COLORADO
Department of Public Health & Environment

To: Michael Ogletree, Designee of the Executive Director of the Colorado Department of Public Health and Environment

From: Stefanie Shoup, Manager, Office of Innovations in Planning and Air Quality Data Air Pollution Control Division

Date: May 13, 2025

Subject: Request for Rulemaking Hearing to Adopt 5 CCR 1004-2 Water and Efficiency Standards Regulation, concerning Proposed Alternative Standard to the Standard Established in C.R.S. § 6-7.5-105(5)(j) for Residential Windows, Doors and Skylights

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REQUEST FOR RULEMAKING HEARING
for 5 CCR 1004-2 Water and Efficiency Standards

The Colorado General Assembly began requiring the regulation of energy efficiency standards for certain products in 2019. In 2023, the Colorado General Assembly established, through House Bill 23-1161 codified in § 6-7.5-105(5)(j), C.R.S., that on or after January 1, 2026, residential windows, doors, and skylights included in the scope of the Energy Star program cannot be sold or leased for residential use in Colorado unless their rated performance satisfies the Northern climate zone Energy Star specification for these products. As of the date of this request, covered residential windows, doors and skylights would need to comply with the ENERGY STAR V.7 specification. Later, in 2024, the General Assembly adopted SB24-214, which granted the Executive Director of the Colorado Department of Public Health and Environment (CDPHE) the option to evaluate and adopt an alternative standard for residential windows, doors, and skylights established in HB23-1161 if the Executive Director, in consultation with the Colorado Energy Office (CEO) determined that the standards cannot reasonably be met.

CEO performed an analysis on the standard for residential windows, doors, and skylights established in HB23-1161 and concluded that "the standard cannot be met by manufacturers without imposing too high of a financial burden on the majority of Colorado households. The standard would also significantly reduce consumer options for doors." For instance, the HB23-1161 standard is expected to increase the retail cost of residential vinyl windows by 15-40% and would make the sale of solid wood doors illegal because these doors cannot meet the ENERGY STAR V.7 specification. The standard would also decrease the amount of flexibility available to homebuilders because there would be no lower performance (and less expensive) windows, doors, and skylights available for purchase. As a result, homebuilders would not be able to take advantage of the tradeoffs allowed by the weight-average method and the performance energy rated index pathways in the International Energy Conservation Code (IECC). The net result of the HB23-1161 standard would be potentially increased project costs with marginal improvements in building energy efficiency. Therefore, CEO's study

"recommends that the CDPHE propose an alternative standard that would have a more positive economic impact on Colorado consumers."

Under the HB23-1161 standard, ENERGY STAR V.7 products in the Northern climate zone must have National Fenestration Rating Council (NFRC)-certified U-Factor (the heat transfer per time per area and per degree of temperature difference (Btu/h ft2·˚F)) ratings at levels which meet or exceed the minimum criteria specified.

1. Residential windows: U-factor of 0.26 or lower
2. Residential skylights: U-factor of 0.45 or lower
3. Residential doors, >½-lite: U-factor of 0.26 or lower
4. Residential doors, <½-lite: U-factor of 0.23 or lower

CEO proposes that the alternative standard be based on the prescriptive maximum U-factor listed for vertical fenestration (i.e. windows and doors) and skylights in the 2024 edition of the residential IECC. CEO also proposes that this standard should only apply to residential doors with significant amounts of glazing, (those defined as ">½-lite") so that consumer residential exterior door options are not significantly limited by the standard.

Based on the 2024 IECC, this proposed alternative standard would require residential windows, doors, skylights to meet the following criteria to be sold or leased for residential use in Colorado.

1. Residential windows: U-factor of 0.30 or lower
2. Residential skylights: U-factor of 0.50 or lower
3. Residential doors, >½-lite: U-factor of 0.30 or lower
4. Residential doors, other than >½-lite: exempted, no U-factor requirement

The CEO analysis also concluded that a residential window, door, and skylight standard should apply only to product U-factor and should not limit product solar heat gain coefficient (SHGC) in any way. Excluding SHGC from the standard would allow homeowners and homebuilders the flexibility to decide if they wish to take advantage of passive solar heating in their home or if they instead prefer to prevent potential overheating in warm months. Simply establishing a maximum product U-factor would create energy savings for households and has no risk of potentially causing overheating discomfort to building occupants.

AGENDA ITEM CONTROL SHEET

for 5 CCR 1004-2 Water and Efficiency Standards

Is this rulemaking due to a change in state statute?

- ☑ Yes, the bill number is SB24-214. Rules are
  - ☑ Authorized
  - ☐ Required
- ☐ No

Does this rulemaking include proposed rule language that incorporate materials by reference?

- ☑ Yes
- ☐ No

Does this rulemaking include proposed rule language to create or modify fines or fees?

- ☐ Yes
- ☑ No

Does the proposed rule language create (or increase) a state mandate on local government?

- ☑ No
  - The proposed rule does not require a local government to perform or increase a specific activity for which the local government will not be reimbursed;
  - The proposed rule requires a local government to perform or increase a specific activity because the local government has opted to perform an activity, or;
  - The proposed rule reduces or eliminates a state mandate on local government.

- ☐ Yes
  - This rule includes a new state mandate or increases the level of service required to comply with an existing state mandate, and local government will not be reimbursed for the costs associated with the new mandate or increase in service. The state mandate is categorized as:
    - ☐ Necessitated by federal law, state law, or a court order
    - ☐ Caused by the State's participation in an optional federal program
      - ☐ Imposed by the sole discretion of a Department
      - ☐ Other: _____
        (i.e. requested by local governments and consensus was achieved)
  - Has an elected official or other representatives of local governments disagreed with this categorization of the mandate?
    - ☐ Yes
    - ☐ No
    - If "yes," please explain why there is disagreement in the categorization.
  - Please elaborate as to why a rule that contains a state mandate on local government is necessary.

5 CCR 1004-2 Water and Efficiency Standards
1.0: WINDOWS/DOORS/SKYLIGHTS

Pursuant to Colorado Revised Statutes § 24-4-103 (12.5), materials incorporated by reference are available for public inspection during normal business hours, or copies may be obtained at a reasonable cost from the Office of the Executive Director of the Colorado Department of Public Health and Environment, 4300 Cherry Creek Drive South, Denver, Colorado 80246-1530. Materials incorporated by reference are those editions in existence as of the date indicated and do not include any later amendments.

Unless otherwise indicated, any incorporation by reference of provisions of the 2024 International Energy Conservation Code, R402.1.2 ("2024 IECC") are to the edition effective as of August 14, 2024.

Unless otherwise indicated, any incorporation by reference of provisions of the National Fenestration Rating Council, Inc., ANSI/NFRC 100-2023, Procedure for Determining Fenestration Product U-factors ('NFRC 100") are to the edition effective as of January, 2025.

1.1. On or after January 1, 2026, to be sold or leased for residential use in Colorado, residential windows, doors, and skylights must meet either the criteria established in § 6-7.5-105(5)(j)(I) C.R.S. or the following criteria:

1.1.1. Residential windows:

Residential windows must have U-factor equal to or lower than the maximum U-factor requirement for climate zone 5 listed in the "Maximum Assembly U-Factors and Fenestration Requirements" table (Table R402.1.2) of residential 2024 IECC. If the IECC lists an alternative maximum U-factor requirement for a given product type for climate zone 5 installations in buildings at high elevation, the maximum U-factor requirement for high elevation installations in climate zone 5 shall be used for this standard for that product type.

Window and >½-lite door products must satisfy the "Fenestration U-Factor" maximum requirement and skylight products must satisfy the "Skylight U-Factor" maximum requirement.

1.1.2. Residential skylights:

Residential skylights must have U-factor equal to or lower than the maximum U-factor requirement for climate zone 5 listed in the "Maximum Assembly U-Factors and Fenestration Requirements" table (Table R402.1.2) of the residential IECC If the IECC lists an alternative maximum U-factor requirement for a given product type for climate zone 5 installations in buildings at high elevation, the maximum U-factor requirement for high elevation installations in climate zone 5 shall be used for this standard for that product type.

1.1.3. Residential doors, >½-lite:

Residential >½-lite doors must have U-factor equal to or lower than the maximum U-factor requirement for climate zone 5 listed in the "Maximum Assembly U-Factors and Fenestration

Requirements" table (Table R402.1.2) of the residential IECC.If the IECC lists an alternative maximum U-factor requirement for a given product type for climate zone 5 installations in buildings at high elevation, the maximum U-factor requirement for high elevation installations in climate zone 5 shall be used for this standard for that product type.

Window and >½-lite door products must satisfy the "Fenestration U-Factor" maximum requirement and skylight products must satisfy the "Skylight U-Factor" maximum requirement. A >½-lite door is defined as a door with greater than 900 square inches of glazing or a sidelite with greater than 281 square inches glazing (per NFRC 100). This definition includes ¾-lite and fully glazed doors and sidelites.

1.1.4. Residential doors, other than >½-lite: exempted

Residential doors that do not meet the definition of >½-lite are not required to satisfy the criteria described above. A >½-lite door is defined as a door with greater than 900 square inches of glazing or a sidelite with greater than 281 square inches glazing (per NFRC 100). This definition includes ¾-lite and fully glazed doors and sidelites.

1.2. Statement of Basis and Purpose and Specific Statutory Authority, June 20, 2025

1.2.1. Basis

To establish an alternative energy standard for residential windows, doors, and skylights requirements currently established in HB23-1161. The alternative standard, the 2024 IECC standards including higher U-factor thresholds, may be used and applied for compliance with §6-7.5-105, C.R.S., instead of the standards initially established in the statute for residential doors, windows and skylights.

1.2.2. Specific Statutory Authority

§ 6-7.5-105(5)(j)(II), C.R.S requires the CDPHE Executive Director (or his or her designee) to set an alternative standard for residential windows, residential doors, and residential skylights, if the Executive Director (or his or her designee) determines that the standard established in §6-7.5-105, C.R.S. "cannot reasonably be met by manufacturers". This determination may be made after consultation with CEO and with consideration of (a) impacts on net consumer costs; and (b) supply chain constraints.

1.2.3. Purpose

After discussions with manufacturers of covered residential windows, doors and skylights, and further analysis, CEO concluded that the standard based on ENERGY STAR V.7 established in HB23-1161 cannot reasonably be met by manufacturers without imposing an unreasonably high net cost on consumers. The standard based on Energy Star v.7 would also significantly reduce the number of residential door product types available for purchase in Colorado and would limit the number of window product types available for Coloradans that live above approximately 9,000 feet in elevation. Accordingly, CEO recommended an alternative standard that would improve building energy efficiency without imposing an unreasonably high cost on consumers or significantly reducing the number of residential window, door, and skylight product types available in Colorado.

Based on the CEO analysis, it is estimated that requiring residential windows to meet the ENERGY STAR V.7 specification established in HB23-1161 would increase the cost of vinyl windows by 15-40%. For a typical Colorado home, purchasing new windows that meet the ENERGY STAR V.7 specification would cost an additional $1,500 to $2,500 (for replacement of all windows in the home) when compared to purchasing baseline windows with U-factor of 0.35. The payback period for the incremental investment is estimated to be between 20 and 30 years for the vast majority of Coloradans. For this calculation, the payback period is defined as the number of years it would take for the annual energy bill savings to make up for the upfront incremental investment required to purchase the ENERGY STAR V.7compliant windows.

After the warranty period for a window has lapsed, a consumer has no recourse if the glass seal in a window fails. Such a failure would increase the U-factor of the window and likely reduce its energy efficiency to such an extent that the window would no longer meet the ENERGY STAR v.7 specification. CEO calculated that the projected payback period for Energy Star v.7 compliant windows is 20-30 years, which is longer than the typical window warranty. CEO ultimately concluded that an alternative standard that resulted in payback periods 15 years or shorter for residential window purchases, which is more in line with typical warranty lengths, results in a more reasonable cost for consumers.

The alternative window, door, and skylight standard proposed by CEO results in an estimated payback period for efficient window, door, and skylight purchases of between 10 and 15 years for the majority of Coloradans and does not significantly limit consumer product choices.

REGULATORY ANALYSIS
for 5 CCR 1004-2 Water and Efficiency Standards

Please coordinate these answers with your Fiscal Services Manager. For rulemakings, tied to legislation, please incorporate the fiscal note analysis. If the assumptions have changed since the fiscal note, document that here.)

1. A description of the classes of persons affected by the proposed rule, including the classes that will bear the costs and the classes that will benefit from the proposed rule.

Group of persons/entities Affected by the Proposed Rule	**Size of the Group**	**Relationship to the Proposed Rule Select category: C/CLG/S/B**
Consumers	5,600,000	B
Manufacturers	100	C
Vendors	250	C

While all are stakeholders, groups of persons/entities connect to the rule and the problem being solved by the rule in different ways. To better understand those different relationships, please use this relationship categorization key:

C = individuals/entities that implement or apply the rule.
S = individuals/entities that do not implement or apply the rule but are interested in others applying the rule.
B = the individuals that are ultimately served, including the customers of our customers. These individuals may benefit, be harmed by or be at-risk because of the standard communicated in the rule or the manner in which the rule is implemented.

More than one category may be appropriate for some stakeholders.

2. To the extent practicable, a description of the probable quantitative and qualitative impact of the proposed rule, economic or otherwise, upon affected classes of persons.

Economic outcomes
Summarize the financial costs and benefits, include a description of costs that must be incurred, costs that may be incurred, any Department measures taken to reduce or eliminate these costs, any financial benefits.

C: The current ENERGY STAR V7.0 certified product market share is minimal, the availability of windows that perform to that level is limited. Allowing the alternative standard would increase the supplier market with vinyl-framed windows, which are both the least expensive and most efficient frames.

B: Requiring residential windows to meet the ENERGY STAR V7.0 Northern climate zone specifications will result in payback periods greater than 20 years long for the majority of Coloradans. Only Colorado households in the coldest regions of the state (climate

zone 7) realize payback periods less than 15 years long when upgrading their windows to an ENERGY STAR V7.0 Northern qualified product. For typical homes in Colorado it is estimated that installing vinyl vertical slider windows that meet the ENERGY STAR V7.0 Northern climate zone specification instead of baseline vinyl vertical slider windows with U-factor equal to 0.35 will cost an additional $1,500 to $2,500 per home.

Non-economic outcomes
Summarize the anticipated favorable and non-favorable non-economic outcomes (short-term and long-term), and, if known, the likelihood of the outcomes for each affected class of persons by the relationship category.

C: There are no identified supply chain constraints that would prevent manufacturers from selling products that satisfy the proposed standards. Furthermore, the IECC evaluates and considers product availability and affordability when deciding whether to decrease the prescriptive maximums for windows, doors, and skylights.

B: The alternative standards would give consumers more options for doors, windows, and skylights.

3. The probable costs to the agency and to any other agency of the implementation and enforcement of the proposed rule and any anticipated effect on state revenues.

A. Anticipated CDPHE personal services, operating costs or other expenditures: There are no anticipated changes to personal services, operating costs, or other expenditures from this alternative standard.

Anticipated CDPHE Implementation Costs: There are no anticipated changes to the implementation costs from this alternative standard.

B. Anticipated personal services, operating costs or other expenditures by another state agency: NA

Anticipated Revenues for another state agency: NA

4. A comparison of the probable costs and benefits of the proposed rule to the probable costs and benefits of inaction.

Along with the costs and benefits discussed above, the proposed rules:

- ☑ Comply with a statutory mandate to promulgate rules.
- ☑ Comply with federal or state statutory mandates, federal or state regulations, and department funding obligations.
- ☑ Maintain alignment with other states or national standards.
- ☐ Implement a Regulatory Efficiency Review (rule review) result
- ☐ Improve public and environmental health practice.
- ☑ Implement stakeholder feedback.
- ☑ Advance the following CDPHE Strategic Plan priorities (select all that apply):
  - ☐ Improve outcomes in public health and environmental protection for all people of Colorado.

- ☐ Realize a human-first, progress-forward culture!
- ☐ Accomplish bold and Wildly Important Goals (WIGs) with an annual focus on a few key issues.
- ☑ Continuously pursue operational excellence in support of our programs.
- ☐ Strengthen Colorado's governmental public health system and promote effective public health practice.
- ☐ Advance CDPHE Division-level strategic priorities.
  Identify division strategic plan item or strategic priority:

The costs and benefits of the proposed rule would not be incurred if inaction was chosen.

5. A determination of whether there are less costly methods or less intrusive methods for achieving the purpose of the proposed rule.

This proposed alternative standard is in response to the CEO analysis finding that window, door, and skylight manufacturers cannot reasonably meet the HB23-1161 standard for residential windows, doors and skylights without creating a significant negative impact on net consumer costs. Accordingly, a method that results in lower costs to consumers and allows more consumer choice while achieving appliance efficiency is being proposed through the alternative standard. CEO considered other standards that could potentially be less costly and less intrusive. However, those other alternatives considered were not appropriate and would not achieve the purpose of the proposed rule, as described in more detail below.

6. Alternative Rules or Alternatives to Rulemaking Considered and Why Rejected.

Other potential alternative standards for residential windows, doors and skylights were considered in developing the proposed alternative standard including, alignment with the ENERGY STAR V.6 standard, complete alignment with the IECC prescriptive maximums for fenestration and skylight products, including a solar heat gain coefficient proponent, and creating an exemption from the U-factor requirement for certain door and window types. For reasons stated in more detail below, these alternatives would either result in a less reasonable payback period for consumers purchasing covered products, would cause confusion amongst the regulated entities and the regulators, and could place significant burdens on consumers living in high elevation areas.

Additionally, alternatives to rulemaking were considered. However, as explained throughout, an alternative standard is necessary because the existing standard for residential windows, doors, and skylights cannot reasonably be met. For the proposed standard to be enforceable, a rulemaking in compliance with § 24-4-103, C.R.S. must take place.

7. To the extent practicable, a quantification of the data used in the analysis; the analysis must take into account both short-term and long-term consequences.

CEO's Analysis of Window, Door, and Skylight Standard Re: SB 24-214 and HB 23-1161 utilized a variety of data sources including: window component cost estimates produced by the Environmental Protection Agency (EPA) ENERGY STAR program, retail window price data gathered by the EPA ENERGY STAR program, window component cost data gathered from CEO conversations with window manufacturers, retail window price data gathered by CEO via

online price searches, building energy modeling and utility bill cost data produced by Lawrence Berkeley National Laboratory (LBNL) for EPA ENERGY STAR program, energy modeling and utility bill cost data produced by CEO staff, Colorado building and energy code data gathered by CEO staff, Colorado building stock data gathered by CEO staff, and National Fenestration Ratings Council (NFRC) Certified Product Directory (CPD) data on window product availability provided to CEO by LBNL.

These data were used to perform the economic analysis which determined that the residential window, door, and skylight standard enacted by HB 23-1161 would produce the following outcomes:

Unreasonable Financial Burden: The proposed standard would impose excessive costs on Colorado households.

Reduced Consumer Choice: It would significantly limit the variety of available doors across all of Colorado, and would limit the variety of windows available for Coloradans that live at very high altitude.

High Incremental Costs: Upgrading to ENERGY STAR V.7 windows costs $1,500–$2,500 more per home when compared to the cost of purchasing builder grade windows with U-factor equal to 0.35.

Long Payback Period: The estimated payback period for the purchase of windows compliant with the Energy Star v.7 standard exceeds 20 years, longer than typical window warranties.

Limited Impact on Market Prices: Colorado’s small population (less than 2% of the U.S.) would likely not shift national manufacturing demand enough to reduce the cost of the products that meet the Energy Star v.7 specification.

No Precedent: No other states have adopted similar ENERGY STAR-based standards for windows and doors.

STAKEHOLDER ENGAGEMENT
for 5 CCR 1004-2 Water and Efficiency Standards

State law requires agencies to establish a representative group of participants when considering to adopt or modify new and existing rules. This is commonly referred to as a stakeholder group.

Early Stakeholder Engagement:
The following individuals and/or entities were invited to provide input and included in the development of these proposed rules:

Organization	**Representative Name and Title (if known)**
Environmental Protection Agency	Doug Anderson, Project Manager
Xcel Energy	Julie Herman, Senior Product Developer
Lawrence Berkeley National Laboratory	Robert Hart, Technology Researcher
Alpen Windows	Brad Begin, Chairman
Cardinal Glass	Rob Grommesh, Technical Service Manager
Jeld-Wen	Steve Stawn, Program Manager, Codes and Regulatory
Fenestration and Glazing Industry Alliance	Kathy Harkema, US Technical Operations Director
Renewal by Anderson Colorado	Matt Seiler, Permitting Specialist
Pella Windows and Doors	Nicole Willits, Manager of Strategic Project Initiatives
Marvin Windows and Doors	Brad Fevold, Director of Regulatory Affairs
Andersen Corporation	Drew Pavlacky, Glass Technical Lead
Agnora Glass	Adam Mitchell, Marketing Manager
Birch Point Consulting	Thomas Culp, Owner
Signature Windows and Doors	Gwenael Hagan, Owner
Frontier Energy, Inc.	Simon Pallin, Engineering Manager
Pitkin County	Jeffrey Erickson, Chief Building Official
Shums Coda Associates	Hope Medina, Energy & Sustainability Consultant
Mozingo Code Group LLC	Shaunna Mozingo, President
Southwest Energy Efficiency Project	Christine Brinker, Sr. Buildings Policy Manager

Stakeholder Group Notification

The stakeholder group was provided notice of the rulemaking hearing and provided a copy of the proposed rules or the internet location where the rules may be viewed. Notice was provided prior to the date the notice of rulemaking was published in the Colorado Register.

- ☐ Not applicable
- ☑ Yes

Summarize major factual and policy issues encountered and the stakeholder feedback received. If there is a lack of consensus regarding the proposed rule, please also identify the Department's efforts to address stakeholder feedback or why the Department was unable to accommodate the request.

