit for thermal mass. Steel joist floors need R-6.7 cavity insulation vs. R-5.3 (R-38 cavity insulation vs. R-30) or to achieve a U-0.183 vs. U-0.214 (U-0.032 vs. U-0.038). Wood framed floors also need R-6.7 cavity insulation vs. R-5.3 (R-38 cavity insulation vs. R-30) or to achieve a U-0.153 vs. U-0.188 (U-0.027 vs. U-0.033).

For slab on grade floors in nonresidential conditioned spaces, unheated slabs (i.e. those that do not have heating elements in the slab itself) must have R-2.6 (R-15) perimeter insulation extending down 600 mm (24 inches) from the top of the slab vs. previously no insulation was required to achieve an F-0.900 vs. F-1.264 (F-0.52 vs. F-0.73). Heated slabs (i.e. those that have heating elements such as pipes with hot water or electric coils in the slab) must have R-3.5 perimeter insulation extending down 600 mm from the top of the slab vs. R-2.6 for 600 mm (R-20 perimeter insulation extending down 24 inches from the top of the slab vs. R-15 for 24 inches) or to achieve an F-1.459 vs. F-1.489 (F-0.843 vs. F-0.86). Note that the F-factor is the heat loss through the slab expressed per lineal foot of perimeter of the slab, rather than per square foot of slab area.

For opaque doors in nonresidential conditioned spaces, both swinging and nonswinging doors have a maximum U-2.839 vs. previously U-3.975 and U-2.839, respectively (U-0.50 vs. previously U-0.70 and U-0.50, respectively), meaning that the doors need to have an insulated core vs. previously no insulation was required.

For vertical fenestration in nonresidential conditioned spaces, the maximum area allowed in the prescriptive compliance option is 30% of the gross wall area vs. previously 40% maximum. This covers the average fenestration area for most building types.

For vertical fenestration in nonresidential conditioned spaces, the requirement is for U-1.82 vs. U-2.27 (U-0.32 vs. U-0.40) for nonmetal framing, U-2.16 vs. U-2.84 (U-0.38 vs. U-0.50) for fixed windows with metal framing including curtainwalls, U-2.56 vs. U-3.12 (U-0.45 vs. U-0.55) for operable windows with metal framing, and U-4.37 vs. U-4.83 (U-0.77 vs. U-0.85) for entrance doors with metal framing. All of these are meant to correspond to an excellent double-glazed product in an excellent frame. The solar heat gain coefficient requirement is SHGC-0.30 vs. SHGC-0.40. The VT/SHGC ratio is 1.10 vs. previously no requirement in the prescriptive compliance option, though criteria did exist in the EnvStd performance alternate in Appendix C).

For skylights in nonresidential conditioned spaces, the maximum area allowed in the prescriptive compliance option is 3% of the gross roof area vs. previously 5% maximum.

For skylights in nonresidential conditioned spaces, the requirement is U-3.41 for all skylights vs. previously U-6.64 for glass skylights with curbs, U-7.38 for plastic skylights with curbs, and U-3.92 for all skylights without curbs (U-0.60 for all skylights vs. previously U-1.17 for glass skylights with curbs, U-1.30 for plastic skylights with curbs, and U-0.69 for all skylights without curbs). The solar heat gain coefficient requirement is SHGC-0.40 vs. SHGC-0.34 to SHGC-0.65 depending on skylight type and skylight area as a percent of gross roof area. There is no VT/SHGC ratio requirement in the prescriptive compliance option, though criteria do exist in the EnvStd performance alternate in Appendix C.

Skylight criteria match those in the 2009 version of the ICC International Energy Conservation Code (IECC).

6.2 Residential Conditioned Spaces

For roofs with insulation above the roof deck vs. a typical flat roof, the user can comply either by installing R-5.3 vs. R-3.5 (R-30 vs. R-20) insulation in a continuous manner uninterrupted by framing or by any other method that will achieve a maximum U-factor of 0.184 vs. U-0.273 (U-factor of 0.032 vs. U-0.048). Note that the maximum U-factor for a metal building roof is higher at U-0.199 vs. U-0.369 (U-0.035 vs. U-0.065), even though the insulation requirements are comparable at R-3.3 + R-1.9 liner system vs. previously R-3.3 cavity insulation only (R-19 + R-11 liner system vs. previously R-19 cavity insulation only) reflecting the compression of insulation and thermal bridging by the metal that is typical in metal buildings. For attics, the U-factor of U-0.119 vs. U-0.153 (U-0.021 vs. U-0.027) is the lowest and the insulation requirement of R-8.6 vs. R-6.7 (R-49 vs. R-38) is the highest of the roof types.

For walls above grade in residential conditioned spaces, the highest U-factor of U-0.513 vs. U-0.513 (U-0.090 vs. U-0.090) and the lowest insulation requirements are for mass walls at R-2.0 continuous insulation uninterrupted by framing vs. R-2.0 c.i. (R-11.4 continuous insulation uninterrupted by framing vs. R-11.4 c.i.) thereby providing a credit for thermal mass. For metal building walls, the U-factor criteria of U-0.286 vs. U-0.642 (U-0.050 vs. U-0.113) now rely upon continuous insulation of R-3.3 vs. previously R-2.3 cavity insulation (continuous insulation of R-19 vs. previously R-13 cavity insulation) to avoid the thermal bridging of the metal studs. Steel stud walls need R-2.3 cavity insulation plus R-2.2 insulation which is continuous over the framing vs. R-2.3 + R-1.3 c.i. (R-13 cavity insulation plus R-12.5 insulation which is continuous over the framing vs. R-13 + R-7.5 c.i.) or to achieve a U-0.277 vs. U-0.365 (U-0.049 vs. U-0.064). Wood stud walls need R-2.3 cavity insulation plus R-1.8 insulation which is continuous over the framing vs. previously R-2.3 + R-0.7 c.i. (R-13 cavity insulation plus R-10 insulation which is continuous over the framing vs. previously R-13 + R-3.8 c.i.) or to achieve a U-0.257 vs. U-0.365 (U-0.045 vs. U-0.064).

For walls below grade in residential conditioned spaces, the requirement is C-0.522 vs. C-0.678 (C-0.092 vs. C-0.119) and the insulation requirements are R-1.8 continuous insulation uninterrupted by framing vs. R-1.3 c.i. (R-10 continuous insulation uninterrupted by framing vs.

R-7.5 c.i.). Again, note that the overall assembly requirement is expressed in terms of a C-factor which only includes the components of the wall assembly itself, and does not include air films or soil. (The air films and soil were considered in developing the criteria, but have been removed from the values in the table to simplify the compliance process.)

For floors in residential conditioned spaces, the highest U-factor of U-0.287 vs. U-0.420 (U-0.051 vs. U-0.074) and the lowest insulation requirements are for mass floors at R-2.9 vs. R-1.8 (R-16.7 vs. R-10.4) thereby providing a credit for thermal mass. Steel joist floors need R-6.7 cavity insulation vs. R-5.3 (R-38 cavity insulation vs. R-30) or to achieve a U-0.183 vs. U-0.214 (U-0.032 vs. U-0.038). Wood framed floors also need R-6.7 cavity insulation vs. R-5.3 (R-38 cavity insulation vs. R-30) or to achieve a U-0.153 vs. U-0.188 (U-0.027 vs. U-0.033).

For slab on grade floors in residential conditioned spaces, unheated slabs (i.e. those that do not have heating elements in the slab itself) must have R-2.6 perimeter insulation extending down 600 mm from the top of the slab vs. R-1.8 for 600 mm (R-15 perimeter insulation extending down 24 inches from the top of the slab vs. R-10 for 24 inches) or to achieve an F-0.900 vs. F-0.935 (F-0.52 vs. F-0.54). Heated slabs (i.e. those that have heating elements such as pipes with hot water or electric coils in the slab) must have R-3.5 perimeter insulation extending down 1200 mm from the top of the slab vs. R-2.6 for 600 mm (R-20 perimeter insulation extending down 48 inches from the top of the slab vs. R-15 for 24 inches) or to achieve an F-1.191 vs. F-1.489 (F-0.688 vs. F-0.86). Again, note that the F-factor is the heat loss through the slab expressed per lineal foot of perimeter of the slab, rather than per square foot of slab area.