In the course of its analysis of the window, door, and skylight standard established in HB23-1161, CEO gathered feedback from a diverse set of stakeholders. CEO determined that the majority of manufacturers selling window, door, and skylight products in the United States are able to produce products that can meet the Energy Star v.7 specification. In addition, manufacturers did not mention any significant raw material or component supply chain constraints that are currently limiting their ability to produce products that meet the Energy Star v.7 specification. However, most manufacturers noted that the cost to produce these Energy Star v.7 compliant products is high enough that significant price increases would be passed through to consumers in Colorado when compared to baseline market standard products. The majority of manufacturers engaged did not support the standard established in HB23-1161 for a variety of reasons including:

- The majority of manufacturers stated that retail prices for windows would significantly increase (up to 40%), potentially reducing demand for new windows, doors, and skylights
- Several manufacturers stated that they would be incentivized to sell more windows with high solar heat gain coefficient, which they believe provide poor thermal comfort to building occupants and increase air conditioning costs
- Given Colorado's high elevation geography, several manufacturers stated that they would need to modify their manufacturing processes and order management systems to produce argon-filled windows for the entire Colorado market. Manufacturers were not able to estimate a cost for implementing these changes but suggested that it would not be trivial.
- Several manufacturers commented that the Energy Star program is a voluntary program meant to encourage development and adoption of energy efficient products, but is not meant to be the model for a statewide product efficiency standard. They stated that the current low market share of Energy Star Most Efficient windows shows that consumers do not believe high efficiency windows provide a good return on investment.
- The majority of manufacturers interviewed by CEO said the number of product lines available to Colorado consumers would decrease since it is more difficult to affordably meet the Energy Star v.7 specification at high elevation with dual pane windows, wood framed windows, double hung windows, fire rated doors, and windows or doors with safety glass

Aside from product manufacturers, several other stakeholders also expressed opposition or concern with the window, door, and skylight standard established in HB23-1161. A summary of the feedback gathered by CEO is as follows:

- The standard would not be well aligned with the energy code in most jurisdictions in Colorado and would limit design flexibility for homebuilders and architects
- The standard would potentially increase the adoption of high solar heat gain coefficient windows which can increase air conditioning demand in the summer
- The standard would potentially force high elevation consumers to purchase triple pane windows, which are more costly and can be difficult to install in retrofit situations
- Market understanding and knowledge about HB23-1161 is limited and consumers and contractors are not aware of the coming standard

Several stakeholders, including at least one window manufacturer, were supportive of the window, door, and skylight standard established in HB23-1161 for a variety of reasons including:

- Manufacturers are currently able to produce products that can conform to the Energy Star v.7 standard, even at high elevation, and this standard would increase the market adoption of these products
- When compared to average construction cost of a new home in Colorado, the incremental cost required to purchase Energy Star v.7 windows is insignificant (less than 1% of the construction cost)
- Manufacturers have historically been reluctant to sell argon-filled windows throughout Colorado and this standard would push more manufacturers to do so
- The standard would improve the thermal envelope of buildings and have a positive greenhouse gas emission reduction benefit

A portion of stakeholders also provided feedback on potential alternative window, door, and skylight standards that could be put in place in the event the standard established in HB23-1161 was deemed unreasonable. A summary of the potential alternative standards is as follows:

- Align the statewide standard with the Energy Star v.6 specification that was in place from 2015 to 2023
- Align the statewide standard with climate zone 5 prescriptive maximums for fenestration and skylight products in the most recent version of the IECC
- Align the statewide standard fully with the 2024 IECC prescriptive maximums for fenestration and skylight products
- Align the statewide standard fully with the 2024 IECC prescriptive maximums for fenestration and skylight products, but do not allow for the the high altitude exception and/or make this exception apply to buildings above 6,000 meet instead of 4,000 feet
- Create exemptions to any standard for fire-rated products, products that require safety glass, and products used in unconditioned spaces (e.g. basements, garages, sheds)
- Do not include solar heat gain coefficient requirements in any standard

When developing the proposed alternative window, door, and skylight standard, CEO attempted to address stakeholder feedback to the extent possible. The alternative standard proposed by CEO is aligned with the high altitude prescriptive maximum U-factor values for climate zone 5 in the most recent version of the IECC (with an exception for certain door types). Reseasoning for not proposing any of the suggested standards noted above is as follows:

- Alignment with the Energy Star v.6 standard would impose payback periods of approximately 20 years for the majority of Coloradans. CEO believes a 15 year payback period is more reasonable.
- Complete alignment with the IECC prescriptive maximums for fenestration and skylight products would result in different product standards for the different climate zones in Colorado. CEO believes one uniform standard should apply across the whole state in order to reduce confusion for consumers and retailers.
- CEO chose to base the standard on the IECC high altitude (above 4,000 feet) prescriptive maximum for climate zone 5 because ~90% of Colorado's population lives in climate zone 5 and lives above 4,000 feet.
- CEO did not include a solar heat gain coefficient proponent in the proposed alternative standard and created an exemption from the U-factor requirement for certain door types (including opaque fire rated doors)
- CEO recognizes that the incremental investment required to upgrade to windows that meet the Energy Star v.7 specification is modest compared to the cost to build a new home in Colorado. However, the window, door, and skylight standard established in HB23-1161 applies to retrofit projects in addition to new construction, so CEO chose to focus its economic analysis on payback periods.

Please identify environmental justice considerations, values or outcomes related to this rulemaking.

This proposed rule will decrease consumer cost and increase the materials available in Colorado to meet the requirements of the proposed alternative standard.

Overall, after considering the benefits, risks and costs, the executive director (or their designee) has determined that an alternative standard is necessary, as specified in § 6-7.5-105, 5(j)(II) C.R.S

- ☑ Yes
- ☐ No

APPENDICES

for 5 CCR 1004-2 Water and Efficiency Standards

APPENDIX A: 2024 International Energy Conservation Code, R402.1.2 ("2024 IECC"), August 14, 2024.

https://codes.iccsafe.org/content/IECC2024V1.0/chapter-re-4-residential-energy-efficiency

TABLE R402.1.2 MAXIMUM ASSEMBLY *U*-FACTORS[a] AND FENESTRATION REQUIREMENTS

CLIMATE ZONE	0	1	2	3	4 EXCEPT MARINE	5 AND MARINE 4	6	7 AND 8
Vertical fenestration *U*-factor	0.50	0.50	0.40	0.30	0.30	0.28[d]	0.28[d]	0.27[d]
Skylight *U*-factor	0.60	0.60	0.60	0.53	0.53	0.50	0.50	0.50
Glazed vertical fenestration SHGC	0.25	0.25	0.25	0.25	0.40	NR	NR	NR
Skylight SHGC	0.28	0.28	0.28	0.28	0.40	NR	NR	NR
Ceiling *U*-factor	0.035	0.035	0.030	0.030	0.026	0.026	0.026	0.026
Insulation entirely above roof deck	0.039	0.039	0.039	0.039	0.032	0.032	0.032	0.028
Wood-framed wall *U*-factor	0.084	0.084	0.084	0.060	0.045	0.045	0.045	0.045
Mass wall *U*-factor[b]	0.197	0.197	0.165	0.098	0.098	0.082	0.060	0.057
Floor *U*-factor	0.064	0.064	0.064	0.047	0.047	0.033	0.033	0.028
Basement wall *U*-factor	0.360	0.360	0.360	0.091[c]	0.059	0.050	0.050	0.050
Unheated slab *F*-factor[e]	0.73	0.73	0.73	0.54	0.51	0.51	0.48	0.48
Heated slab *F*-factor[e]	0.74	0.74	0.74	0.66	0.66	0.66	0.66	0.66
Crawl space wall *U*-factor	0.477	0.477	0.477	0.136	0.065	0.055	0.055	0.055

For SI: 1 foot = 304.8 mm.

1. **a.**
   Nonfenestration *U*-factors and *F*-factors shall be obtained from measurement, calculation, an *approved source*, or Appendix RF where such appendix is adopted or *approved*.
2. **b.**
   Mass walls shall be in accordance with Section R402.2.6. Where more than half the insulation is on the interior, the mass wall *U*-factors shall not exceed 0.17 in Climate Zones 0 and 1, 0.14 in Climate Zone 2, 0.12 in Climate Zone 3, 0.087 in Climate Zone 4 except Marine, 0.065 in Climate Zone 5 and Marine 4, and 0.057 in Climate Zones 6 through 8.
3. **c.**
   In Warm Humid locations as defined by Figure R301.1 and Table R301.1, the basement wall *U*-factor shall not exceed 0.360.
4. **d.**
   A maximum *U*-factor of 0.30 shall apply in Marine Climate Zone 4 and Climate Zones 5 through 8 to vertical fenestration products installed in buildings located either:
   1. **1.**
      Above 4,000 feet in elevation above sea level, or
   2. **2.**
      In windborne debris regions where protection of openings is required by Section R301.2.1.2 of the *International Residential Code*.
5. **e.**
   F-factors for slabs shall correspond to the *R*-values of Table R402.1.3 and the installation conditions of Section R402.2.10.1.

APPENDIX B: National Fenestration Rating Council, Inc., ANSI/NFRC 100-2023, Procedure for Determining Fenestration Product U-factors ('NFRC 100"), January 2025.

https://nfrccommunity.org/page/TD

ANSI/NFRC 100-2023[E0A3]

Procedure for Determining Fenestration Product U-factors

An American National Standard

Prepared by:

National Fenestration Rating Council

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NFRC

National Fenestration Rating Council®

FOREWORD

The National Fenestration Rating Council, Incorporated (NFRC) has developed and operates a uniform rating system for energy and energy-related performance of fenestration products. The Rating System determines the U-factor, Solar Heat Gain Coefficient (SHGC) and Visible Transmittance (VT) of a product, which are mandatory ratings for labeling NFRC certified products, are mandatory ratings for inclusion on label certificates, and are supplemented by procedures for voluntary ratings of products for Air Leakage (AL), and Condensation Resistance. Together, these rating procedures, as set forth in documents published by NFRC, are known as the NFRC Rating System.

The NFRC Rating System employs computer simulation and physical testing by NFRC-accredited laboratories to establish energy and related performance ratings for fenestration product types. The NFRC Rating System is reinforced by a certification program under which NFRC-licensed responsible parties claiming NFRC product certification shall label and certify fenestration products to indicate those energy and related performance ratings, provided the ratings are authorized for certification by an NFRC-licensed certification and Inspection Agency (IA).

The requirements of the rating, certification, and labeling program (Certification Program) are set forth in the most recent versions of the following as amended, updated, or interpreted from time to time:

- NFRC 700 Product Certification Program (PCP).
- NFRC 705 Component Modeling Approach (CMA), Product Certification Program (CMA-PCP).

Through the Certification Program and the most recent versions of its companion programs as amended, updated, or interpreted from time to time:

- The laboratory accreditation program (Accreditation Program), as set forth in the NFRC 701 Laboratory Accreditation Program (LAP).
- The IA licensing program (IA Program), as set forth in NFRC 702 Certification Agency Program (CAP).
- The CMA Approved Calculation Entity (ACE) licensing program (ACE Program), as set forth in the NFRC 708 Calculation Entity Approval Program (CEAP).

NFRC intends to ensure the integrity and uniformity of NFRC ratings, certification, and labeling by ensuring that responsible parties, testing and simulation laboratories, and IAs adhere to strict NFRC requirements.

In order to participate in the Certification Program, a Manufacturer/Responsible Party shall rate a product whose energy and energy-related performance characteristics are to be certified in accordance with mandatory NFRC rating procedures. At present, a Manufacturer/Responsible Party may elect to rate products for U-factor, SHGC, VT, AL, Condensation Resistance, or any other procedure adopted by NFRC, and to include those ratings on the NFRC temporary label affixed to its products, or on the NFRC Label Certificate. U-factor, SHGC and VT, AL, and Condensation Resistance rating reports shall be obtained from a laboratory that has been accredited by NFRC in accordance with the requirements of the NFRC 701.

The rating shall then be reviewed by an IA which has been licensed by NFRC in accordance with the requirements of the NFRC 702. NFRC-licensed IAs also review label format and content, conduct in-plant inspections for quality assurance in accordance with the requirements of the NFRC 702, and issue a product Certification Authorization Report (CAR), or approve for issuance an NFRC Label Certificate for site-built or CMA products and attachment products. The IA is also responsible for the investigation of potential violations (prohibited activities) as set forth in the NFRC 7007 Compliance and Monitoring Program (CAMP).

Ratings for products that are labeled with the NFRC Temporary and Permanent Label, or products that are listed on an NFRC Label Certificate in accordance with NFRC requirements, are considered to be NFRC-certified. NFRC maintains a Certified Products Directory (CPD), listing product lines and individual products selected by the manufacturer/responsible party for which certification authorization has been granted.

NFRC manages the Rating System and regulates the Product Certification Program (PCP), Laboratory Accreditation Program (LAP) and Certification Agency Program (CAP) in accordance with the NFRC 700 (PCP), the NFRC 701 (LAP), the NFRC 702 (CAP), the NFRC 705 (CMA-PCP), and the NFRC 708 (CEAP) procedures, and conducts compliance activities under all these programs as well as the NFRC 7007 (CAMP). NFRC continues to develop the Rating System and each of the programs.

NFRC owns all rights in and to each of the NFRC 700, NFRC 701, NFRC 702, NFRC 705, NFRC 7007, NFRC 708 and each procedure, which is a component of the Rating System, as well as each of its registration marks, trade names, and other intellectual property.

The structure of the NFRC program and relationships among participants are shown in Figure 1, Figure 2, and Figure 3. For additional information on the roles of the IAs and laboratories and operation of the IA Program and Accreditation Program, see the NFRC 700 (PCP), NFRC 701 (LAP), and NFRC 702 (CAP) respectively.

Figure 1

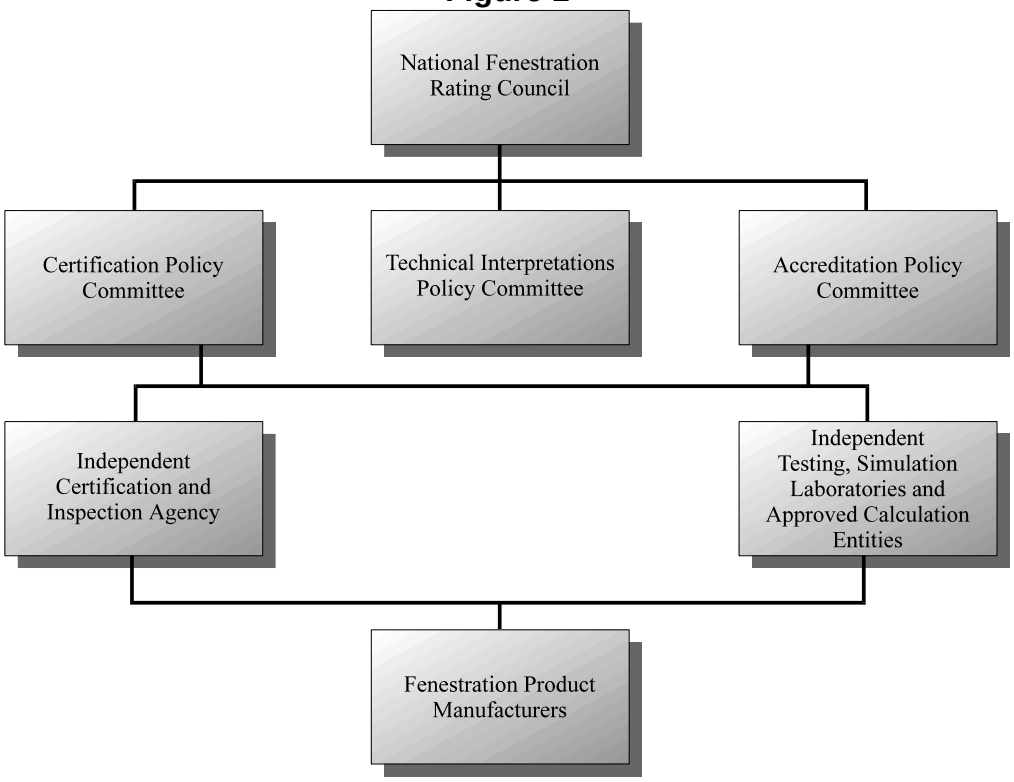


Figure 2

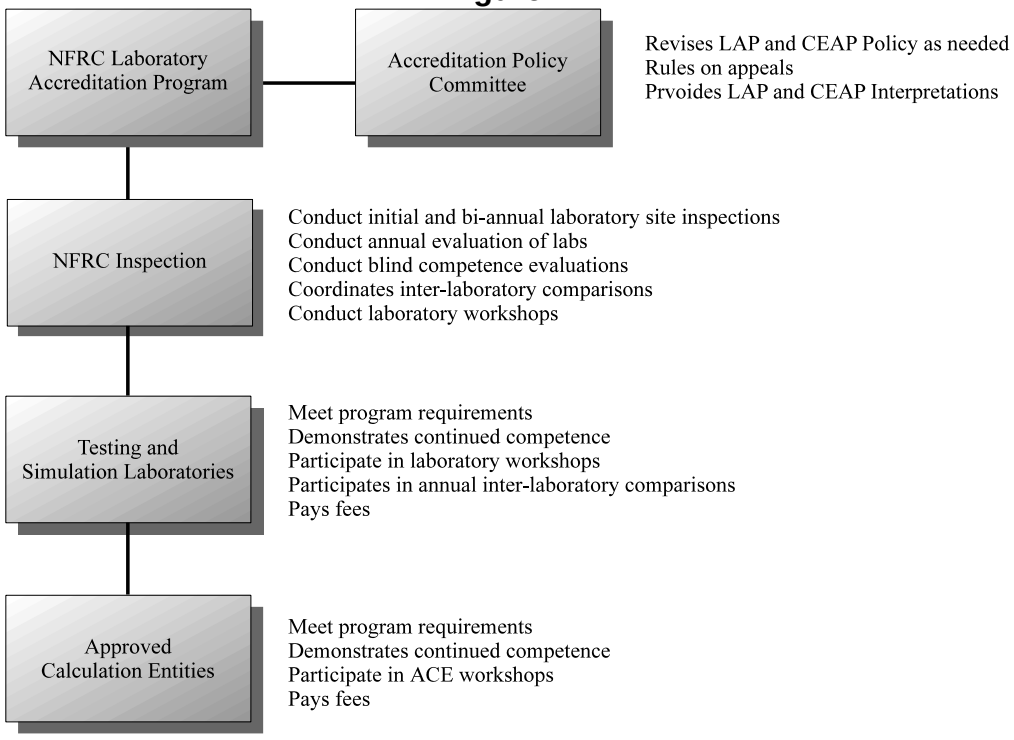
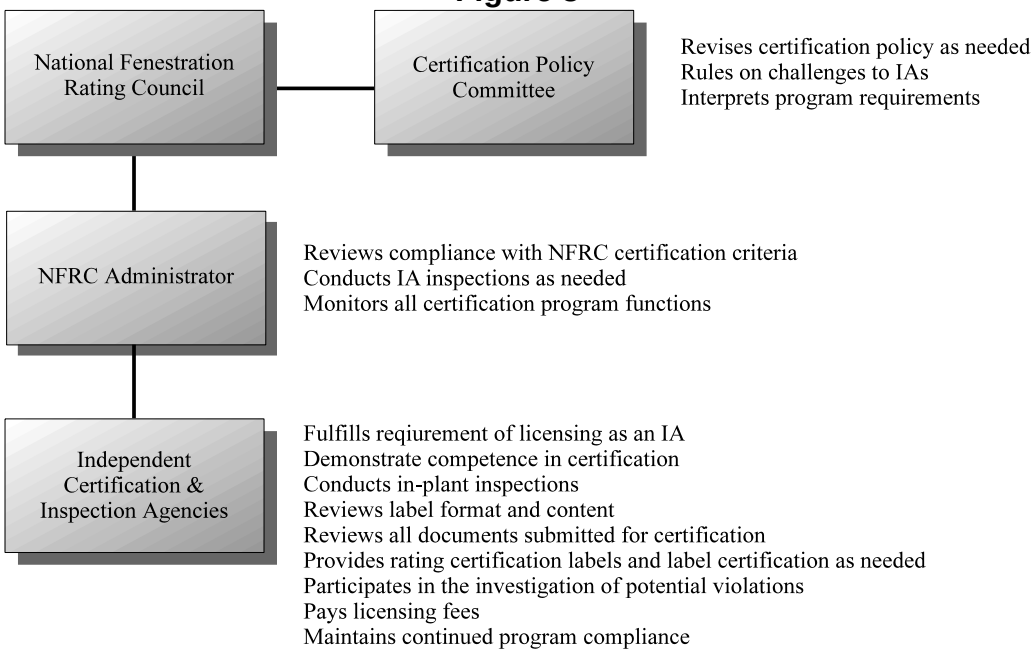


Figure 3



Questions on the use of this procedure should be addressed to:

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DISCLAIMER

NFRC certification is the authorized act of a Manufacturer/Responsible Party in: (a) labeling a fenestration or related attachment product with an NFRC Permanent Label and NFRC Temporary Label, or (b) generating a site built or CMA label certificate, either of which bears one or more energy performance ratings reported by NFRC-accredited simulation and testing laboratories and authorized for certification by an NFRC-licensed IA. Each of these participants acts independently to report, authorize certification, and certify the energy-related ratings of fenestration and related attachment products.

NFRC does not certify a product and certification does not constitute a warranty of NFRC regarding any characteristic of a fenestration or fenestration-related attachment product. Certification is not an endorsement of or recommendation for any product or product line or any attribute of a product or product line. NFRC is not a merchant in the business of selling fenestration products or fenestration-related products, and therefore cannot warrant products as to their merchantability or fitness for a particular use.

NFRC THEREFORE DISCLAIMS ANY AND ALL LIABILITY THAT MAY ARISE FROM OR IN CONNECTION WITH SERVICES PROVIDED BY, DECISIONS MADE BY OR REPORTS OR CERTIFICATIONS ISSUED OR GRANTED BY ANY NFRC-ACCREDITED LABORATORY, NFRC-LICENSED IA OR ANY PRODUCT MANUFACTURER/ RESPONSIBLE PARTY; RELIANCE ON ANY NFRC PRODUCT DESCRIPTION, SPECIFICATION, RATING, TEST OR CERTIFICATION, WHETHER APPEARING IN A REPORT, A PRODUCT CERTIFICATION AUTHORIZATION OR A PRINTED OR ELECTRONIC DIRECTORY, OR ON A LABEL, OR ON A LABEL CERTIFICATE; OR THE SALE OR USE OF ANY NFRC-RATED OR CERTIFIED PRODUCT OR PRODUCT LINE; INCLUDING BUT NOT LIMITED TO DAMAGES FOR PERSONAL OR OTHER INJURY, LOST PROFITS, LOST SAVINGS OR OTHER CONSEQUENTIAL OR INCIDENTAL DAMAGES.

NFRC program participants are required to indemnify NFRC from and against such liability.

This standard is maintained by the Continuous Maintenance Process.

Approval of ANSI / NFRC 100 as an American National Standard is maintained using the continuous maintenance process. Comments or proposals for revisions on any part of this standard may be submitted to the National Fenestration Rating Council at any time. Written comments or proposals must be in writing and be submitted to the NFRC Accredited Standards Developer at standards@nfrc.org.

Any written comments or proposals submitted to NFRC as provided above shall be submitted by NFRC to its consensus body for consideration within a reasonable timeframe not to exceed one year. The submitter will be notified by NFRC of the expected time frame for consideration of the proposal or comments. NFRC shall apply for reaffirmation of this standard regardless of any comment or proposals every three years.

Table of Contents

1. PURPOSE

To specify a method of determining fenestration product U-factor (thermal transmittance).

2. SCOPE

2.1 Products and Effects Covered

The following products and effects are within the scope of ANSI/NFRC 100 and shall be permitted to be rated in accordance with this procedure.

A. Products of all types as defined in Table 4-3;

B. Products of all frame materials, including (but not limited to) aluminum, steel, thermally broken aluminum, wood, vinyl, reinforced vinyl, fiberglass, and plastic, used singularly or in combination, or products utilizing foam as a core material;

C. Products of all glazing materials, tints, and types, including (but not limited to) clear glass, tinted glass, laminated glass (diffuse or specular), stained glass, fritted glazing, etched glazing, sandblasted glazing, glass block, silicone coated glazing, thin plastic films (internally suspended, internally applied, or externally applied, diffuse or specular), rigid plastics (diffuse or specular), and translucent fiberglass with or without any solar control, low-E, or any other partially transparent coating, and products with manufactured decorative opaque insulated glazing panels, designed for interchangeability with other glazing options;

D. Products with any or no gap width between glazing layers;

E. Products with any spacer or spacer system between glazings, including (but not limited to) metallic, non-metallic, or composite spacers;

F. Products utilizing any and all glazing dividers, including (but not limited to) interior, exterior or between glazing grilles, muntin bars, true divided lites, or simulated divided lites;

G. Products with any gas-fill between glazing layers, including (but not limited to) air, argon, krypton, or mixes of these gases;

H. Products utilizing shading systems, diffusing systems, or dynamic glazing that are an integral part of the product as shipped from the manufacturer;

I. Vacuum insulating glass (VIG); and

J. Dynamic Attachment for Swinging Doors.

2.2 Products and Effects Not Covered

The following products and effects are beyond the scope of ANSI/NFRC 100 and shall not be rated in accordance with this procedure.

A. Fenestration products with shading and/or diffusing systems other than those listed in Section 2.1;

B. Thermal performance changes of a fenestration product over the course of time, i.e., long-term energy performance;

C. Issues related to water tightness, structural capacity, and air leakage;

D. Pet doors; and

E. Permanently attached louvers.

3. DEFINITIONS

Air Leakage, AL:
The volume of air flowing per unit time per unit area through a fenestration system due to air pressure or temperature difference between the outdoor and indoor environment.

Architectural Skylight Systems:
A multiple-lite glazed system used as a roofing element, with glazing at a slope greater than 30º from the vertical plane, excluding unit skylights and roof windows. This category encompasses all types of skylights including but not limited to: Single Pitch Skylight, Single Pitch Skylight with Vertical Ends, Double Pitch Ridge Skylight, Double Pitch Ridge Skylight with Vertical Ends, Double Pitch Ridge Skylight with Hipped Ends, Pyramid Skylight, Polygonal Skylight, Continuous Vaulted Skylight and Continuous Vaulted Skylight with Vertical End Walls. These products shall be rated as sloped glazing products.

Areas:

Center of glazing Area (A_c):
All glazing areas except those within 63.5 mm (2.5 in) of any part of a primary sash, and/or frame, and/or divider; or any part of a primary door, and/or frame, and/or divider. See Figures 4-1, 4-2, 5-11, 5-12, 5-13, 5-14, 5-15, 5-19, and 5-20.

Divider Area (A_d):
The projected area in the plane(s) parallel to the fenestration product's glazing of all interior or exterior applied non-removable dividers, true dividers, and simulated dividers or between glazing dividers. See Figures 4-1 and 4-2.

Door Core Area (A_{dc}):
The projected area of the door less the frame, edge-of-frame, lite glazing frame, edge-of-glazing, center-of-glazing, edge-of-divider, divider, edge-of-panel and panel areas. See Figures 4-3, 5-1, 5-2, 5-11, 5-12, 5-13, 5-16, 5-17, and 5-18.

Edge-of-divider Area (A_{de}):
All glazed vision areas within 63.5 mm (2.5 in) of any part of a divider area. The edge-of-divider area shall exclude any edge-of-glazing area. See Figures 4-1 and 4-2.

Edge-of-glazing Area (A_{eg}):
All glazed vision areas within 63.5 mm (2.5 in) of any part of the frame and sash or of the door lite frame sight line, excluding any divider or edge of divider. See Figures 4-1, 4-2, 5-11, 5-12.

Edge-of-panel Area (A_{ep}):
The projected area extending from the point 25 mm (1 in) of uniform thickness on the panel, to the point which includes 25 mm (1 in) of door core material from the interface of any decorative bead or from the interface of the panel cutout and the door core. See Figures 4-3, 5-1, 5-2, 5-11, 5-12.

End Stile Area (A_{es}):
The projected area of the end stile in the plane(s) parallel to the garage door surface. See Figures 5-11, 5-12, 5-17.

Frame Area (A_f):
The projected area of frame and sash in the plane(s) parallel to the glazing surface, except for doors, which shall include the projected areas of the door jambs, header, threshold, door bottom sweep and the peripheral structural elements of the door slab, in a plane parallel to the door core surface. See Figures 4-1, 4-2, 5-1, 5-2, 5-11, 5-16, 5-17, 5-19, and 5-20.

Exterior Door System Area:
The total door system that includes all frame, lite frame, divider, edge-of-divider, edge-of-glazing, center-of-glazing, door core, edge-of-panel, and panel areas; the door, slab, or slab door together with the surrounding frame, weatherstrip, sill, and sweep.

Lite Frame Area (A_{lf}):
Specific to doors, the projected area extending from the sight line of the lite frame into the surrounding homogeneous door core surface for a distance of 25 mm (1 in) beyond the outer edge of the lite frame and parallel to the door core surface. See Figures 5-11 and 5-12.

Panel Area (A_p):
The projected area of all decorative panels of uniform thickness and extending from a point 25 mm (1 in) of uniform thickness, in a plane parallel to the door core surface. See Figures 4-1, 4-2, 5-1, 5-2, 5-11, and 5-12.

Projected Fenestration Product Area (A_{pf}):
The area of the rough opening in the wall or roof, for the fenestration product, less installation clearance.

Note: Where a fenestration product has glazed surfaces facing in only one direction (typical products), the sum of the edge-of-divider area, the edge-of-glazing area, the divider area, the center-of-glazing area, and the frame area will equal the total projected fenestration product area (Apf). Where a fenestration product has glazed surfaces in more than one direction (e.g., greenhouse/garden, bay/bow windows) the sum of the areas will exceed the projected fenestration product area.

Total Fenestration Product Area (A):
The area of the total fenestration product that includes all frame, divider, edge-of-glazing, edge-of-divider, and center-of-glazing areas.

Awning Window:
A window with one (or more) sash that rotates about its top hinge and projects outward.

Base Profile:
Primary structural member of a fenestration product line which forms the basis for comparison, such as groupings.

Baseline Product:
Within a product line, the individual product selected for validation testing. To verify door glazing and lite frame simulations, the baseline product for door, sidelite, and garage (vehicular access) door product lines which include glazed options, shall include glazing.

Basement Window:
A window usually with one sash that projects inward and is intended to be used at or below grade; rated as the appropriate product type.

Bay Window:
A combination assembly which is composed of two or more individual windows joined side by side and which projects away from the wall on which it is installed. Center windows, if used, are parallel to the wall on which the bay is installed. The two side windows are angled with respect to the center window(s). Common angles are 30º and 45º, although other angles are sometimes employed. Individual windows are rated as the appropriate product type.

Bead:
(1) A strip used around the periphery of the glazing to secure it in a frame or sash (also referred to as a “stop”); (2) S strip of sealant, such as caulking or glazing compound.

Blackbody:
A perfect emitter and absorber of thermal radiation. A blackbody emits radiant energy at each wavelength at the maximum rate possible as a consequence of its temperature and absorbs all incident radiant flux.

Bow Window:
A rounded bay window that projects from a wall in the shape of an arc. Individual windows rated as the appropriate product type.

Breather/Capillary Tube:
A tube providing an intentional breach of the IG seals to allow for pressure equalization.

Caming:
Material that divides and holds pieces of glazing together to form a single decorative glazing panel.

Casement Window:
A window containing one (or more) sash, hinged to open from the side, that projects outward or inward from the plane of the window in a vertical plane. A conventional casement window has a sash that projects outward.

Certification:
The affixing by a licensed Responsible Party of an NFRC label on a fenestration product, or on a box/packaging containing an attachment product, or the distribution of an NFRC Label Certificate for which Certification Authorization has been granted.

Certified Simulator:
Any individual that has attended at least one NFRC-sanctioned Simulation Training Workshop, completed and satisfactorily passed all necessary examinations, participated

in NFRC simulation round robins, and is approved by NFRC to use at least one NFRC-approved simulation software tool.

Cladding:
An applied rigid or semi-rigid roll-formed or extruded covering that is placed over or is attached to and follows the contour of the interior or exterior framing member for the primary purpose of protection from environmental elements and/or aesthetics. Cladding adds no structural integrity to the framing member.

Combination Assembly:
An assembly formed by a combination of two or more separate fenestration.

Composite Assembly (Unit):
A window, door, or skylight unit consisting of two or more sash, leaves, lites, or sliding door panels within a single frame utilizing an integral mullion. (Not to be confused with products made from composite materials.)

Commercial Fenestration:
Fenestration typically installed in commercial building, but not limited to commercial building application.

Commercial Trendline Approach (CTA):

A trendline methodology used for rating Commercial Fenestration,

Computer Simulation:
The process by which a product is analyzed for energy performance characteristics utilizing NFRC-approved computer software and manufacturer supplied product specifications and drawings, in accordance with the requirements of the NFRC Rating System.

Convective Film Coefficient (h):
The time rate of convection heat transfer from a unit area of a surface to its surroundings, induced by a unit temperature difference between the surface and the environment.

Curb:
A wall or frame used to raise roof windows, skylights, or sloped glazing above the surface of the roof.

Curtain Wall:
A non-load-bearing exterior wall, comprised of multiple fenestration elements, with vertical framing members which are designed to run past the face of the floor slabs, which is secured to and supported by the structural members of the building.

Daylight Opening Size:
The glazing infill dimension measured from the glazing sightline, also known as the vision area.

Decorative Panel/Panel Insert:
A decorative raised molding that is inserted into a cut-out in an insulated door slab. Decorative panels are typically molded from a composite material. The gap between the two halves of the panel may be filled with an insulating material.

Detailed Door Rating (DDR) Method:
A modeling procedure that combines opaque Door or Sidelite slab simulations with various glass simulations projected into the opaque unit(s) to determine a total product U-factor.

Diffuse (adj.):
Referring to radiometric quantities, indicates that flux propagates in many directions, as opposed to a direct beam, which refers to quasi-collimated flux from the sun, whose angular diameter is approximately 0.5O. When referring to reflectance, it is the directional hemispherical reflectance less the specular reflectance. Diffuse has been used in the past to refer to hemispherical collection (including the specular component). This use is deprecated in favor of the more precise term hemispherical.

Diffuser:
A translucent glazing layer or fenestration product accessory designed to transmit direct-beam radiation diffusely, i.e. many directions.

Divider:
Any vertical or horizontal bar used to separate glazing into multiple lites or placed in the gap between sheets of glazing. Dividers may be external or internal, may be removable or non-removable, and may be real (true) or simulated. Dividers may also be called grids, grilles, or muntins.

Doorglass Assembly Area (DGAA):
Sum of the Lite-Frame-Area (A_{lf}), Edge-of-Glazing Area (A_{eg}), Center-of-Glazing Area (A_c), Edge-of-Divider-Area (A_{ed}), Divider Area (A_d)

Slab:
For an operable door or sidelite system, the swinging portion of the system, whose primary function is to allow human egress/ingress or ventilation. A slab may also be included as part of a non-operable door or sidelite system. Sometimes referred to as a leaf in the industry.

Composite (material) Slab:
A door manufactured from skins molded from plastics, fiberglass compounds, compressed composites, or other non-metallic materials. The door slab may or may not incorporate a structural perimeter constructed from materials, including (but not limited to) wood, wood products, composites, or other reinforcing materials. The core of the door slab may be filled with materials including, but not limited to insulating polyurethanes, styrenes, or honeycombs.

Steel Door:
A door manufactured from steel skins, which may be coated with paint, plastic, wood veneers, or other finishes. The door leaf may or may not incorporate a structural perimeter, including (but not limited to) materials of wood, wood products, composites, or other reinforcing materials. The core of the door leaf may be hollow or filled with material, including (but not limited to) insulating polyurethanes, styrenes, or honeycombs.

Wood Slab:
A door manufactured from solid wood, wood veneers, wood laminates, or a combination thereof. Such doors are generally assembled from stiles, rails, and raised panels, but may also be wood flush doors of solid or hollow core construction.

Aluminum Slab:
A door manufactured from aluminum extrusions for the vertical stiles and horizontal rails with glazed panel area. Aluminum doors may also be flush doors manufactured with aluminum skins (exterior and interior sides) applied over the aluminum stiles and rails with an insulating core.

Door Panel:
The portion of a sliding glass door or exterior bi-fold door that is installed in a frame and includes the glazing, stiles, and rails. A panel may be operable or non-operable.

Dual Action Window:
A window that operates in two different ways. Typically, the window consists of a sash that tilts from the top and swings inward from the side.

Dynamic Attachment:
Any Fenestration Attachment that incorporates Dynamic Glazing.

Dynamic Glazing Product:
Any Fenestration Product that incorporates Dynamic Glazing.

Embossed/Raised Panel:
Decorative areas on a door slab. On a steel door these may be pressed into the steel skin or achieved by the application of plastics or other trim materials. On composite (material) doors these are usually molded into the door skin or may be achieved by the use of surface applied trim. Wood doors usually incorporate thinner wood sections assembled into the stiles and rails. [Note: See Figure 5-3 for typical 6-panel layout.]

Emissivity (ε):
The relative ability of a surface to reflect or emit heat by radiation. Emissivity ranges from 0.00 to 1.00 (Blackbody emissivity is 1.0).

Energy Panel:
A glazed Fenestration Attachment designed to be mounted to the interior or exterior of a primary fenestration product such that a gap is created between the glazing systems of the attachment and the primary fenestration product. This includes, but is not limited to, storm windows, storm doors, and storm panels. Also see “Fenestration Attachment.”

Exterior Bi-Fold Doors (aka Folding Walls, Bi-Fold Glass Wall System):
A door with two or more panels, typically fully-glazed, where each panel folds on top of the adjacent panel to open. These are classified as Side-Hinged Exterior Door and shall be rated and tested as either single or double door products.

Exterior Bi-Fold Window
A window with two or more sash where each sash folds on top of the adjacent sash to open. This window operator type shall be rated and tested as a Double Casement.

Film:
Fenestration attachment products that consist of a flexible adhesive-backed polymer film which may be applied to the interior or exterior surface of an existing glazing system. See Fenestration Attachment.

Finish:
The final treatment or coating of a surface.

Fixed Window:
A window designed to be non-operable.

Frame:
The enclosing structure of a window, door, or skylight which fits into the wall or roof opening and receives either, glazing, sash, or vents.

Fully CLOSED Position:
The orientation or condition of a Dynamic Glazing Product with a shading system, or a shade/blind fenestration attachment product, that allows the minimum Visible Transmittance (VT) within the design limitations of the product.

Fully OFF Position:
The orientation or condition of a Dynamic Glazing Product, such as chromogenic glazing, where the glazing is de-energized, de-activated, or otherwise “OFF.”

Fully ON Position:
The orientation or condition of a Dynamic Glazing Product, such as chromogenic glazing, where the glazing is energized, activated, or otherwise “ON.”

Fully OPEN Position:
The orientation or condition of a Dynamic Glazing Product with a shading system, or a shade/blind fenestration attachment product, that allows the maximum Visible Transmittance (VT) within the design limitations of the product.

Gap Width:
The distance between two adjacent glazing surfaces.

Gas-fill:
The process of adding a gas between glazing panes. Term typically used to indicate gases other than air, such as argon and krypton.

Glass:
An inorganic, amorphous substance, usually transparent, composed of silica (sand), soda (sodium carbonate), and lime (calcium carbonate) with small quantities of other materials.

Glazed Wall:
A collective term used to describe any system which meets the definition of curtain wall or window wall.

Glazing System/Glazing In-fill:
A generic term used to describe an in-fill material, such as glass, plastic, or other transparent or translucent material, or assembly of glazing material, spacer, and desiccant, used to enclose openings in a building created by a specific framing system.

Glazing System:
The assembly of the glazing, spacer, and desiccant combined to be placed in the opening in a window, skylight, door, or sidelite.

Greenhouse/Garden Window:
A window unit that consists of a three-dimensional, five-sided structure generally protruding from the wall in which it is installed. Operable sash may or may not be included.

Grid(s):
See “Divider.”

Group Leader:
The single option defined as representing all other options in that group for purposes of grouping.

Grouping:
The process of reducing the number of individual options by selecting the worst performing option as representative.

Horizontal Sliding Window:
A window that contains one or more operable sash(es) that slide horizontally within a common frame. Operable sash (X) and a non-operable sash/lite (O) comprising a unit is termed a single slider (XO or OX). When two operable sashes are separated by a non-operable sash/lite, the unit is termed a picture slide (XOX) or end vent. When an operable sash separates two non-operable sash/lites, the unit is termed a center slide (OXO). When two bi-parting sashes are located at the center of the unit with the non-operable sash/lites at each end, the unit is termed a bi-part center slide (OXXO). When adjacent sashes bypass one another, the unit is termed a double slide (XX or XXO) or a double slide and vent (XXX).

Hybrid Tubular Daylighting Device (HTDD):
The HTDD category has been retired and all products have been placed in the TDD category.

Individual Product:
Any one specific fenestration product within a product line, specific to weather seals, glazing method, hardware, operable/non-operable configurations, ventilators, weep systems, and sills.

Inset Mount:
Where the frame of the skylight extends below the roof’s deck and into the rough opening.

Insulating Glass Unit (IGU), Sealed Insulating Glass Unit:
A preassembled unit comprising lites of glass, which are sealed at the edges and separated by dehydrated space(s). The unit is normally used for windows, window walls, picture windows, sliding doors, patio doors, or other types of fenestration.

Label:
Permanent and/or temporary marker or device applied to a fenestration product, listing rating information and indicating compliance with certification requirements.

Label Certificate:
A document used in lieu of an NFRC Temporary Label specific to certain products that have received certification authorization (see NFRC 705).

Lite:
Another term for glazing used in a fenestration product. Frequently spelled “lite” in industry literature to avoid confusion with “light,” as in “visible light.”

Low-E Coating:
Microscopically thin metal, metal oxide, or multilayer coating deposited on a glazing surface to reduce its thermal infrared emittance.

Model Size:
The size listed in Table 4-3 that is used to rate a fenestration product.

Mullion:
A structural member connecting two or more products. Mullions may be of the following types:

Combination Mullion:
A member formed by joining two or more individual fenestration products together with or without an additional reinforcing member (mullion stiffener).

Integral Mullion:
A member bound at both ends by crossing frame members.

Mullion Stiffener:
An additional reinforcing member used in a reinforcing mullion. Mullion stiffeners may be designed to carry the total load or may share the load with the adjacent framing members.

Reinforcing Mullion:
A member with an added continuous mullion stiffener joining two or more individual fenestration products along the sides of the mullion stiffener.

Nail Flange, Nailing Fin:
An extension of a fenestration product frame that generally laps over the conventional stud construction and through which fasteners are used to secure the frame in place.

Obscure Glazing:
Glazing layer that fully or partially obscures or distorts the image through the layer. Including but not limited to acid-etched, imaged, fritted, silicone coated, embossed, patterned, textured, wired, and stained glass. Also included are products with privacy applied films and light-scattering interlayers.

Opaque In-fill Systems:
Fenestration systems that include opaque elements. See “Spandrel.”

Outdoor Air Ventilator Assembly (OAVA):
A device, other than a sash unit, for the purpose of controlling the passage of air though a fenestration product. An OAVA shall not allow outside air access to cavities within the cross-sectional boundaries of the sash, frame, or glazing.

Pivoted Window:
A window with a horizontal or vertical pivot axis that is fixed in place within the frame and the sash travel traverses both the interior and exterior planes of the frame during operation.

Pivot Door:
A single door with a pivot axis that is fixed in place within the frame and with a door slab that traverses both the interior and exterior planes of the frame during operation. See "Side-Hinged Exterior Door" as operator type.

Product Line:
A series of individual fenestration products of the same operator type manufactured from the same profiles. Individual variations such as glazing, spacer, or small variations in frame profiles are considered individual products within product lines.

Product Type:
A designation used to distinguish between fenestration products based on non-operable and operable sash and frame members. [Note: Referred to as operator type in previous versions.]

Radiation:
The transfer of heat in the form of electromagnetic waves or photons from one body to another.

Rating:
Performance values obtained using NFRC-approved procedures used for comparative purposes only (i.e., U-factor, SHGC, VT, etc.).

Rating System:
A system that consists of NFRC simulation and test procedures for determining comparative fenestration product energy performance characteristics, as supported by the Certification Program.

Reference Fenestration Product:
The fenestration product that an attachment is combined with for the purposes of rating. A reference fenestration product comprises a reference glazing system and a reference frame with a specified construction.

Reference Frame:
The frame of the reference fenestration product. This may or may not correspond to an actual frame type available commercially.

Reference Glazing System:
The glazing system in the reference fenestration product.

Representative Size:
The actual size of a specimen used for validation testing.

Roof Mount:
Where the frame of the skylight is directly mounted on top of the roof deck with or without a curb, manufacturer supplied, or site fabricated.

Roof Window:
See "Unit Skylight/Roof Window."

Rough Opening:
The framed opening in a wall or roof where a fenestration product is to be installed.

Sash:
The portion of a fenestration assembly that is installed in a frame and includes the glazing, stiles, and rails. A sash may be operable or non-operable.

Sealant:
A flexible material placed between two or more parts of a structure, with adhesion to the joining surfaces, to prevent the passage of certain elements such as air, moisture, water, dust, and other matter.

Side-Hinged Exterior Door: A non-operable and/or operable exterior door system. An operable door system shall have at a minimum, a slab and a frame, and hinge attachment of any type between a slab and jamb, mullion, or edge of another slab (e.g. bi-fold doors) or shall have a single, fixed vertical axis (swinging/pivoted) about which the slab rotates between open and closed positions. A non-operable door system shall have at a minimum a slab and a frame.

Shading System:
A device that is integral to a fenestration system or integral to a glazing system which has the fully reversible ability to affect the Solar Heat Gain Coefficient (SHGC) or the Visible Transmittance (VT) of the fenestration system or glazing system.

Sidelite
A fenestration product that is used as a companion product installed on one or both sides of a door system. Sidelites may consist of a glazed frame, sash or slab within a frame.

Sightline:
The line formed by the highest opaque member (frame, sash, spacer, divider, or shading system) that is interior, exterior, or within the glazing system cavity of the fenestration cross-section and the glazing in a plane perpendicular to the surface. A change in sightline will result in a change in the projected frame dimension (PFD) between frame cross-sectional profiles of individual products within a product line (see Figure 4-4).