For opaque doors in residential conditioned spaces, both swinging and nonswinging doors have a maximum U-2.839 vs. previously U-3.975 and U-2.839, respectively (U-0.50 vs. previously U-0.70 and U-0.50, respectively), meaning that the doors need to have an insulated core vs. previously no insulation was required for swinging doors.

For vertical fenestration in residential conditioned spaces, the maximum area allowed in the prescriptive compliance option is 30% of the gross wall area vs. previously 40% maximum. This covers the average fenestration area for most building types.

For vertical fenestration in residential conditioned spaces, the requirement is for U-1.82 vs. U-2.27 (U-0.32 vs. U-0.40) for nonmetal framing, U-2.16 vs. U-2.84 (U-0.38 vs. U-0.50) for fixed windows with metal framing including curtainwalls, U-2.56 vs. U-3.12 (U-0.45 vs. U-0.55) for operable windows with metal framing, and U-3.86 vs. U-4.83 (U-0.68 vs. U-0.85) for entrance doors with metal framing. All of these are meant to correspond to an excellent double-glazed product in an excellent frame. The solar heat gain coefficient requirement is SHGC-0.30 vs. SHGC-0.40. The VT/SHGC ratio is 1.10 vs. previously no requirement in the prescriptive compliance option, though criteria did exist in the EnvStd performance alternate in Appendix C.

For skylights in residential conditioned spaces, the maximum area allowed in the prescriptive compliance option is 3% of the gross roof area vs. previously 5% maximum.

For skylights in residential conditioned spaces, the requirement is U-3.41for all skylights vs. previously U-5.56 for glass skylights with curbs, U-7.38 for plastic skylights with curbs, and

U-3.29 for all skylights without curbs (U-0.60 for all skylights vs. previously U-0.98 for glass skylights with curbs, U-1.30 for plastic skylights with curbs, and U-0.58 for all skylights without curbs). The solar heat gain coefficient requirement is SHGC-0.40 vs. SHGC-0.19 to SHGC-0.62 depending on skylight type and skylight area as a percent of gross roof area. There is no VT/SHGC ratio requirement in the prescriptive compliance option, though criteria do exist in the EnvStd performance alternate in Appendix C.

Skylight criteria match those in the 2009 version of the ICC International Energy Conservation Code (IECC).

7. REFERENCES

(1) ASHRAE. 2007. *BSR/ASHRAE/IESNA 90.1-2007, Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

(2) ASHRAE. 2009. *BSR/ASHRAE/IES Addendum bb to ANSI/ASHRAE/IES Standard 90.1-2007, Second Public Review - ISC*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

ASHRAE/IESNA Standard 90.1-2010 vs. as proposed in addendum bb), SI units

Table 5.5-4 Building Envelope Requirements For Climate Zone 4 vs. A,B,C) vs. SI)*

	NONRESIDENTIAL			RESIDENTIAL			SEMIHEATED		
OPAQUE ELEMENTS	**Assembly Maximum**	**Insulation Min. R -Value**		**Assembly Maximum**	**Insulation Min. R -Value**		**Assembly Maximum**	**Insulation Min. R -Value**	
Roofs									
Insulation Entirely above Deck	U-0.184	R-5.3 c.i.		U-0.184	R-5.3 c.i.		U-0.527	R-1.8 c.i.	
Metal Building[a]	U-0.199	R-3.3 + R-1.9 Ls		U-0.199	R-3.3 + R-1.9 Ls		U-0.466	R-3.3	
Attic and Other	U-0.119	R-8.6		U-0.119	R-8.6		U-0.192	R-5.3	
Walls, Above Grade									
Mass	U-0.592	R-1.7 c.i.		U-0.513	R-2.0 c.i.		U-3.293	NR	
Metal Building	U-0.341	R-0 + R-2.8 c.i.		U-0.286	R-0 + R-3.3 c.i		U-0.920	R-2.3	
Steel Framed	U-0.315	R-2.3 + R-1.8 c.i		U-0.277	R-2.3 + R-2.2c.i.-		U-0.705	R-2.3	
Wood Framed and Other	U-0.291	R-2.3 + R-1.3 c.i.		U-0.257	R-2.3 + R-1.8 c.i.		U-0.504	R-2.3	
Wall, Below Grade									
Below Grade Wall	C-0.678	R-1.3 c.i.		C-0.522	R-1.8 c.i.		C-6.473	NR	
Floors									
Mass	U-0.321	R-2.6 c.i.		U-0.287	R-2.9 c.i.		U-0.606	R-1.1 c.i.	
Steel Joist	U-0.183	R-6.7		U-0.183	R-6.7		U-0.296	R-3.3	
Wood Framed and Other	U-0.153	R-6.7		U-0.153	R-6.7		U-0.288	R-3.3	
Slab-On-Grade Floors									
Unheated	F-0.900	R-2.6 for 600 mm		F-0.900	R-2.6 for 600 mm		F-1.264	NR	
Heated	F-1.459	R-3.5 for 600 mm		F-1.191	R-3.5 for 1200 mm		F-1.558	R-1.8 for 600 mm	
Opaque Doors									
Swinging	U-2.839			U-2.839			U-3.975		
Non-Swinging	U-2.839			U-2.839			U-8.233		
FENESTRATION	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**
Vertical Fenestration, 0-30% of Wall		vs. for all frame types)			vs. for all frame types)			vs. for all frame types)	
Nonmetal framing vs. all)	U-1.82	SHGC-0.30	1.10	U-1.82	SHGC-0.30	1.10	U-2.90	NR	NR
Metal framing, fixed	U-2.16			U-2.16			U-4.14		
Metal framing, operable	U-2.56			U-2.56			U-4.60		
Metal framing, entrance door	U-4.37			U-3.86			U-4.37		
Skylight, 0-3% of Roof									
All types	U-3.41	SHGC-0.40	NR	U-3.41	SHGC-0.40	NR	U-6.53	NR	NR

* The following definitions apply: c.i. = continuous insulation vs. see Section 3.2), FC = filled cavity vs. see Section A2.3.2.5), Ls = liner system vs. see Section A2.3.2.4), NR = no vs. insulation) requirement.

[a] When using the R-value compliance method for metal building roofs, a thermal spacer block is required vs. see Section A2.3.2).

ASHRAE/IESNA Standard 90.1-2010 vs. as proposed in addendum bb), I-P units

Table 5.5-4 Building Envelope Requirements For Climate Zone 4 vs. A,B,C) vs. IP)*

	NONRESIDENTIAL		RESIDENTIAL		SEMIHEATED	
OPAQUE ELEMENTS	**Assembly Maximum**	**Insulation Min. R -Value**	**Assembly Maximum**	**Insulation Min. R -Value**	**Assembly Maximum**	**Insulation Min. R –Value**
Roofs						
Insulation Entirely above Deck	U-0.032	R-30 c.i.	U-0.032	R-30 c.i.	U-0.093	R-10 c.i.
Metal Building[a]	U-0.035	R-19 + R-11 Ls	U-0.035	R-19 + R-11 Ls	U-0.082	R-19
Attic and Other	U-0.021	R-49	U-0.021	R-49	U-0.034	R-30
Walls, Above Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.060	R-0 + R-15.8 c.i.	U-0.050	R-0 + R-19 c.i.	U-0.162	R-13
Steel Framed	U-0.055	R-13 + R-10 c.i.	U-0.049	R-13 + R-12.5c.i.-	U-0.124	R-13
Wood Framed and Other	U-0.051	R-13 + R-7.5 c.i.	U-0.045	R-13 + R-10 c.i.	U-0.089	R-13
Wall, Below Grade						
Below Grade Wall	C-0.119	R-7.5 c.i.	C-0.092	R-10 c.i.	C-1.140	NR
Floors						
Mass	U-0.057	R-14.6 c.i.	U-0.051	R-16.7 c.i.	U-0.107	R-6.3 c.i.
Steel Joist	U-0.032	R-38	U-0.032	R-38	U-0.052	R-19
Wood Framed and Other	U-0.027	R-38	U-0.027	R-38	U-0.051	R-19
Slab-On-Grade Floors						
Unheated	F-0.520	R-15 for 24 in.	F-0.520	R-15 for 24 in.	F-0.730	NR
Heated	F-0.843	R-20 for 24 in.	F-0.688	R-20 for 48 in.	F-0.900	R-10 for 24 in.
Opaque Doors						
Swinging	U-0.500		U-0.500		U-0.700	
Non-Swinging	U-0.500		U-0.500		U-1.450	