Simplified Door Rating (SDR) Method:
A modeling procedure allowing component simulations to be conducted by separate entities and re-assembled by an authorized end-user to calculate a total U-factor. Component U-factor and corresponding areas are determined for up to four size configurations of doorglass assemblies and up to five panel/door core/frame-sill configurations for each glass option.

Simulation Software:
Any computer software used for Computer Simulation.

Site-Built Products:
Fenestration products that are designed to be field glazed or field assembled and are comprised of specified framing and glazing components.

Skylight:
See “Unit Skylight/Roof Window”

Sliding Glass Door:
Sliding glass doors contain one or more operable panels that slide horizontally within a common frame. Operable panel (X) and a non-operable lite/panel (O) comprising a unit is termed a single slider (XO or OX). When two operable panels are separated by a non-operable lite/panel, the unit is termed a picture slide (XOX) or end vent. When an operable panel separates two non-operable lites/panels, the unit is termed a center slide (OXO). When two bi-parting panels are located at the center of the unit with the non-operable lites/panels at each end, the unit is termed a bi-part center slide (OXXO). When adjacent panels by-pass one another, the unit is termed a double slide (XX or XXO) or a double slide and end vent (XXX).

Sloped Glazing:
A multiple-lite glazed system (similar to a curtain wall) that is mounted at a slope greater than 30º from the vertical plane, excluding unit skylights and roof windows.

Spandrel Panel System:
A non-vision application of a fenestration product; typically used to hide or obscure features of the building structure or used for visual effect. A spandrel panel system consists of an exterior exposed glazing layer with an interior insulated opaque panel.

Spectral (adj):
Indicating that the property or quantity was evaluated at a specific wavelength (λ), within a small wavelength interval ($\Delta\lambda$ about λ). Usually indicated by placing the wavelength symbol λ, as a subscript following the symbol for the quantity, as with E_λ, thereby indicating that the flux-related quantity is a concentration of flux at the indicated wavelength, or it may be placed inside parentheses following the symbol for the material property, as with α (λ). It is permissible to indicate the wavelength dependence of a flux quantity as follows: E_λ (λ).

Specified Size:

The specified product size used when installed into the building envelope opening**.**

Structurally Glazed Framing:
A method of glazing where framing members are generally not exposed to the exterior (i.e., two-sided or four-sided structural glazed).

Sunroom/Solarium:
A glazed envelope system that has one wall (or a portion thereof) that opens to a primary structure and remaining walls which may include a number of fenestration

systems, such as windows, doors, skylights, kneewalls, etc., in varying percentages per the design of the system.

Surface Heat Transfer Coefficient, Surface Conductance, Film Coefficient ($_h$):
The time rate of heat flow between a surface and its surroundings per unit area and per unit temperature difference.

Thermal Break:
A material of low thermal conductivity that is inserted between members of high conductivity in order to reduce the heat transfer. Thermal barrier material conductivity shall not be more than 0.52 W/mK (3.60 Btu·in/h·ft^2·ºF).

Thermal Bridge:
A path of high thermal conductance from the exterior to interior surfaces of a system that has lower thermal conductance in all other areas. An example would be a metal fastener penetrating an insulating wall or thermally broken frame.

Thermal Opening Area:
The area of the TDD/HTDD product at the interior-most plane of the building's thermal envelope.

Thermally Broken Members (TB):
System members with a minimum of 5.30 mm (0.210 in) separation provided by a low conductance material (where thermal conductivity ≤ 0.5 W/mK, (≤ 3.6 Btu·in/h·ft^2·ºF) or open-air space between the interior and exterior surfaces. Examples of such systems include (but are not limited to) pour and debridged urethane systems, crimped-in-place plastic isolator systems, and pressure glazed systems with intermittent fasteners.

Note: Intermittent fasteners shall be manufacturer's standard. Nominal spacing of fasteners shall be 150 mm (6 in) apart or greater.

Thermally Improved Members (TI):
System members with a separation ≥ 1.60 mm (0.062 in) separation provided by a material [where thermal conductivity ≤ 0.5 W/mK, (≤ 3.6 Btu·in/h·ft^2·ºF)] or open-air space between the interior and exterior surfaces. Such systems include members with exposed interior or exterior trim attached with clips and all skip/debridged systems.

Transom:
A non-operable fenestration product that is used as a companion product installed above another fenestration product. Transoms may consist of a glazed frame or a non-operable sash within a frame. A transom may be rated as either a fixed window or a transom at the discretion of the manufacturer. An operable transom product shall be rated as the appropriate operator type.

Tubular Daylighting Device (TDD):
A non-operable device primarily designed to transmit daylight from a roof surface to an interior ceiling surface via a tubular conduit. The device consists of an exterior glazed weathering surface, a light transmitting tube with a reflective inside surface and an interior sealing device, such as a translucent ceiling panel. See also “Hybrid Tubular Daylighting Device.”

U-factor, Thermal Transmittance (U):
The heat transfer per time per area and per degree of temperature difference. The U-factor multiplied by the interior-exterior temperature difference and by the projected fenestration product area yields the total heat transfer through the fenestration product due to conduction, convection, and long-wave infra-red radiation.

Center-of-glazing U-factor (U_c):
The U-factor representative of the center-of-glazing area.

Divider U-factor (U_d):
The U-factor representative of the divider area.

Door Core U-factor (U_{dc}):
The U-factor representative of the door core area.

Edge-of-divider U-factor (U_{de}):
The U-factor representative of the edge-of-divider area.

Edge-of-glazing U-factor (U_e):
The U-factor representative of the edge-of-glazing area.

Edge-of-panel U-factor (U_{ep}):
The U-factor representative of the edge-of-panel area.

End Stile U-factor (U_{es}):
The U-factor representative of the garage door end stile area.

Frame U-factor (U_f):
The U-factor representative of the frame and sash area.

Lite Frame U-factor (U_{lf}):
The U-factor representative of the lite frame area.

Panel U-factor (U_p):
The U-factor representative of the panel area.

Total Fenestration Product U-factor (U_t):
The U-factor representative of the total system.

Unit Skylight/Roof Window:
A window designed for sloped or horizontal application, the primary purpose of which is to provide daylighting and/or ventilation. Typically, the term “roof window” is not used for horizontal applications. This product can be either roof mounted or inset mounted.

Vacuum Insulating Glass (VIG): an assembly with an evacuated gap between glass lites which are sealed at the edges and separated by a pillar array or other system designed to maintain spacing between glass lites.

Validation Matrix:
Two or more product lines whose U-factor can be validated by a single test.

Vehicular Access (Garage Door):
A door that is used for vehicular traffic at entrances of buildings (such as garages, loading docks, parking lots, factories, and industrial plants) that is not generally used for pedestrian traffic. The garage door includes vertical jamb tracks, all divider, edge-of-divider, edge-of-glazing, center-of-glazing, door panel core, edge-of-panel, and stile (end cap) areas.

Vertical Sliding Window:
A window that contains at least one operable sash that slides vertically within a common frame. Operable sash (X) and a non-operable sash/lite (O) comprising a unit are called single hung windows and units with two operable sash (X/X) are called double hung windows.

Weatherstrip:
A flexible component used to reduce air leakage, water penetration, or both between the sash or panels and/or sash or panels and frame.

Window Wall:
A non-load-bearing fenestration system, comprised of multiple fenestration elements, with vertical framing members which are designed to span from the top of a floor slab to the underside of the next higher floor slab or roof. Also referred to as a "storefront", “strip window” or “horizontal ribbon window system.”

4. GENERAL

4.1 Compliance

Fenestration product ratings shall be determined following the procedures outlined in Section 4.1.1, in accordance with the criteria specified in Sections 4.2 through 4.8, as modified by applicable portions of Section 5.

4.1.1 Product Line Simulation and Testing

A. Determine the representative size matrix of U-factors. List all individual products and associated representative sizes (see Section 4.4) within a product line. The representative size matrix or list of U-factors for a product line is given as follows:

Representative Size Matrix of U-factors

Product ID List	U-factor for Model Size
Individual Product #1	
Individual Product #2	
Individual Product #XX	
Individual Product #Last	

B. Compute the total fenestration product U-factor for the baseline product in the representative size matrix of U-factors. Using the approved total fenestration product U-factor calculation procedure (see Section 4.3.1), compute the U-factor for the baseline product (see Section 4.2.6).

Note: Compute as many U-factors in this representative size matrix as is necessary to definitely determine the baseline product.

C. Test the baseline fenestration product using the approved total fenestration product U-factor test procedure in Section 4.3.2.1.

D. Validation of the simulation procedure: if the simulated and tested U-factors for the baseline product are equivalent (as defined in Section 4.7.1), then the computational procedure presented in Section 4.3.1 shall be considered validated for all the products in the product line. The approved total fenestration product U-factor calculation procedure presented in Section 4.3.1 shall then be used to determine U-factors for the model size matrix of U-factors of Section 4.5.1. These are the values that shall be reported. If the simulated and tested U-factors for the baseline product are not equivalent (as defined in Section 4.7.1), then the alternative test procedure presented in Section

4.1.2 may be used for all products within the product line—with written permission from NFRC.

4.1.2 Testing Alternative

If an individual product listed in Section 2.1 cannot be simulated in accordance with Section 4.3.1, the test procedure found in Section 4.3.2.1 shall be used to determine the U-factors of the individual fenestration product(s) for the size defined in Table 4-3.

Currently the following products cannot be simulated:

A. Non-planar products including but not limited to:
   i. Greenhouse/garden windows
   ii. Tubular daylighting devices
   iii. Domed skylights without frames or flashing

B. Complex glazed products other than the following:
   i. Vertical products with between-glass venetian blinds
   ii. Products with outdoor woven shades
   iii. Products with fritted glazing

The test specimen size shall be the size with the lowest deviation determined from Equation 4-2. If the test specimen cannot be fabricated at the Table 4-3 size, the tested U-factor shall be adjusted to the model size using the following, unless other provisions for specific products have been made in ANSI/NFRC 100:

$$U_{mod} = \frac{(U_{rep}A_{rep})}{A_{mod}}$$

Equation 4-1

Where:

U_{mod} = U-factor at model size
U_{rep} = U-factor at representative size (test size)
A_{rep} = Area at representative size
A_{mod} = Area of model size

4.1.3 Custom Product Rating

A custom product is an NFRC individual product which meets all of the following criteria:

A. A custom product shall be composed of unique frame/sash components not covered within an existing standard product line's U-factor matrix;

B. The specific configuration of a custom product shall not be offered publicly in a manufacturer's catalog or similar literature; and

C. Fewer than 500 units shall be produced annually or shall be produced as part of one purchase order.

U-factors for custom products (which meet the criteria above) may be represented by U-factor ratings generated for a similar stock individual product made of the same product type and materials. A simulation analysis from an NFRC-certified simulator employed by an NFRC-accredited simulation laboratory, confirming that the custom product's U-factor is equal to or lower than the stock product, shall be provided to the NFRC or NFRC's designated representative.

4.1.4 Dynamic Glazing Product Rating

Products meeting the definition of a Dynamic Glazing Product shall be rated at their Fully ON/CLOSED and Fully OFF/OPEN Positions. A manufacturer does not have to model dynamic glazing products in both positions. If only one position is modeled, it shall be the Fully OFF/OPEN position. The manufacturer shall specify the appropriate procedure to achieve the stated positions. Rating procedures for these positions shall be the same as for non-Dynamic Glazing Products, as outlined in Section 4.1.1 or Section 4.1.2 as appropriate.

When rating Dynamic Glazing Products with slatted blinds between glass in the Fully OFF/OPEN position, the standardized slat stack heights of Table 4-1shall be used.

Table 4-1 Standardized Slat Stacked Height

Product Types Covered	Product Overall Height	Blind Stack Height (Dim A)	
	mm	mm	in
Windows			
Awning, Door Transom	600	20	0.8
Vertical Slider	1500	27	1.1
Horizontal Slider	1200	45	1.8
Fixed, Casement, Dual Action	1500	57	2.2
Sliding Glass Doors			
Sliding Glass Doors	2000	77	3.0
Swinging Door and Door Sidelites Typical overall height of door is 2090mm			
Swinging Doors and Door Sidelites	**Typical Door Lite IG Height**	**Blind Stack Height (Dim A)**	
	mm (in)	mm	in
¼ Lite (Doors Only)	457 (18)	19	0.7
½ Lite	889 (35)	36	1.4
¾ Lite	1194 (47)	48	1.9
Full Lite	1600 (63)	65	2.6

4.2 Product Lines and Individual Products

U-factors shall be determined for all individual products within a product line, except as allowed in Section 4.2.4. All product lines shall be simulated separately.

4.2.1 Product Lines

A product line is a series of fenestration products of the same product type (as listed in Table 4-3) manufactured from the same profiles and components. The following changes are the only allowable exceptions within a product line:

A. Overall fenestration product size;

B. Center-of-glazing and edge-of-glazing characteristics such as glazing types and thicknesses, glazing coatings, tints and obscurity, gas-fills, gap widths, shading systems between glazing layers, dividers, and spacers;

C. Operable/non-operable configurations, as defined in Table 4-3;

i. Product types defined as operable that have a non-operable version (Casement-Single, Dual-Action, Pivoted (Horizontal Axis), Pivoted (Vertical Axis) and Projecting/Awning-Single) may be included in the same product line, at the manufacturer's discretion, as long as the changes to render the product non-operable comply with Section 4.2. If there is no operable version of the product, it shall be classified as a Fixed Window.

ii. Product types defined as either operable or non-operable (Greenhouse/Garden, Skylight/Roof Window) may be included in the same product line, at the manufacturer's discretion, as long as the changes to render the product non-operable comply with Section 4.2. If the changes do not comply with Section 4.2, the product shall be treated as two separate product lines.

D. Changes to accommodate glazing unit variations, limited to changes of geometry, number, or material type to stops, beads, adhesives, or gaskets designed to retain the glazing. Changes to frame and sash profiles are allowed to accommodate glazing unit variations. This provision does not allow for interior and exterior glazed products to be in the same product line;

E. Frame/sash modifications made to accommodate operating hardware and reinforcement for the purpose of addressing higher/lower loads and stresses: limited to changes that do not change the exterior perimeter shape of the assembled cross section;

NOTE: "Exterior perimeter" is defined as the perimeter of the entire assembled cross-section (Interior, Adiabatic, and Exterior boundaries of the frame and sash).

F. Frame or sash changes where one component is replaced by another component of the same physical shape with a thermal conductivity that does not differ by more than 10 times the thermal conductivity of the original material;

G. Products with and without cladding can be incorporated into one product line, provided that the only changes made to the unclad product are notches or grooves to accommodate the cladding, or removal of the frame/sash material up to the depth of the cladding;

H. Changes to the frame/sash profiles to allow for different installations, limited to the following:

i. Any changes to interior/exterior appendages added to the main web of the frame that are removable or not exposed after product installation, i.e., nailing fins,

ii. Changes in the width (dimension perpendicular to the plane of the glazing) of the main frame or main frame components to allow for installation in different wall thicknesses, i.e., lengthening, shortening, and the addition of extruded or pultruded walls within a hollow cavity (web walls),

iii. Door products manufactured in both in-swing and out-swing options when only the frame is modified. This section only applies to side-hinged exterior door products. Any other products with inswing/outswing options (e.g. operable casements) shall be separate product lines.

iv. Any changes to the exterior beyond the plane of the nailing fin, J-channel, the exterior plane of the wall, or interior most point of exterior accessory groove, i.e. screen tracks, varying shapes of brickmold, J-channels, or stucco bars formed in (integral) or applied to the frame and that do not change the sightline,

v. Any changes or additions to accessory grooves or decorative flanges, i.e., lengthening, shortening, and the addition of reinforcing web wall(s);

vi. Any changes to trim/stops due to an application of a screen system that cover or hold the screen. The product offered without a screen system shall be used to represent this product and minor frame changes to accommodate the screen system are permitted.

I. Any sightline changes due to:

i. Lengthening or shortening of existing walls,

ii. Components added or replaced for equal and unequal lite configuration options,

iii. For the installation of an outside air ventilator assembly (OAVA), or

iv. Changes to the frame profiles to allow for different installations including pocket or sloped-sill configuration options and sill height modifications;

v. Sightline changes that occur due to any situation in 4.2.1 shall also be allowed. For example, the sightline change due to a change in the glazing bead shall be allowed per Section 4.2.1 (D).

NOTE: A change in sightline will result in a change in the projected frame dimension (PFD) between frame profiles of individual products within a product line.

J. Changes to the following are deemed minor revisions made to the profiles:

i. Limited to changes in the size and shape of snap beads, stops, jamb extensions, dividers (including simulated and true divider lites), weather strip sockets and kerfs, exterior trim caps on curtain walls, window walls, and sloped glazing,

NOTE: The term “stop” above refers to any stop and not just glazing stops.

ii. Decorative elements such as grooves, beads, or brickmolds or exterior trim components and/or casings formed in or applied to the frame or sash are also allowed,

iii. Addition, removal, or modification of pull/lift handles utilized on the interior side of the product, whether it is an integral extrusion of the sash/glazing bead or mechanically fastened, or

iv. Addition, removal, or replacement of a snap-in extrusion (in which the thermal conductivity does not differ by more than 10 times of the original material) for sealing and /or interlocking purposes;

K. Addition, deletion, or changes in hardware and reinforcement (may include reinforcing web walls);

L. Changes to interior or exterior finishes or coatings;

M. Sealing characteristic variables and elements: limited to changes in gaskets, sealants, adhesives, weather strips, or the addition/removal of drip-caps, in the same profile (profile changes to accommodate seal changes shall be allowed); and

N. Vinyl caps attached to the interior.

4.2.2 Individual Products

An individual product is any one specific combination of the product line variables (singularly or in combination) allowed in Section 4.2.1.

All individual products shall be simulated except as allowed in Section 4.2.1.

The following changes are the only allowable exceptions to an individual product:

A. Variations in frame or sash interior/exterior finish, paint, varnish, or stain shall not constitute different individual products provided that each of these variations does not change the surface emittance by more than 0.1 or overall thickness by more than 0.400 mm (0.016 in);

B. Products with different variations in glazing divider patterns do not need to be treated as different individual products:

   i. The manufacturer shall be permitted to define a standard glazing divider pattern (which shall be a standard product offering) which uses glazing dividers 305 mm (12 in) on-center or less,

   ii. A glazing divider pattern with an on-center spacing closest to but not greater than 305 mm (12 in) shall be designated as the glazing divider pattern, or

   iii. The overall window dimension shall be used to determine the number of dividers;

C. Fenestration products that include an outdoor air ventilator assembly (OAVA) shall be considered the same individual product if the OAVA projected dimension (including any components to facilitate installation of the OAVA) is less than or equal to 45 mm (1.75 in). If this dimension exceeds 45 mm (1.75 in) it shall be simulated as an individual product; and

D. Dynamic glazing products shipped with integral or attached shading systems shall be considered individual products within the product line.

4.2.3 Validation Test Matrix

A validation test matrix of multiple product lines of the same product type or multi-purpose products of different product types shall be permitted to be created.

4.2.3.1 Same Product Type

When the changes listed below are made, two or more product lines of the same product type (as listed in Table 4-3) shall be permitted to be included within the same validation test matrix if the overall U-factor difference between the product lines is ± 0.06 W/m^2K (0.01

Btu/h·ft^2·ºF) or less when simulated with the lowest center-of-glazing option.

A. Changes to shift the location of the glazing relative to the sash or frame – exterior to interior;

B. Changes (to sash profiles only) to accommodate interior and exterior glazed products;

C. Product lines fabricated with both pocket and sloped sill options;

D. Changes to installation orientation of a product where the product has been designed to function when installed facing into or out of the room; or

E. Changes to accommodate in-swing and out-swing product lines with nearly identical frame/sash base profiles. Minor changes to profiles to accommodate the in-swing and out-swing operation change are allowed, but are limited to: (a) movement, addition, or deletion of specific elements (i.e. walls & cavities), (b) weather-stripping and associated sealing characteristics, and (c) any component changes that occur as a direct result of any hardware changes.

4.2.3.2 Multi-Purpose Products

Multi-purpose products incorporating nearly identical frame/sash base profiles shall be permitted to be within one validation matrix provided that the differences between the base profiles are limited to minor changes to accommodate different product types. The minor changes allowed are:

A. The movement or addition of specific elements (i.e. walls and cavities) to accommodate the differing operating hardware;

B. Adding or deleting components to adapt a channeled frame to use a tilt sash;

C. The use of the hung window sash stiles as the bottom rail;

D. Deleting of the roller track of the horizontal slider;

E. The addition of sash balance covers; or

F. Any other component changes that occur as a direct result of the hardware changes. Any elements added to the profile to accommodate operating hardware shall be of the same material types used in the original profile.

4.2.4 Grouping of Products

This section presents rules that shall be permitted to reduce the number of simulations for individual products that represent a product line. If this approach is used, the total fenestration product U-factor for the group leader shall be used to represent the total fenestration product U-factors for all individual products within that group. These grouping rules shall not be used to group individual products from different product lines into one product line.

To ensure consistent ratings, groupings shall be done in the following order:

Center-of-glazing (includes dividers)	Section 4.2.4.1
Shading systems between glazing layers	Section 4.2.4.2
Frame/Sash	Section 4.2.4.3
Spacer	Section 4.2.4.4
Sightline Grouping	Section 4.2.4.5

Any combination of groupings shall be done in the order established above. All grouping comparisons shall be based on three significant digits.

4.2.4.1 Center-of-Glazing Grouping

For the purpose of determining U-factors, center-of-glazing groups shall consist only of variations in glazing thickness, gap width, gas fill, low-E coatings, and the presence or absence of internal grids. Once all center-of-glazing options have been identified within a product line, the center-of-glazing U-factor shall be simulated for each option. Then these products shall be permitted to be grouped, with each group represented by the center-of-glazing group leader (which shall be the center-of-glazing option with the highest center-of-glazing U-factor):

A. Glazing options with different numbers of glazing layers shall not be grouped together;

B. Glazing options with clear glazing in all layers shall not be grouped with glazing options with one or more low-E layers (E is less than or equal to 0.50); and

C. Only individual products that contain the same mixture of gases shall be permitted to be grouped. Variable concentrations of the same mixture of gases shall be permitted to be grouped as a center-of-glazing grouping as long as the total gas concentration, other than air, is more than 60% and

does not vary by more than ± 10% from the group leader.

D. For the purpose of determining U-factors, divider groups shall consist only of variations in divider materials and shapes. After all divider options have been identified within a product line the divider heat loss shall be simulated for each divider option using the glazing option with the lowest center-of-glazing U-factor in the product line. Dividers shall not be grouped by Center-of-Glass (COG) alone.