FENESTRATION	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Min. VT/SHGC**
Vertical Fenestration, 0-30% of Wall		vs. for all frame types)			vs. for all frame types)			vs. for all frame types)	
Nonmetal framing vs. all)	U-0.32	SHGC-0.30	1.10	U-0.32	SHGC-0.30	1.10	U-0.51	NR	NR
Metal framing, fixed	U-0.38			U-0.38			U-0.73		
Metal framing, operable	U-0.45			U-0.45			U-0.81		
Metal framing, entrance door	U-0.77			U-0.68			U-0.77		
Skylight, 0-3% of Roof									
All types	U-0.60	SHGC-0.40	NR	U-0.60	SHGC-0.40	NR	U-1.15	NR	NR

* The following definitions apply: c.i. = continuous insulation vs. see Section 3.2), FC = filled cavity vs. see Section A2.3.2.5), Ls = liner system vs. see Section A2.3.2.4), NR = no vs. insulation) requirement.

[a] When using the R-value compliance method for metal building roofs, a thermal spacer block is required vs. see Section A2.3.2).

ASHRAE/IESNA Standard 90.1-2007, SI units

TABLE 5.5-4 Building Envelope Requirements for Climate Zone 4 (A, B, C)[*]

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.273	R-3.5 c.i.	U-0.273	R-3.5 c.i.	U-0.982	R-0.9 c.i.
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-0.551	R-1.8
Attic and Other	U-0.0.153	R-6.7	U-0.153	R-6.7	U-0.300	R-3.3
Walls, Above-Grade						
Mass	U-0.592	R-1.7 c.i.	U-0.513	R-2.0 c.i.	U-3.293	NR
Metal Building	U-0.142	R-2.3	U-0.642	R-2.3	U-0.761	R-1.8
Steel-Framed	U-0.365	R-2.3 + R-1.3	U-0.365	R-2.3 + R-1.3 c.i.	U-0.705	R-2.3
Wood-Framed and Other	U-0.504	R-2.3	U-0.365	R-2.3 + R-0.7 c.i.	U-0.504	R-2.3
Walls, Below-Grade						
Below-Grade Wall	C-6.473	NR	C-0.678	R-1.3 c.i.	C-6.473	NR
Floors						
Mass	U-0.496	R-1.5 c.i.	U-0.420	R-1.8 c.i.	U-0.780	R-0.7 c.i.
Steel-Joist	U-0.214	R-5.3	U-0.214	R-5.3	U-0.390	R-2.3
Wood-Framed and Other	U-0.188	R-5.3	U-0.188	R-5.3	U-0.376	R-2.3
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-0.935	R-1.8 for 600 mm	F-1.264	NR
Heated	F-1.489	R-2.6 for 600 mm	F-1.489	R-2.6 for 600 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Nonswinging	U-2.839		U-2.839		U-8.233	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-2.27		U-2.27		U-6.81	
Metal framing (curtainwall/storefront)[c]	U-2.84	SHGC-0.40 all	U-2.84	SHGC-0.40 all	U-6.81	SHGC-NR all
Metal framing (entrance door)[c]	U-4.83		U-4.83		U-6.81	
Metal framing (all other)[c]	U-3.12		U-3.12		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–6.64	$SHGC_{all}$–0.49	U_{all}–5.56	$SHGC_{all}$–0.36	U_{all}–11.24	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–6.64	$SHGC_{all}$–0.39	U_{all}–5.56	$SHGC_{all}$–0.19	U_{all}–11.24	$SHGC_{all}$–NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–7.38	$SHGC_{all}$–0.65	U_{all}–7.38	$SHGC_{all}$–0.62	U_{all}–10.79	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–7.38	$SHGC_{all}$–0.34	U_{all}–7.38	$SHGC_{all}$–0.27	U_{all}–10.79	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–3.92	$SHGC_{all}$–0.49	U_{all}–3.29	$SHGC_{all}$–0.36	U_{all}–7.72	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–3.92	$SHGC_{all}$–0.39	U_{all}–3.29	$SHGC_{all}$–0.19	U_{all}–7.72	$SHGC_{all}$–NR