These products shall be permitted to be grouped with each group represented by the divider group leader, which shall be the divider option with the highest divider frame heat loss. If this approach is used, the total fenestration product U-factor for the divider group leader shall be used to represent the total fenestration product U-factors for all individual products within that divider group.

i. For glazing matrix consisting of both double pane and triple pane glazing configurations, dividers can be grouped by simulating each divider option in the appropriate glazing category (double pane or triple pane) with the lowest center-of-glazing U-factor in the glazing category. Divider group leaders for double pane and triple pane configurations shall represent the double pane group and triple pane group, respectively.

ii. Products with glazing dividers, or decorative tape-applied caming bars between layers of an insulated glass (IG) unit shall be permitted to be assumed to have the same U-factors as identical products without such dividers, providing the following:

(a) For dividers, there is at least 3.00 mm (0.118 in.) air/gas space between the divider and both adjacent glazing surfaces.

(b) For simulated caming bars applied with decorative tape, there shall be a minimum airspace of 9.5mm (0.375 in.) between the caming bar and adjacent glazing surface.

4.2.4.2 Shading Systems between Glazing Layers Grouping

When rating dynamic glazing products with shading systems between glazing layers, it shall be permitted to group combinations of shading systems and glazing layers. For purposes of determining U-factors, the shading system and glazing layers comprising each group leader shall be determined as follows:

A. Glazing layers within a group, and the corresponding glazing layers used in the group leader, shall be determined in accordance with the center-of-glazing grouping rules of Section 4.2.4.1.

B. Shading systems within a group may vary by color, material, finish, rise (i.e., the arc in the case of venetian blind slats), and thickness of the shading systems. ; and

   i. Grouping by color shall adhere to one of the two options per ANSI/NFRC 200, Section 4.2.3.C.i; or

   ii. Grouping by the default venetian blind slat material shall use aluminum alloy (k=160 W/mK) as the material and the finish (i.e., surface emittance) per ANSI/NFRC 200, Section 4.2.3.C.ii.

   iii. The venetian slat rise of 0mm shall be permitted to represent all offered rises.

4.2.4.3 Frame/Sash Grouping

A. For the purpose of determining U-factors, frame groups shall consist only of frame/sash base profile variations consistent with the definition of a product line. After all frame options have been identified within a product line, the frame and edge-of-glazing heat loss shall be simulated for each option with the lowest center-of-glazing U-factor in the product line. The frame group leader shall be identified as the set of frame options within the highest whole product heat loss. If this approach is used, the total fenestration product U-factor for the frame group leader shall be used to represent the total fenestration product U-factors for all individual products within that group.

B. To determine the frame group leader the spacer used in simulation shall be a spacer used by the manufacturer. If more than one spacer is available, the spacer used shall be selected from the list below in the following order:

Group 1 – Spacer containing aluminum

Group 2 – Spacer containing mild steel (i.e. galvanized steel, tin-plated steel)

Group 3 – Spacer containing stainless steel

Group 4 – Spacer containing all non-metallic materials

4.2.4.4 Spacer Grouping

For the purpose of determining U-factors, spacer groups shall consist only of variations in spacer assembly materials and shapes. After all spacer options have been identified within a product line, the frame and edge-of-glazing heat loss shall be simulated for each spacer option with the lowest center-of-glazing U-factor and the frame group leader in the product line. These products shall be permitted to be grouped with each group represented by the spacer group leader (which shall be the option with the highest whole product heat loss). If this approach is used, the total fenestration product U-factor for the spacer group leader shall be used to represent the total fenestration product U-factors for all individual products within that group.

For glazing matrix consisting of both double pane and triple pane glazing configurations, spacers can be grouped by simulating each spacer option in the appropriate glazing category (double pane or triple pane) with the lowest center-of-glazing U-factor in the glazing category. Spacer group leaders for double pane and triple pane configurations shall represent the double pane group and triple pane group, respectively.

4.2.4.5 Sightline Grouping

Sightline groups shall consist only of individual products with sightline differences due to frame/sash base profile variations. These products shall be permitted to be grouped with each group represented by the sightline group leader, which shall be the sightline option within the group with the highest total fenestration product U-factor. Since sightline changes may be in small size increments, the determination

of the highest total fenestration product U-factor for each sightline group shall be determined for the frame/sash with the greatest and least daylight opening areas, using the lowest center-of-glazing U-factor option and the model size for the product type per Table 4-3.

4.2.5 General Simulation Rules

A. If a nail flange is not removable and is identified as such by the manufacturer, the product shall be simulated and tested with the nail flange covered with a nominal 1 in x 4 in fir trim. If a nail flange is removable, the product shall be simulated and tested without the nail flange;

B. Products with integral appendages that extend beyond the rough opening and are not exposed after installation shall be permitted to be assumed to have the same U-factors as identical products without such appendages;

C. Products with elements added to the outer surface of the framing so as to expand the frame in the direction parallel to the plane of installation and allow for different installations, shall be permitted to have the same U-factors as identical products without such added elements:

   Examples of such elements include, but are not limited to, subsills and frame expanders;

D. Nominal glass thickness shall be permitted to be used for determining U-factor provided the emissivity of the glass is taken from the approved NFRC Spectral data file and the air gap dimension is maintained at the dimensions specified by the manufacturer. The nominal glass thickness to be used shall be listed in ASTM C 1036 [Reference 6]. If the glass thickness does not fall within the nominal thickness ranges, the actual thickness shall be used;

E. An infill system with a “Center-of-Glazing Component Test” that utilizes an adaptor between the infill and frame which allows for direct replacement of the standard glazing shall be considered an individual product in the same product line with the standard glazing, as long as all components (including the adaptor) are included in the simulation for the infill glazing system;

F. Non-rectangular fenestration products shall be rated as rectangular fenestration products per the model size in Table 4-3 (develop a product line with the same frame cross sections as the non-rectangular fenestration product); and

G. IG units manufactured with breather or capillary tubes designed to remain closed after manufacturing shall be simulated as having the same gas content; IG units manufactured with breather tubes intended to be opened at some point after manufacturing shall be simulated as air-filled IG units:

H. For the purpose of determining U-factors, only glazing tint and/or obscurity (including obscure glass) shall be permitted to be assumed to have the same U-factor as the clear glass and does not need to be simulated separately unless this change is associated with a change in coating properties. This option can be used as an alternative to obtaining product properties using the measurement procedure defined in NFRC 301 for diffuse products; and

I. Products with removable or non-removable dividers (e.g. SDL) or decorative tapes that are applied to glazing to simulate the appearance of dividers applied to the room side and/or exterior side glazing surface shall be permitted to be assumed to have the same U-factors as identical products without such dividers. However, any component (shadow bar) of an SDL that is within the cavity of the IGU shall be treated as a normal internal divider. At the discretion of the manufacturer, a simulator shall be permitted to model an SDL in accordance with Section 8.3.2 of the NFRC Simulation Manual.

J. Laminated glass layers which incorporate embedded Building Integrated Photovoltaics (BIPV) shall be permitted to be assumed to have the same U-factor as the clear laminated glass version.

4.2.6 General Testing Rules

The baseline product shall be the individual product selected for validation testing (see Section 4.1.1). The individual product selected as the baseline product shall have a simulated U-factor within 0.60 W/m^2K (0.10 $Btu/h \cdot ft^2 \cdot ºF$) or 20% of the lowest simulated U-factor, whichever is greater. Size variations shall be limited to the representative size as defined in Section 4.6.1 for the product type. If more than one product type is being validated with a single test, then the baseline product shall be selected from the product lines in the validation test matrix.

4.2.7 General Rating Rules

A. Combination products shall not be rated in combination.

B. Sash kits, sliding door panels, and side hinged door slabs shall be rated using one of two options:

Option1: Simulate and test (if required) in a frame of similar material and design as the proposed installation. Manufacturers of sash kits, sliding door panels, and side hinged door slabs shall provide information on the intended installations for those products. (See Figure 5-6 for an example of a default double hung frame when a sash kit is intended to be installed in a wood double hung window.)

Option 2: Sash kits, sliding door panels, and side hinged door slabs that are identical in material and design as a manufacturer's rated product line may use the same ratings. The manufacturer shall verify the rated frame meets the requirements of Option 1.

4.2.8 Additions to the Product Line

The product line validated simulation procedure (see Section 4.1.1) may be used to determine U-factors of additions to a validated product line if the simulated U-factor for the additional product(s) is either higher than the previously computed baseline product U-factor, or not more than 0.60 W/m^{2}K (0.10 Btu/h·ft^2·ºF) or 20% (whichever is greater) lower than a previously simulated baseline product U-factor.

If the simulated U-factor of the addition to the product line is outside these bounds, a new baseline product shall be established and validated by testing.

If a manufacturer introduces a new individual product into multiple product lines (see Section 4.2.6 for an example of glazing or spacer options) that has simulated U-factor more than 0.60 W/m^{2}K (0.10 Btu/h·ft^2·ºF) or 20% lower than the simulated baseline product U-factor, only one product line with a new individual product shall be tested. If the simulation of the new baseline product validates, then all other product lines using this option shall be validated and those new individual products shall be permitted to be simulated to obtain U-factors.

4.3 Standard Conditions

This section presents standard simulations, tests, and calculations for determining total or component fenestration product U-factors.

4.3.1 Simulation

The requirements of Reference 2 (NFRC Simulation Manual) and of Section 4.3.2.1 shall be used to determine total fenestration product U-factors.

Skylights and other sloped glazing products shall be simulated and rated at a slope of 20º above the horizontal. Until accurate simulation

software is available, tubular daylighting devices (TDDs) shall be tested and rated with the tube in a vertical orientation (Figures 5-14a and b). All other products shall be simulated and rated in the vertical position.

Spandrel panel systems shall be simulated with 254mm (10 in.) of “Edge” assigned to the spandrel panel system instead of the required 63.5mm (2.5 in.) as noted in Section 4.3.1.A below.

All calculations shall be based on computer simulations using the latest approved software (which shall be in compliance with ISO 15099), with the following exceptions:

A. For calculating the overall U-factor (per ISO 15099), the area-weighted method as described in Section 4.1.4 of ISO 15099 shall be the only method permitted, with the exception of opaque spandrel panel systems which shall use 254mm (10 in.) of edge-of-glazing dimension;

B. Thermophysical properties of materials shall be determined in accordance with NFRC 101;

   i. For metallic frames not specifically noted in Table 4-2, *Boundary Conditions*, the following interior boundary conditions shall be used:

      (a) All non-thermally broken metal frames shall use "Interior Aluminum Frame (convection only)";

      (b) All thermally improved metal frames shall use "Interior Thermally Improved Frame (convection only)"; and

      (c) All thermally broken metal frames shall use "Interior Thermally Broken Frame (convection only)";

   ii. For metallic surfaces, they shall be assigned the emissivity for exposed, painted, or anodized as appropriate. Surfaces to be considered exposed shall follow the same rules as aluminum alloy frames but with the emissivity appropriate for that material.

C. For fenestration products incorporating venetian blinds:

   i. Include models for venetian blinds slats (See References 13 and 14);

   ii. Thermal radiation from venetian blinds shall be calculated using directional diffuse radiation (See References 13 and 14);

D. Include models for fritted, etched, sand-blasted glazing, and other light-scattering products that can be measured according to NFRC 301 (See Reference 14 and 15);

i. Glazing layers that are partially covered with a light-scattering element shall be simulated using the properties of the fully covered layer and properties of the non-scattering layer, and the final result is the area-weighted mix of the different areas. This could be done for any number of different areas.

ii. Using data according to NFRC 301 for light-scattering products is an alternative to using a clear glazing as approximation as described in 4.2.5 H;

E. Include models for fenestration products incorporating vacuum insulating glass (VIG) (See Reference 16 and 17)

F. Section 8.2 in ISO 15099 addresses environmental conditions. The following conditions shall be used for the determination of U-factor:

NFRC Simulation Conditions:

T_{in} = interior ambient temperature of 21.0º C (69.8º F)
T_{out} = exterior ambient temperature of -18.0º C (-0.4º F)
V = wind speed of 5.5 m/s (12.3 mph)
$T_{rm,out}$ = T_{out}
$T_{rm,in}$ = T_{in}
I_s = 0 W/m^2 (0 Btu/h·ft^2)

G. Section 8.3 in ISO 15099 addresses convective film coefficients on the interior and exterior of the fenestration product;

H. The indoor side convective heat transfer coefficient shall be based on the center of glass temperature and the entire fenestration product height; this film coefficient shall be used on all glass and edge of glass indoor surfaces with the exception of spandrel panel systems. The spandrel panel shall be assigned a boundary condition as noted in Table 4-2 below.

I. Frame section indoor convective film coefficients shall be constants, which depend on frame material type; these values are listed in Table 4-2;

J. The outdoor side convective heat transfer coefficient shall be calculated based on wind speed (as defined under 4.3.1.E) and shall be applied to all outdoor surfaces, glass and frame. Standard values for outdoor convective surface heat transfer coefficients is listed in Table 4-2;

K. On the indoor side of a fenestration product, detailed radiation model, based on gray body radiation model as described in Section 8.4.2.1 in ISO 15099, shall be used for all products. This model applies to both glass and frame surfaces;

L. The use of detailed radiation model on indoor fenestration surfaces makes the use of “slightly or partially ventilated cavities” on the indoor frame surfaces redundant (see Section 6.7.1 of ISO 15099). The standard frame convective film coefficients (h_c) shown in Table 4-2 and detailed radiation model referenced above shall thus be applied to all interior frame surfaces;

M. On the outdoor side of a fenestration product, blackbody radiation model (as defined in ISO 15099) shall be used. This model applies to both glass and frame surfaces;

N. Frame absorptance does not affect the total product U-factor; therefore, it is not required to use the default frame absorptance values stated in ANSI/NFRC 200, Section 4.5.D. Only the individual products used to generate the $SHGC_0$, $SHGC_1$, VT_0, and VT_1 shall be calculated using the default absorptance values; and

O. All cross-sections shall include 150 mm (6 in) of glazing section from the sightline to the end of the glazing section, while maintaining a 63.5 mm (2.5 in) edge-of-glazing dimension. The exception is with spandrel panel systems which shall be 406mm (16 in.) of spandrel panel section while maintaining a 254mm (10 in.) edge dimension.

Table 4-2 – Boundary Conditions

Boundary Condition	Radiation Model	Convective Film Coefficient Boundary	
		Tilt = 90° W/m²K (Btu/h·ft²·°F)	Tilt = 20° W/m²K (Btu/h·ft²·°F)
NFRC 100-2010 Exterior	Blackbody	26.00 (4.578)	26.00 (4.578)
Interior Aluminum Frame (convection only)	Automatic Enclosure Model	3.29 (0.579)	4.65 (0.819)
Interior Thermally Broken Frame (convection only)	Automatic Enclosure Model	3.00 (0.528)	4.09 (0.720)
Interior Thermally Improved Frame (convection only)	Automatic Enclosure Model	3.12 (0.549)	4.32 (0.761)
Interior Wood/Vinyl Frame (convection only)	Automatic Enclosure Model	2.44 (0.429)	3.09 (0.544)
Interior Glazing System boundary condition	Automatic Enclosure Model	Depends on the WINDOW calculations for the imported glazing system	
Steel Skin Door Slabs	Automatic Enclosure Model	Non-Metal Edge of Door Slab shall use "Wood/Vinyl Frame" Steel or Aluminum Edge of Door Slab shall use "Thermally-Improved"	
Interior Insulated Opaque Spandrel Panel	Automatic Enclosure Model	Shall use the interior boundary condition from above that is equivalent to the glazed wall system's intermediate frame type	

4.3.2 Testing

4.3.2.1 Total Fenestration Product Test Procedure

NFRC 102 [Reference 1], shall be used to determine tested total fenestration product U-factors. The following conditions also apply:

A. Test specimen size tested shall be in accordance with Section 4.6.1;

B. All test specimens shall be tested without screens, removable grilles and trims, or any other applied devices;

C. All test specimens shall be tested in the vertical position, except tubular daylighting devices (TDDs). TDDs shall be tested and rated with the tube in a vertical orientation (see Figures 5-10a and b). For determining validation of the baseline product only, skylights and other sloped glazing products shall be simulated in a vertical position; and

D. The test specimen shall not be modified by the testing laboratory, except as allowed in Reference 1 for sealing against air leakage and as required in this section.

4.3.2.2 Center-of-Glazing Component Test Procedure

If the U-factor for the product cannot be simulated in accordance with Section 4.3.1, the test methods in ASTM C1363-97 (or later versions) using NFRC environmental conditions, shall be used to determine the conductance of the center-of-glazing. The conductance value shall be used to determine an effective conductivity at the thickness of the glazing/frame insert which can be used to build a glazing layer in WINDOW.

The specimen shall be 1000 mm x 1000 mm (39 in x 39 in) or closest deviation as determined using Section 4.6. This size represents all product types in Table 4-3.

For a product that consists of a glazing panel only (without frame), the tested U-factor per this section, standardized in accordance with NFRC 102, shall be the U-factor of the product.

Obscure and tinted versions of a clear glazing tested using this procedure may be represented by the clear glazing results as long as the product emissivity does not change.

4.3.2.3 Component Substitution

Component substitutions may be made if using approved NFRC simulation tools to verify the performance equivalence to three significant digits. The original certified U-factors shall be used to represent the new product.

For products certified under the testing alternative method (Section 4.1.2), component substitution shall apply only if the simulation laboratory states in the simulation report that the simulation tools are appropriate for the simulation of the components being substituted.

A. For spacer substitutions, only the spacer shall be modeled, or

B. For glazing system changes, only the center-of-glazing shall be modeled.

4.4 Model Sizes and Configurations

For each individual product, total fenestration product U-factors shall be reported for the specified configuration at the model size as shown in Table 4-3.

For products that, when area-weighted at the model size, have less than 63.5 mm (2.5 in) edge-of-glazing area or edge-of-divider area, the overall product dimensions shall be increased as needed to restore the standard 63.5 mm (2.5 in) of edge-of-glazing for each section (including dividers). The increase in size shall result in zero center-of-glass area.

Table 4-3 – Product Types and Model Sizes

Product Type	Model Size Width x Height, mm (in)	Operable (X) Non-operable (O)
Windows		
Casement – Single	600 x 1500 (24 x 59)	X
Casement – Double	1200 x 1500 (47 x 59)	XX, XO
Dual-Action	1200 x 1500 (47 x 59)	X
Fixed	1200 x 1500 (47 x 59)	O
Greenhouse/Garden	1500 x 1200 (59 x 47)	X, O
Horizontal Slider	1500 x 1200 (59 x 47)	XX, XO
Pivoted	1200 x 1500 (47 x 59)	X
Projecting (Awning – Single)	1500 x 600 (59 x 24)	X
Vertical Slider	1200 x 1500 (47 x 59)	XX, XO
Doors and Door Related		
Side-Hinged Exterior Door	960 x 2090 (38 x 82)	X, O
Side-Hinged Exterior Door (Double)	1920 x 2090 (76 x 82)	XX, XO
Sliding Glass Door	2000 x 2000 (79 x 79)	XX, XO
Sidelite	960 x 2090 (38 x 82)	X, O
Transom	2000 x 600 (79 x 24)	O
Garage (Vehicular Access)/Rolling Door	2134 x 2134 (84 x 84)	X
Skylights		
Skylight/Roof Window	1200 x 1200 (47 x 47)	X, O
Tubular Daylighting Device	350 (14) Diameter	O
Glazed Wall Systems		
Curtain Wall	2000 x 2000 (79 x 79)	OO
Window Wall	2000 x 2000 (79 x 79)	OO
Sloped Glazing	2000 x 2000 (79 x 79)	OO
Spandrel Panel System	2000 x 2000 (79 x 79)	OO

4.5 Simulation Procedures

4.5.1 Total Fenestration Product U-factors for Model Sizes

For a given product line, list all individual products and the associated model size U-factors (see Section 4.4). The model size matrix of U-

factors for a given product line shall be outlined as shown in Section 4.1.1.A.

This matrix shall include all individual products within a product line that are available from the manufacturer, including but not limited to the number of glazing layers, glazing types, glazing coatings, gas fills, gap widths, spacer types, and use of dividers. See Section 4.2.1 for the definition of a product line and Section 4.2.2 for the definition of an individual product.

In order to determine total fenestration product U-factors for all of the entries in this matrix, use the product line validated simulation procedure, presented in Section 4.1.1. The testing alternative, presented in Section 4.1.2, may only be used to determine the U-factor for an individual product(s) within a product line if that individual product(s) cannot be simulated in accordance with Section 4.3.1.

Thus, the only time a product line may contain tested as well as simulated total fenestration product U-factors shall be when an accredited simulation laboratory states in the simulation report that it cannot simulate an individual product(s) to a reasonable accuracy. In addition, the written permission of NFRC shall be required.

4.5.2 Total Fenestration Product

The U-factor of a fenestration product may vary by size, depending upon the component materials and the glazing. To simplify the system, ratings are based on a specific model size. The U-factor for the model size in Table 4-3 for all single-lite products shall be representative of all variations in configuration with one or more lites (operable/non-operable)for the product type. The U-factor for the model size in Table 4-3 for all dual-lite products shall be representative of all variations in configuration with two or more lites for the product type. Casement and Exterior Door products shall be rated as dual-lite types only when a single-lite version is not produced. The U-factor for the model size shall be representative of all variations in size and factory assembled operable and non-operable units in a common frame.

For gas fills other than air, the gas fill concentration percentages represent the initial nominal design value. The maximum gas concentration used in the simulations shall not exceed the following values:

Evacuated Chamber Filling	97% for any gas type
Two-Probe filling with concentration sensor	95% for Argon 90% for any other
Single-Probe Timed Filling	90% for any gas type

Non-continuous elements including (but not limited to: screws and bolts in sloped glazing and poured and debridged thermal barriers that are not fully debridged), shall be simulated as indicated in Reference 2.

The total fenestration product U-factor calculation procedure can be found in the applicable fenestration product section, see Sections 5.1 to 5.10.

4.5.3 Component

4.5.3.1 Approved Center-of-Glazing Simulation Programs

Approved center-of-glazing software shall be used. NFRC approved software is listed in Reference 3.

4.5.3.2 Approved 2-D Heat Transfer Simulation Programs

Approved 2-D heat transfer software shall be used. NFRC approved software is listed in Reference 3.

4.6 Test Procedures

There are two different test procedures used in ANSI/NFRC 100:

Total Fenestration	4.6.1
Glazing	4.6.2.1

Section 4.3.2.1 defines the total fenestration product test procedure, its standard conditions and requirements. The total fenestration product test procedure shall be used to validate the product line simulations (see Section 4.1.1) and shall be used under the testing alternative (see Section 4.1.2), which shall be used only if the U-factor for the product cannot be simulated in accordance with Section 4.3.1. Section 4.3.2.2 defines a glazing component test procedure, which may be used only if the U-factor for the center-of-glazing cannot be simulated in accordance with Section 4.3.1. Since the glazing system may include non-homogeneous elements (e.g. spacers, thermal bridges, etc.), an average conductance shall be assigned to the whole glazing system. Insertion of such a glazing system in the 2-D heat transfer program shall be done as a continuous slab of material with the conductivity equal to the average conductivity of the glazing system.

4.6.1 Total Fenestration Product

For the purposes of testing (see Section 4.3.2), production line units and sizes shall be used. The test specimen size shall be the production line size with the least deviation (D) from the model size (see Table 4-3) as defined by Equation 4-2:

$$D = \sqrt{(W_p - W_m)^2 + (H_p - H_m)^2}$$

Equation 4-2

Where

D = Deviation in mm (in)
W_p, H_p = Width, height of production size in mm (in)
W_m, H_m = Width, height of model size in mm (in)

For rectangular fenestration products, the representative sizes reported by the simulation laboratory shall not vary by more than 13.0 mm (0.5 in) in width or 13.0 mm (0.5 in) in height (25 mm [1 in] for doors) from the reported sizes of the tested specimens.

For non-rectangular products, the simulated product area shall meet the following relationship with the tested specimen area:

$$A_{test} - C(W_m + H_m) \leq A_{sim} \leq A_{test} + C(W_m + H_m)$$

Equation 4-3

Where

A_{sim} = Area of product simulated in mm^2 (in^2)
A_{test} = Area of specimen tested in mm^2 (in^2)
C = A constant, 25 mm (1 in)
W_m, H_m = Width, height of model size in mm (in)

4.6.2 Component

4.6.2.1 Glazing Component Test Procedure

The test methods in Reference 6, using NFRC environmental conditions, shall be used to determine the average conductivity of the glazing. The test results are applicable only to the unit tested, with no variations in shape or material allowed.

4.6.3 Calculation Procedure

The total fenestration product U-factor shall be calculated as outlined below:

A. Determine all of the following, as applicable:

i. Center-of-glazing U-factor per the total product height procedure (as defined in Reference 2) using an approved center-of-glazing simulation program or the

approved glazing test procedure given in Section 4.3.2.2,

ii. Edge-of-glazing U-factor, using an approved 2-D heat transfer simulation program. In the case that center-of-glass thermal performance is simulated, this center-of-glass configuration shall be inserted into the frame and spacer assembly shall be added. In the case that the glazing component test procedure had to be utilized, entire glazing system shall be represented as a homogenous slab of material with conductivity equal to average conductivity of the measured specimen. For mullions and meeting rails, two glazing systems shall be inserted on each end and the reported U-factor shall be the average of the two edge-of-glass U-factors,

iii. Divider U-factor, using an approved 2-D heat transfer simulation program. Divider shall be simulated with two glazing systems pointing in opposite directions, simulated in a vertical orientation,

iv. Edge-of-divider U-factor, using an approved 2-D heat transfer simulation program. Edge-of-divider U-factor shall be the average of the two edge-of-glass section U-factors,

v. Frame U-factor using an approved 2-D heat transfer simulation program. Frame U-factor is always calculated on the exposed indoor side of frame, starting at the bottom of the frame and ending at the indoor sight line. For mullion and meeting rail cross-sections, frame surface is counted from one indoor sight line to another,

vi. The component areas of:

(a) Center-of-glazing area,

(b) Edge-of-glazing area,

(c) Divider area,

(d) Edge-of-divider,

(e) Frame area, and

(f) Projected fenestration product area;

B. Perform the following calculations as explained:

i. Multiply the center-of-glazing, edge-of-glazing, divider, edge-of-divider, and frame U-factors by their corresponding areas,

ii. Total these quantities, and

iii. Divide this total by the projected fenestration product area to produce simulated total fenestration product U-factors for all the fenestration products in the matrix of required U-factors.

4.6.4 Reporting of Ratings

The full floating-point accuracy of any software shall be used for all calculations. The final U-factor shall be reported in IP units (BTU/h·ft^2·ºF) and rounded to two digits following the decimal point after truncating the full precision result to six decimal places. If the U-factor is to be reported in SI units as well as IP units, the SI U-factor shall be converted from the IP U-factor following the procedure outlined in NFRC 700, Section 6.5.I.iii.

4.7 Validation

4.7.1 Equivalence

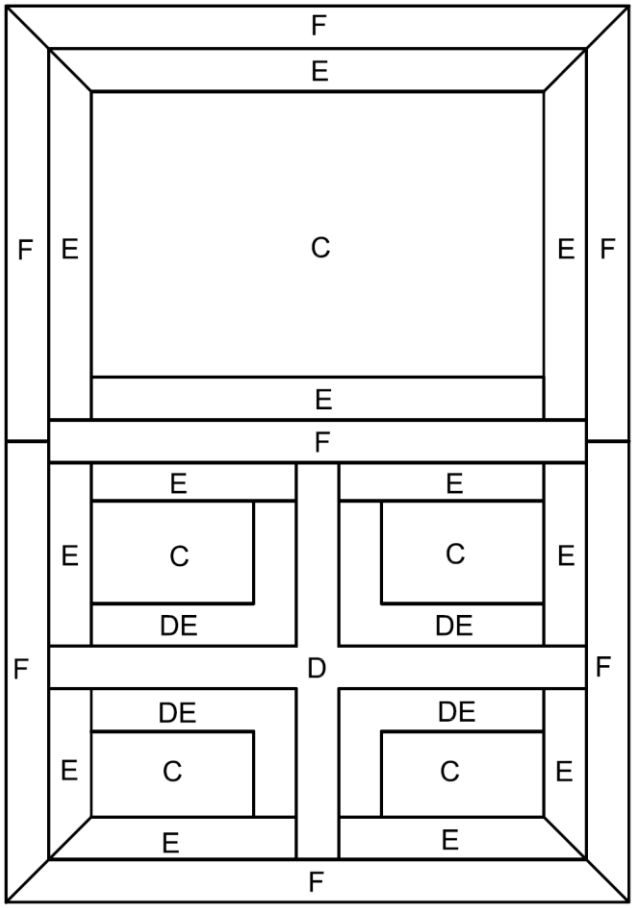
Simulated and tested U-factors for a given total fenestration product shall be considered equivalent if the agreement between the two numbers is within the ranges in Table 4-4.

Table 4-4 -- Equivalence

Simulated U-factor	Accepted Difference Between Tested and Simulated U-factor
1.7 W/m^{2}K (0.3 Btu/h·ft^2·ºF) or less	0.17 W/m^{2}K (0.03 Btu/h·ft^2·ºF) or less
Greater than 1.7 W/m^{2}K (0.3 Btu/h·ft^2·ºF)	10% of Simulated U-factor

4.8 Figures

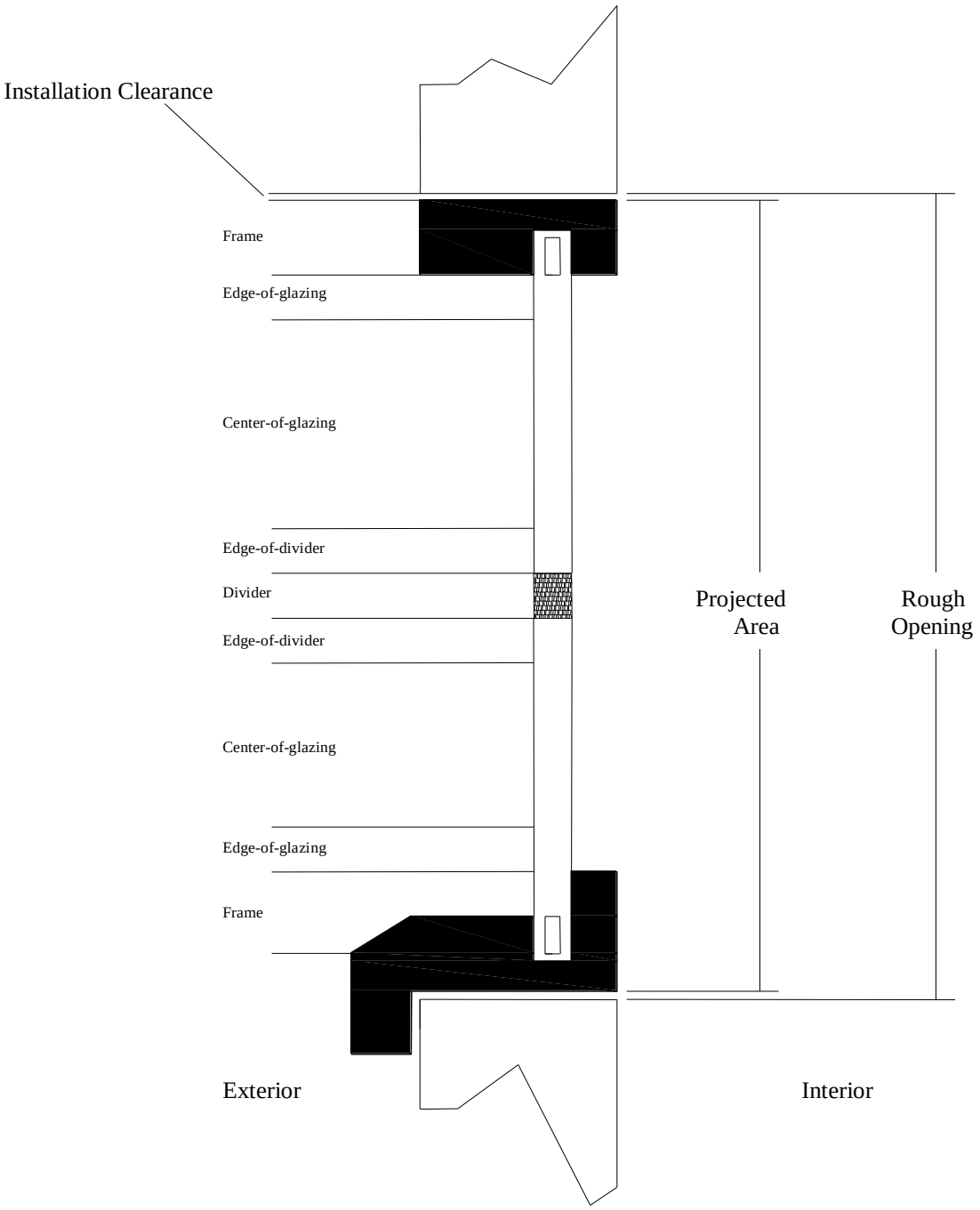
Figure 4-1 – Fenestration Product Schematic – Vertical Elevation



LEGEND
C Center-of-Glazing
E Edge-of-Glazing
F Frame
D Divider
DE Edge-of-Divider

Center-of-glazing, edge-of-glazing, divider, edge-of-divider, and frame areas for a typical fenestration product. Edge-of-glazing and edge-of-divider are 63.5 mm (2.5 in) wide (with exception of Spandrel Panel Systems which shall be 254mm (10 in)). The sum of these component areas equals the total projected fenestration product area.

Figure 4-2 – Fenestration Product Schematic – Vertical Section



Center-of-glazing, edge-of-glazing, divider, edge-of-divider, and frame areas for a typical fenestration product. Edge-of-glazing and edge-of-divider are 63.5 mm (2.5 in) wide. The projected fenestration product area is the rough opening less installation clearances.

Figure 4-3 – Divider Height and Divider Width

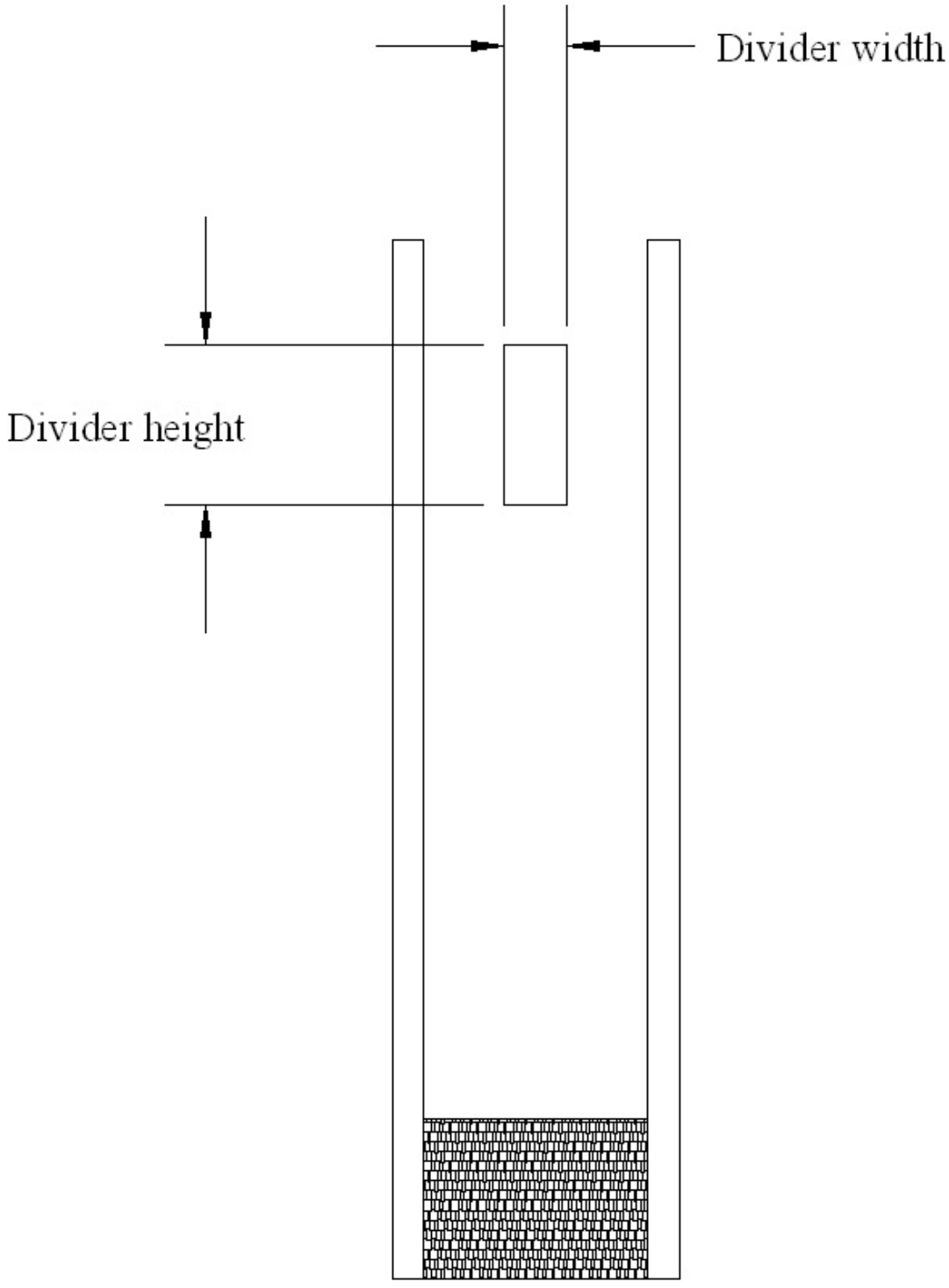
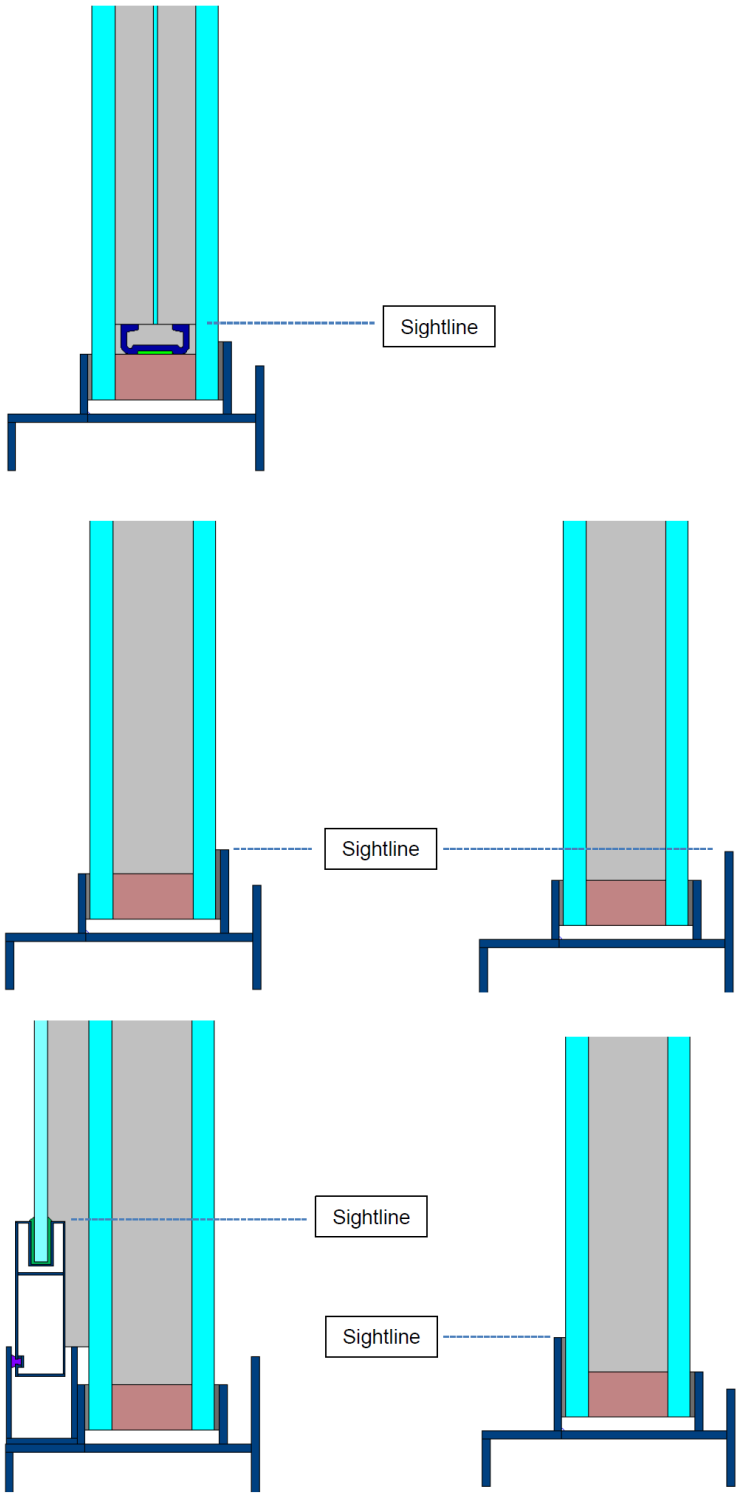


Figure 4-4 – Sightline Examples



5. VARIATIONS FROM THE GENERAL REQUIREMENTS

This section presents and references methods for determining specific product system heat transfer properties or quantities used in the determination of these properties. At this time, the scope of these properties is limited to total product system U-factor.

5.1 Windows and Sliding Glass Doors

5.1.1 Scope

This section presents additional details specific to windows and sliding glass doors.

This section presents and references methods for determining windows and sliding glass doors product system heat transfer properties or quantities used in the determination of these properties. The scope of these properties is limited to windows and sliding glass doors total product system U-factor.

5.1.2 Variations from Standard Product Lines

None

5.1.3 Variations from Standard Individual Products

None

5.1.4 Variations from Standard Simulation and Test Conditions

Sliding glass door product types are limited to XO and XX configurations per Table 4-3, therefore, single panel sliding pocket doors shall be simulated and tested as a single panel door and shall be calculated for U-factor using the single panel side-hinged exterior door product type.

5.1.5 Calculation of Total Product Rating

The total fenestration product U-factor shall be calculated as per Section 4.6.3. Perform the following calculation to determine total product rating.

$$U_t = \frac{\left[\Sigma\left(U_f A_f\right) + \Sigma(U_d A_d) + \Sigma(U_e A_e) + \Sigma(U_{de} A_{de}) + \Sigma(U_c A_c)\right]}{A_{pf}}$$

Equation 5-1

Where:

U_t = Total product U-factor

A_{pf} = Projected fenestration product area

U_f = Frame U-factor
A_f = Frame area
U_d = Divider U-factor
A_d = Divider area
U_e = Edge-of-glazing U-factor
A_e = Edge-of-glazing area
U_{de} = Edge-of-divider U-factor
A_{de} = Edge-of-divider area
U_c = Center-of-glazing U-factor
A_c = Center-of-glazing area

5.1.6 Figures

None

5.2 Side-Hinged Exterior Doors and Sidelites

5.2.1 Scope

This section presents additional details specific to side-hinged exterior doors, sidelites, and exterior bi-fold doors (a.k.a. folding wall) to determine a total product U-factor.

This section presents and references methods for determining specific heat transfer properties and areas used in the determination of these properties for exterior doors, sidelites, and exterior bi-fold doors. These values shall be determined using one of three methods listed below. Manufacturers may choose to perform their simulations using any of the techniques applicable to their specific product.

5.2.1.1 Simplified Door Rating (SDR) Method

The Simplified Door Rating (SDR) method is described in detail in Section 5.2.5.1 and shown in Figure 5-10.

Products Eligible for the SDR Method:

A. Skinned slabs with a foam, wood, or other core;

B. Wood stile and rail doors;

C. Composite assemblies comprised of a side-hinged exterior door slab with a sidelite slab within a single frame (see Composite Assembly definition in Section 3). If the side-hinged exterior door or sidelite are not offered as individual products, the SDR methodology may be used to determine the U-factor of the side-hinged exterior door slab with a default or proprietary frame/sill;

D. Slab sidelites within a proprietary and/or default frame/sill.

5.2.1.2 Detailed Door Rating (DDR) Method

The Detailed Door Rating method utilizes basic NFRC techniques and is described in detail in Section 5.2.5.2.

A side-hinged exterior door system which is configured to only support a full-lite option, shall be permitted to be modeled using the standard techniques (as for windows) described in Section 5.1 or Section 5.11. Product Line Grouping and simplifications that are allowed in Sections 5.2.2 through 5.2.4 may be applied to these systems. These systems typically use extruded or moulded profiles (aluminum, fiberglass, vinyl, wood, etc.) and can only support the glass size dictated by the profiles.

Adding embossed/raised panels to an existing factory assembled full-lite product line does not require re-simulation of the full-lite option; however, the SDR or DDR method shall be used to simulate and calculate U-factors for the opaque, 1/4, 1/2, and 3/4 lite options, as applicable (e.g. manufacturer is adding a 1/2 lite option so they are only required to simulate the 1/2 lite).