[*] The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[b] Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c] Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance doors.

ASHRAE/IESNA Standard 90.1-2007, I-P units

TABLE 5.5-4 Building Envelope Requirements For Climate Zone 4 (A, B, C)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.048	R-20.0 c.i.	U-0.048	R-20.0 c.i.	U-0.173	R-5.0 c.i.
Metal Building	U-0.065	R-19.0	U-0.065	R-19.0	U-0.097	R-10.0
Attic and Other	U-0.027	R-38.0	U-0.027	R-38.0	U-0.053	R-19.0
Walls, Above-Grade						
Mass	U-0.104	R-9.5 c.i.	U-0.090	R-11.4 c.i.	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.134	R-10.0
Steel-Framed	U-0.064	R-13.0 + R-7.5 c.i.	U-0.064	R-13.0 + R-7.5 c.i.	U-0.124	R-13.0
Wood-Framed and Other	U-0.089	R-13.0	U-0.064	R-13.0 + R-3.8 c.i.	U-0.089	R-13.0
Walls, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-0.119	R-7.5 c.i.	C-1.140	NR
Floors						
Mass	U-0.087	R-8.3 c.i.	U-0.074	R-10.4 c.i.	U-0.137	R-4.2 c.i.
Steel-Joist	U-0.038	R-30.0	U-0.038	R-30.0	U-0.069	R-13.0
Wood-Framed and Other	U-0.033	R-30.0	U-0.033	R-30.0	U-0.066	R-13.0
Slab-On-Grade Floors						
Unheated	F-0.730	NR	F-0.540	R-10 for 24 in.	F-0.730	NR
Heated	F-0.860	R-15 for 24 in.	F-0.860	R-15 for 24in.	F-1.020	R-7.5 for 12 in.
Opaque Doors						
Swinging	U-0.700		U-0.700		U-0.700	
Nonswinging	U-1.500		U-0.500		U-1.450	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-0.40	SHGC-0.40 all	U-0.40	SHGC-0.40 all	U-1.20	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-0.50		U-0.50		U-1.20	
Metal framing (entrance door)[c]	U-0.85		U-0.85		U-1.20	
Metal framing (all other)[c]	U-0.55		U-0.55		U-1.20	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}–1.17	$SHGC_{all}$–0.49	U_{all}–0.98	$SHGC_{all}$–0.36	U_{all}–1.98	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.17	$SHGC_{all}$–0.39	U_{all}–0.98	$SHGC_{all}$–0.19	U_{all}–1.98	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}–1.30	$SHGC_{all}$–0.65	U_{all}–1.30	$SHGC_{all}$–0.62	U_{all}–1.90	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–1.30	$SHGC_{all}$–0.34	U_{all}-1.30	$SHGC_{all}$–0.27	U_{all}–1.90	$SHGC_{all}$–NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}–0.69	$SHGC_{all}$–0.49	U_{all}–0.58	$SHGC_{all}$–0.36	U_{all}–1.36	$SHGC_{all}$–NR
2.1%–5.0%	U_{all}–0.69	$SHGC_{all}$–0.39	U_{all}–0.58	$SHGC_{all}$–0.19	U_{all}–1.36	$SHGC_{all}$–NR

*The following definitions apply: c.i. = continuous insulation (see Section 3.2), NR = no (insulation) requirement.
[b]Nonmetal framing includes framing materials other than metal with or without metal reinforcing or cladding.
[c]Metal framing includes metal framing with or without thermal break. The "all other" subcategory includes operable windows, fixed windows, and non-entrance doors.