5.2.2 Variations from Standard Product Lines

A given series of side-hinged exterior door or sidelite assemblies is defined by skin material, core material, and edge-of-door construction that are allowed to differ by:

A. Size;

B. Embossed/raised panel and cut out configurations;

C. Products with multiple slab thickness;

D. Products with multiple embossed/raised panel thickness (i.e. different thicknesses of wood panels, or different depth of embossments);

E. The replacement of core and/or embossed/raised panel area with glazing system;

F. Center-of-lite characteristics and edge-of-lite characteristics, such as glazing types, gap widths, glazing lite areas, use of dividers, use of spacers, glazing coatings, gas fills;

G. Operable/non-operable configurations, e.g. X, O, XX, XO, OXXO etc.;

H. In-swing or out-swing operation;

I. Door slab changes where one component of the same physical shape with a thermal conductivity that does not differ by more than a factor of 10;

J. Frame components, e.g. headers, jambs and threshold; and

K. Variations in frame and/or door interior/exterior finish, paint, varnish, or stain do not constitute different product lines provided that each of these variations does not change the surface emittance by more than 0.10.

5.2.3 Variations from Standard Individual Products

A. Products with a pre-installed storm door from the manufacturer shall be rated with the storm door and associated parts removed from the assembly, or be rated as Test Only for each storm door with side-hinged exterior door embossed/raised panel/glazing configuration;

Exception: full-lite swinging door with a pre-installed full-lite storm door may be rated using simulation;

B. Doors which are designed to be installed in a variety of glazed wall systems shall be rated in the glazed wall system framing in which it is installed and using the Side-Hinged Exterior Door product type. The glazing shall be removed from the glazed wall system (non-door side) and replaced with either a block of wood or a closure panel applicable to the product, as specified by the manufacturer. (See Figures 5-11 and 5-12).

If the door utilizes an additional frame which is inserted into the glazing pocket of the glazed wall system (typically termed an insert frame), the door shall be rated using only the insert frame and shall not include the primary glazed wall framing in which the insert frame is installed (See Figures 5-11 and 5-13).

C. A door or sidelite slab without a frame shall be rated using default frame components. However, products with the same slab and different proprietary frames shall be treated as individual products within one product line. All frame options shall be individually modeled or grouped.

D. Products with multiple sill options, where the sill design changes to accommodate different installation requirements, made of the same materials type shall be different individual products within the same product line.

5.2.4 Variations from Standard Simulation and Test Conditions

This section presents rules that may be used to reduce the number of simulations of individual products necessary to represent a product

line. These rules may be used either with the product line validated simulation procedure (see Section 4.1.1) or with the testing alternative (see Section 4.1.2).

A door offered with one or more door slabs shall be rated in the configuration with the least number of slabs (i.e. single door) of the same style or model. If a door is not offered in a single or double unit, a representative double unit shall be rated, incorporating the two end most slabs and a representative intermediate vertical member, as determined and reported by the simulator.

For opaque doors with flat, raised, or embossed panels, a 6-panel layout shall be representative of all panel doors (regardless of the number of panels). This layout may also be considered representative of flush doors. See Figure 5-3 for a typical 6-panel layout. A specific 6-panel layout which is required for the SDR method and may be used as a default pattern in any other case is shown in Figure 5-10.

When simulating U-factors where a decorative lite (continuous or non-continuous) is used, the decorative lite glass shall be assumed to have the same properties as clear glass of the same glass thickness and each decorative lite caming pattern shall be considered to be a different individual option or the optional caming pattern as shown in the Table 5-1 may be used to represent all decorative lite caming patterns. The default caming profile may be used to represent any caming profile.

Default and/or proprietary components may be used at the manufacturer's discretion for door slab and/or slab sidelites. These can be used to represent proprietary frames (with the limitations noted below). (See Reference 2 for drawings):

A. Default Frame Components (Head and Jambs)

   i. Default Wood Frame: (Representative of any wood, vinyl, or composite material frame) 115 mm (4.56 in) softwood single rabbeted frame of 8% to 12% moisture content, with a specific gravity of 0.35 to 0.45, with a dual durometer plastic compression weatherstrip and flexible sweep. The default door sill shall be a standard combination wood/aluminum sill (where the aluminum does not extend to the interior) that performs as well or better than the default door sill illustrated in Figure 5-8a;

   ii. Default Steel Frame: (Representative of any steel frame, or other metal of equal or lower conductivity) 145 mm (5.75 in) - 16 Ga. pressed painted steel frame with a minimum 120 mm (4.75 in) throat depth, applied weather-strip. The frame shall consist of a head jamb, hinge jamb, lock jamb, and reinforcement for hinges and

locks. See Figure 5-4 and Figure 5-5 for the default head and side jambs.

When using the default steel frame, it is required to use the default non-thermal sill per 5.2.4.B.ii and Figure 5-8b).

B. Default Sill Components

i. Default Thermally Broken Aluminum Sill (Representative of any thermally broken aluminum sill with similar construction or non-metal sill): A standard combination wood/aluminum sill as illustrated in Figure 5-8a;

ii. Default Non-Thermal Sill (Representative of any non-thermally broken metal sill): A standard aluminum non-thermally broken sill with a sill wall thickness of 1.4 mm to 1.6 mm (0.055 in to 0.065 in) and no substrate as illustrated in Figure 5-8b;

C. Default Door Lite Frame (Representative of any non-metal door lite frame). A polypropylene door lite frame as illustrated in Figure 5-9;

D. Default Caming Profile (See Reference 2).

E. Default SDR foam and wood materials used around the perimeter shall be as follows:

i. Polyurethane Foam Insulation: 0.024 W/m·K (0.166 Btu·in/hr·ft^2·F);

ii. Expanded Polystyrene: 0.038 W/m·K (0.263 Btu·in/hr·ft^2·F);

iii. Hardwood: 0.160 W/m·K (1.109 Btu·in/hr·ft^2·F)

F. Allowable SDR door slab dimensions:

i. Door slabs thickness shall be 44mm ± 2mm (1.75” ±0.079”)

ii. Steel Skin thickness shall be no greater than 0.6mm (0.024”)

iii. Fiberglass skin thickness shall be no greater than 1.9mm (0.075”)

Add-Ons

If a manufacturer wishes to simulate a door or sidelite slab in multiple frames, either proprietary or default the manufacturer may either simulate all individual products in the matrix or develop an add-on for the additional frames. To develop the frame add-on, all the individual products in the matrix shall be simulated in the best performing

framing system. The best performing product in the best performing framing system shall then be simulated in the additional frame options. The difference between these two U-factors shall be the frame add-on. The U-factor for the products in the additional frame shall be the U-factor for that product in the best performing frame plus the frame add-on.

For manufacturers offering multiple sill options:

A. Sill systems that meet the requirement of a thermally broken member shall use the product values for the NFRC default sill system;

B. Sill systems that are metal and do not meet the requirement of a thermally broken member may be given total product U-factor of 0.10 W/m^2·K (0.02 BTU/h·ft^2·F) higher than the same door system option with the NFRC default sill system.

5.2.5 Calculation of Total Product Rating

Total fenestration product U-factors for model sizes and configurations shall be calculated in accordance with Section 5.2.5.1 for the Simplified Door Rating (SDR) method and with Section 5.2.5.2 for the Detailed Door Rating (DDR) method.

To reduce the number of individual products necessary to represent a product line, refer to the guidelines prescribed in Sections 4.2.4, 5.2.2, 5.2.3 and 5.2.4.

5.2.5.1 Simplified Door Rating (SDR) Method

A. Modeling of opaque side-hinged exterior doors or sidelites is based on using a six-panel or flush configuration door product area.

i. Modeling of glazed side-hinged exterior doors will consist of two elements, the door opaque area (slab, frame, and sill); plus, the Door Glass Assembly Area (DGAA);

ii. The opaque door area (that is, the area outside the DGAA, including door frame and sill) shall be simulated in five configurations, calculated per Equation 5-2, for the opaque, ¼ lite, ½ lite, ¾ lite, and full-lite opaque areas;

iii. The DGAA of the door shall be simulated using 4 configurations, calculated per Equation 5-3, at the ¼ lite, ½ lite, ¾ lite and full-lite sizes (See Figure 5-10 of door slab with various panel sizes);

B. The total product U-factor will be calculated, per Equation 5-4, by adding the product of the glazed assembly ($U_{DGAA}A_{DGAA}$), and the product of the remaining opaque door or sidelite slab assembly (UsdAsd) divided by the total product area, where:

$$U_{sd}A_{sd} = \left[\left(U_f A_f\right) + \left(U_{dc}A_{dc}\right) + \left(U_p A_p\right) + \left(U_{ep}A_{ep}\right)\right]$$

Equation 5-2

$$U_{DGAA}A_{DGAA} = \left[\left(U_{lf}A_{lf}\right) + \left(U_d A_d\right) + \left(U_{de}A_{de}\right) + \left(U_{eg}A_{eg}\right) + \left(U_c A_c\right)\right]$$

Equation 5-3

Note: U_{DGAA} and A_{DGAA} shall be determined using WINDOW.

$$U_t = \frac{\left[\left(U_{sd}A_{sd}\right) + \left(U_{DGAA}A_{DGAA}\right)\right]}{A_t}$$

Equation 5-4

Where

U_f	=	Frame U-factor
A_f	=	Frame area
U_{lf}	=	Lite frame U-factor
A_{lf}	=	Lite frame area
U_d	=	Divider U-factor
A_d	=	Divider area
U_{de}	=	Edge-of-divider U-factor
A_{de}	=	Edge-of-divider area
U_{eg}	=	Edge-of-lite U-factor
A_{eg}	=	Edge-of-lite area
U_c	=	Center-of-lite U-factor
A_c	=	Center-of-lite area
U_{dc}	=	Door or Sidelite core U-factor
A_{dc}	=	Door or Sidelite core area
U_p	=	Panel U-factor
A_p	=	Panel area
U_{ep}	=	Edge-of-panel U-factor
A_{ep}	=	Edge-of-panel area

U_{DGAA} = Doorglass Assembly Area U factor
A_{DGAA} = Doorglass Assembly Area at ¼ Lite, ½ Lite, ¾ Lite, Full-Lite
U_{sd} = U-factor of Door Slab & Frame/Sill Opaque area
A_{sd} = Opaque Area of NFRC Model Size Swinging Door, or Sidelite, for 1/4 lite, 1/2 lite, 3/4 lite, full-lite and complete opaque configurations
U_t = Total Product U-factor
A_t = Total area

5.2.5.2 Modeling using the Detailed Door Rating (DDR) Method

The Detailed Door Rating Method total door system U-factor shall be calculated as outlined below:

A. Determine all of the following, as applicable, using the approved 2-D heat transfer computational program for all frame, panel, and core modeling and WINDOW for the center-of-lite U-factor:

i. Panel(s) U-factor;

ii. Edge-of-panel U-factor;

iii. Door core U-factor;

iv. Center-of-lite U-factor using WINDOW;

v. Lite frame U-factor;

vi. Edge-of-lite U-factor;

vii. Divider U-factor;

viii. Edge-of-divider U-factor;

ix. Frame U-factor;

x. The component areas of:

(a) Frame area

(b) Lite frame area

(c) Divider area

(d) Edge-of-divider area

(e) Edge-of-lite area

(f) Center-of-lite area

(g) Door core area

(h) Panel area

(i) Edge-of-panel area

(j) Projected total door system area

B. Perform the following calculations as shown in Equation 5-5:

i. Multiply the center-of-lite, divider, edge-of-lite, edge-of-divider, panel, door core, lite frame, edge-of-panel, and frame U-factors by their corresponding areas;

ii. Total these nine quantities; and

iii. Divide this total by the projected total exterior door system area to produce computed total door system product U-factors for all the door systems in the matrix of required U-factors.

$$U_t = \frac{\left[\begin{array}{c}\left(U_f A_f\right) + \left(U_{lf} A_{lf}\right) + \left(U_d A_d\right) + \left(U_{de} A_{de}\right) + \left(U_{eg} A_{eg}\right) + \left(U_c A_c\right) + \\ \left(U_{dc} A_{dc}\right) + \left(U_p A_p\right) + \left(U_{ep} A_{ep}\right)\end{array}\right]}{A_t}$$

Equation 5-5

Where the variables are defined in Section 5.2.5.1 above.

5.2.6 Baseline Product

A. The simulation report shall include simulation results for the exact option as tested.

B. For representative production line specimens; doors, sidelites, and transoms of the complete system (slab, frame, and sill) shall be within ± 25 mm (1 in) of the appropriate model size listed in Table 4-3.

C. For door and sidelite product lines which include glazed options, the baseline product shall be a 1/2 Lite product with a height/width tolerance of the glazing to be within +/- 13mm (0.5 in) of the dimension listed in Figure 5-10.

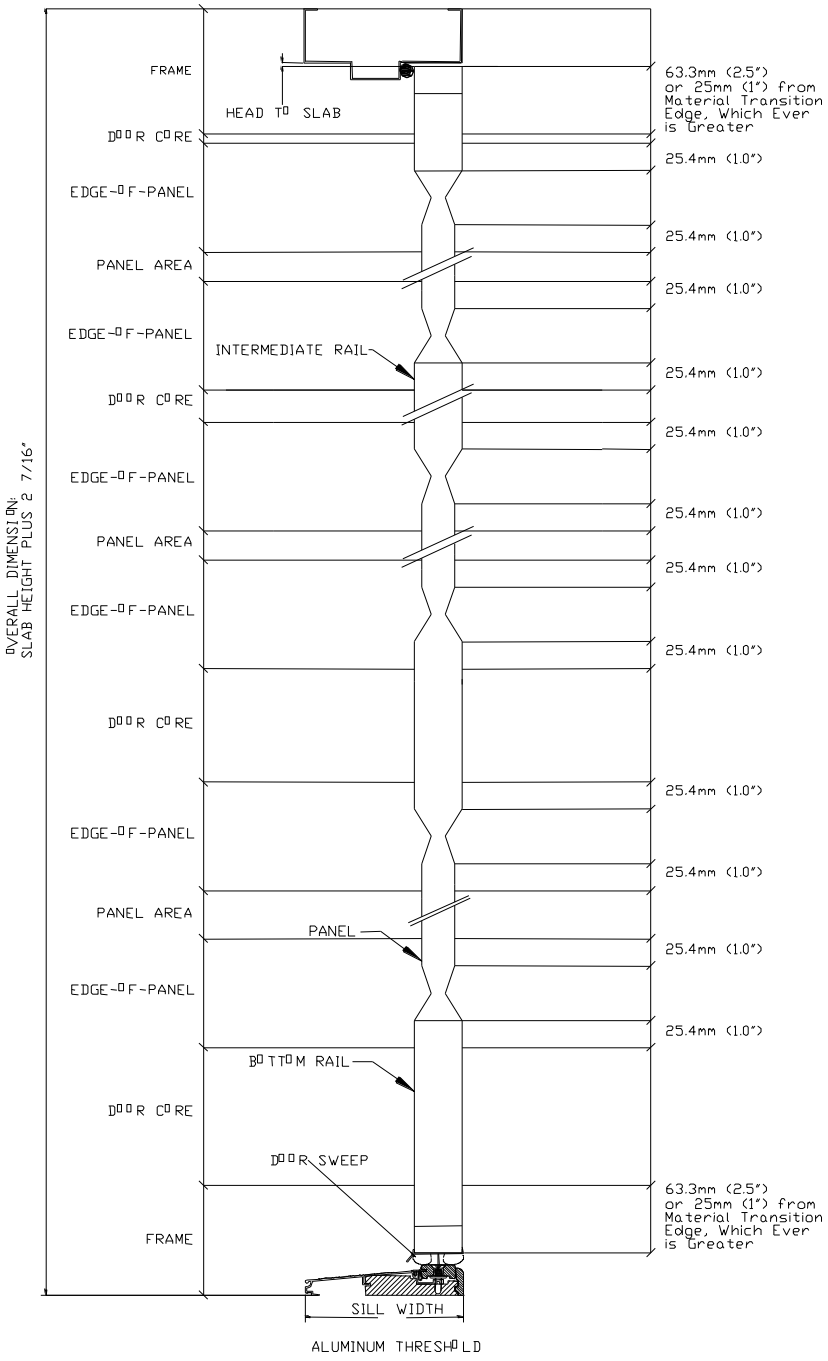
Table 5-1 – Glazing and Divider Patterns for Doors

Individual Product	For Doors with[1]	For Sidelites with[1]	Simulate or Test with Daylight Opening Size	Optional Caming Pattern
1/4 glazing	glazing < 0.265 m^2 (411 in^2)	glazing < 0.042 m^2 (65 in^2)	534 mm x 457 mm (21 in x 18 in)	5 vertical 1 horizontal
1/2 glazing	0.265 m^2 ≥ glazing < 0.581 m^2 (411-901 in^2)	0.042 m^2 ≥ glazing < 0.181 m^2 (65-281 in^2)	534 mm x 889 mm (21 in x 35 in)	5 vertical 8 horizontal
3/4 glazing	0.581 m^2 ≥ glazing < 0.710 m^2 (901-1101 in^2)	0.181 m^2 ≥ glazing < 0.252 m^2 (281-391 in^2)	534 mm x 1194 mm (21 in x 47 in)	5 vertical 10 horizontal
Full glazing	glazing ≥ 0.710 m^2 (1101 in^2)	glazing ≥ 0.252 m^2 (391 in^2)	534 mm x 1600 mm (21 in x 63 in)	5 vertical 13 horizontal

[1] Designated glazing areas are for the daylight opening size in the actual product and are not based on the model sizes from Table 4-3.

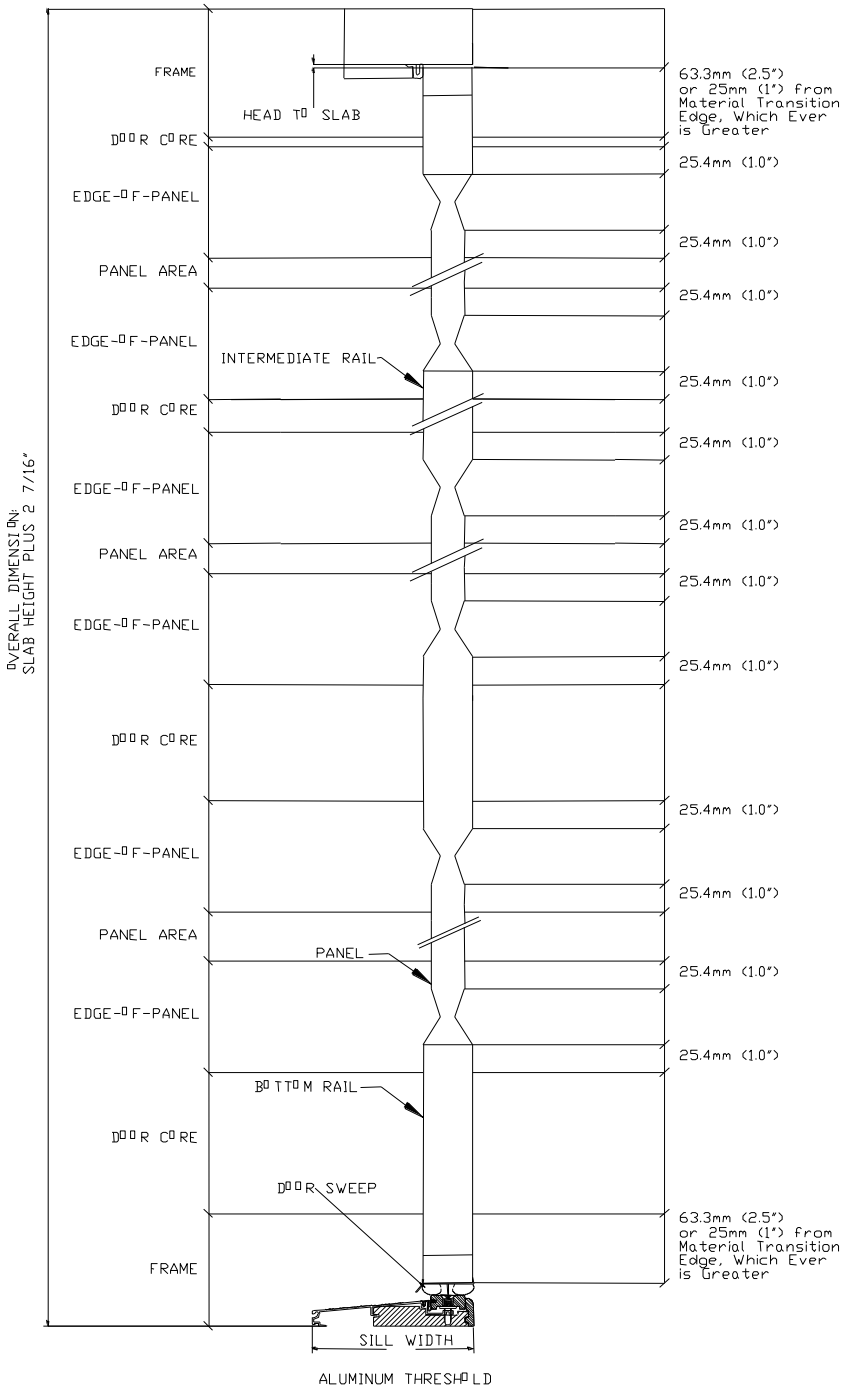
5.2.7 Figures

Figure 5-1a – Exterior Steel/Composite Door System – Vertical Elevation in Steel Frame



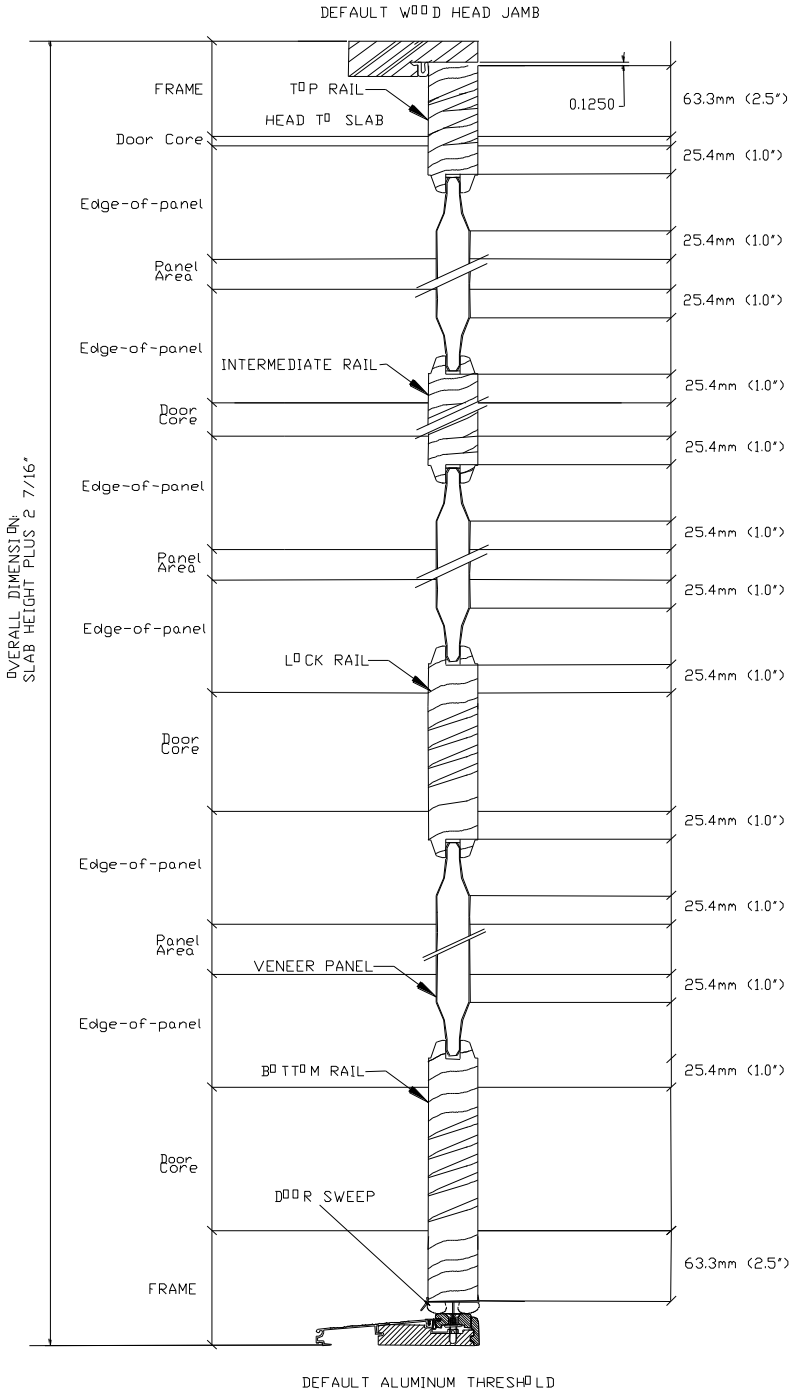
The projected door area is the rough opening area less installation clearances. Sidelite area schematic may be identical or similar without perimeter weatherstrip and bottom sweep.

Figure 5-1b – Exterior Steel/Composite Door System – Vertical Elevation in Wood Frame



The projected door area is the rough opening area less installation clearances. Sidelite area schematic may be identical or similar without perimeter weatherstrip and bottom sweep.

Figure 5-2 – Exterior Wood Door System – Vertical Elevation



The projected door area is the rough opening area less installation clearances. Sidelite area schematic may be identical or similar without perimeter weatherstrip and bottom sweep.

Figure 5-3 – Typical 6-Panel Layout

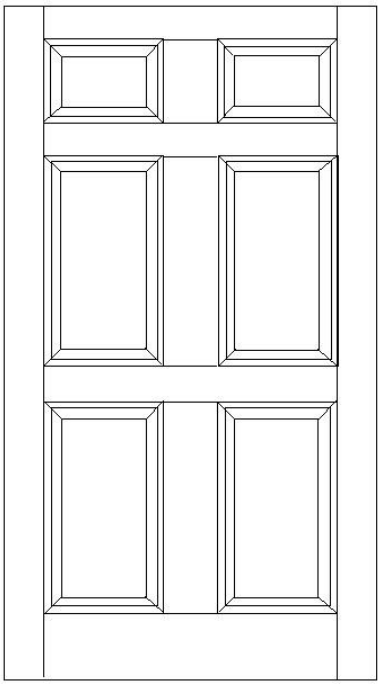


Figure 5-4 – Common Pressed-Steel Frame – Single Unit Type Pressed-Steel Frame

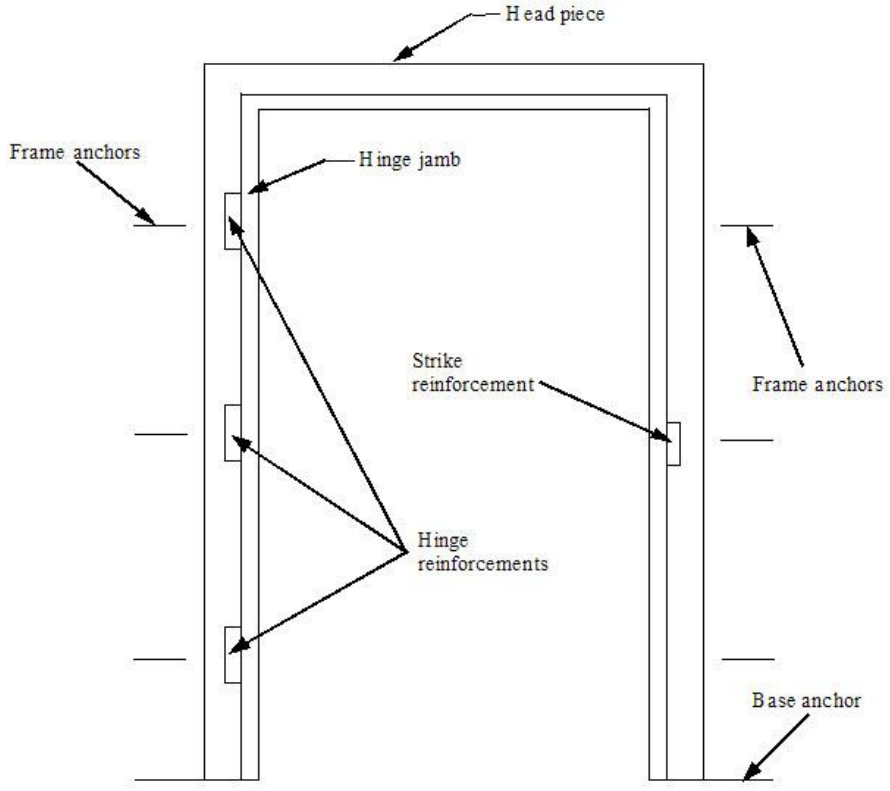
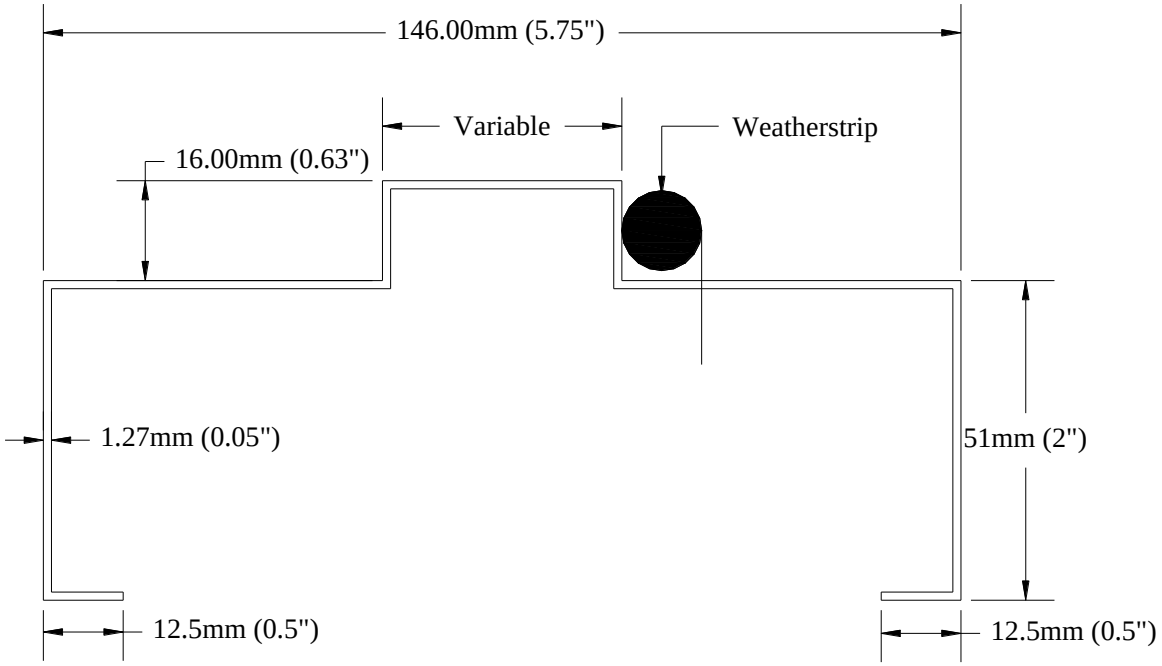


Figure 5-5 – Frame Cross Section



Pressed Steel Frame Specification (16 G)

Pressed Steel Frame Specification

Single-unit type pressed steel frames shall consist of a head, a sill and two jamb pieces, hinge reinforcements, a strike plate reinforcement, and base and wall anchors

The wall anchors provided shall be adjustable or fixed masonry anchors, bolts with expansion shells, channel clips, “Z” clips, wood stud anchors, or steel anchors.

The head and jamb pieces shall be constructed, as shown in Figure 5-4.

Figure 5-6 – Wood Default

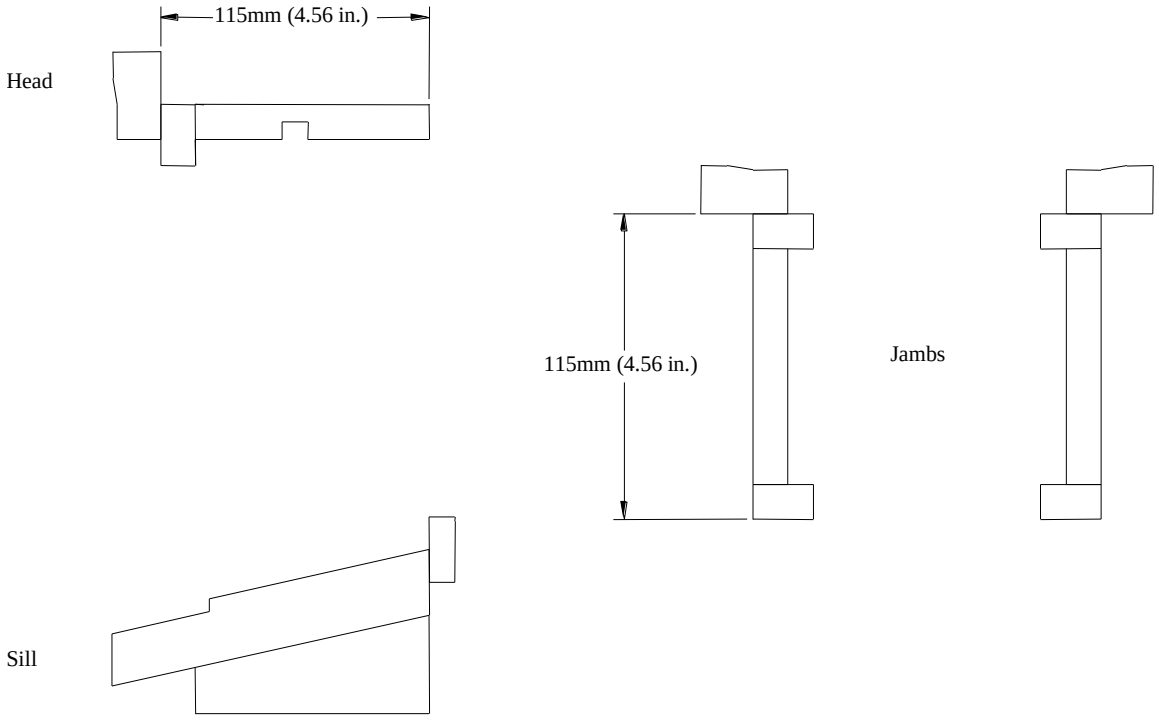


Figure 5-7 – Default Wood Door Head Jamb and Side Jamb

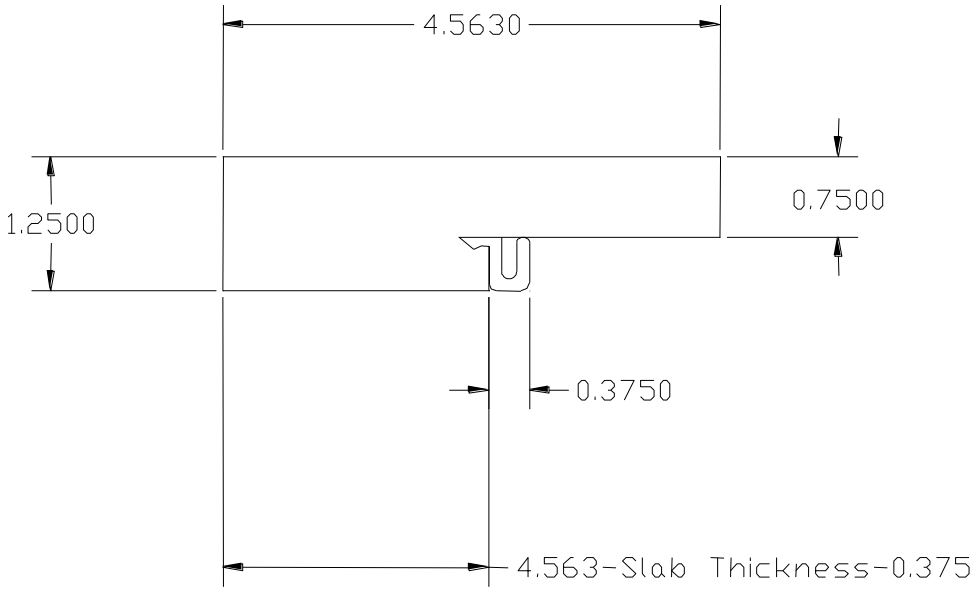
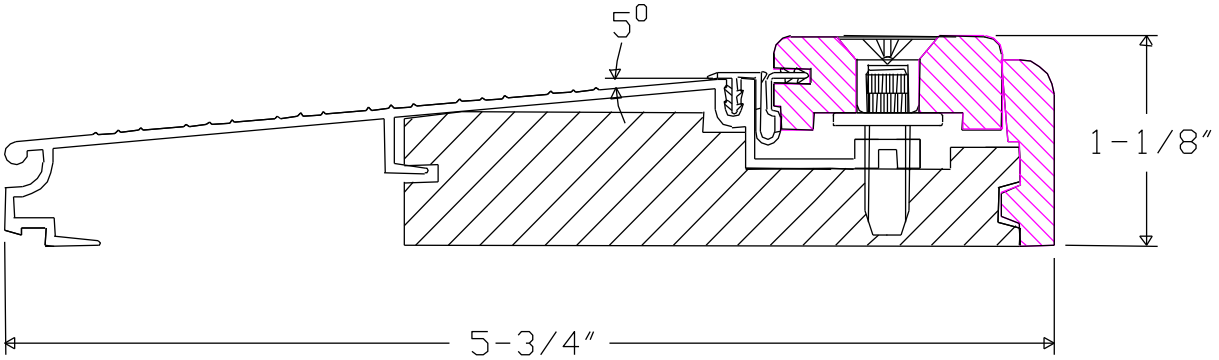


Figure 5-8a – Default Thermally Broken Aluminum Door Sill



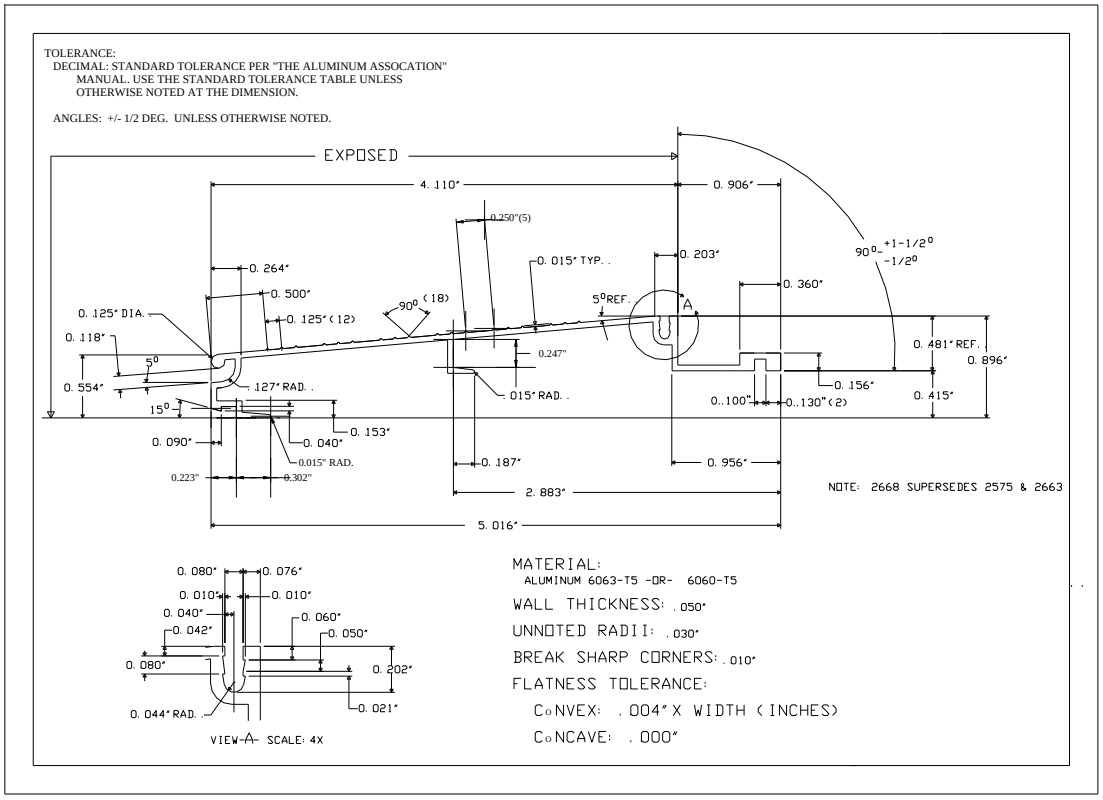


Figure 5-8b – Default Non-Thermal Door Sill

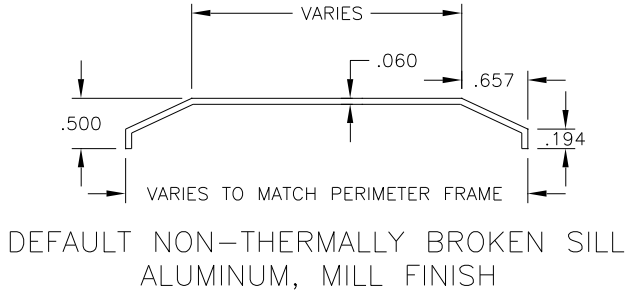
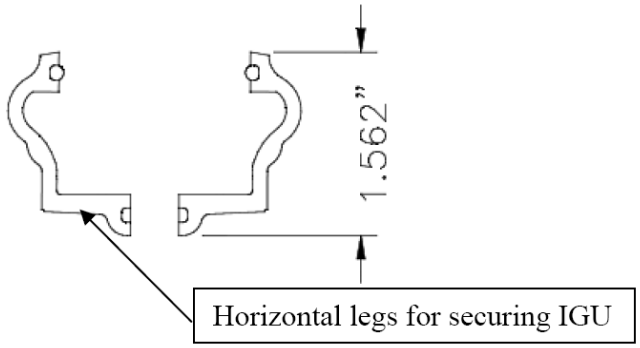


Figure 5-9 – Default Door Lite Frame

The following illustration shall be used. To make a specific IG width fit properly, extend or extract the material of the horizontal legs, as identified below.



A door lite frame DXF file is available on the NFRC website.

Figure 5-10 – SDR Configurations of Single Door or Sidelights

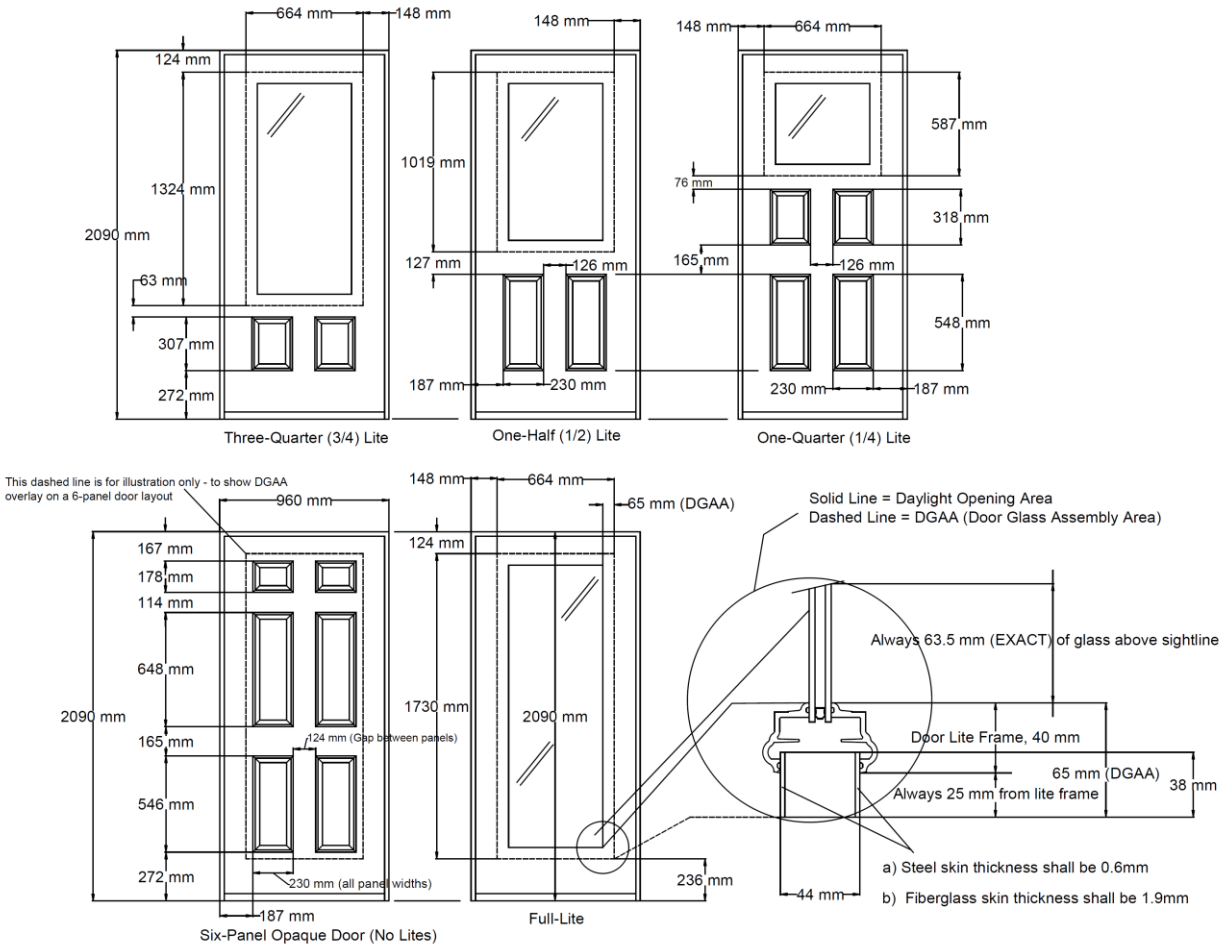


Figure 5-11 – Commercial Door Example in a Glazed Wall System

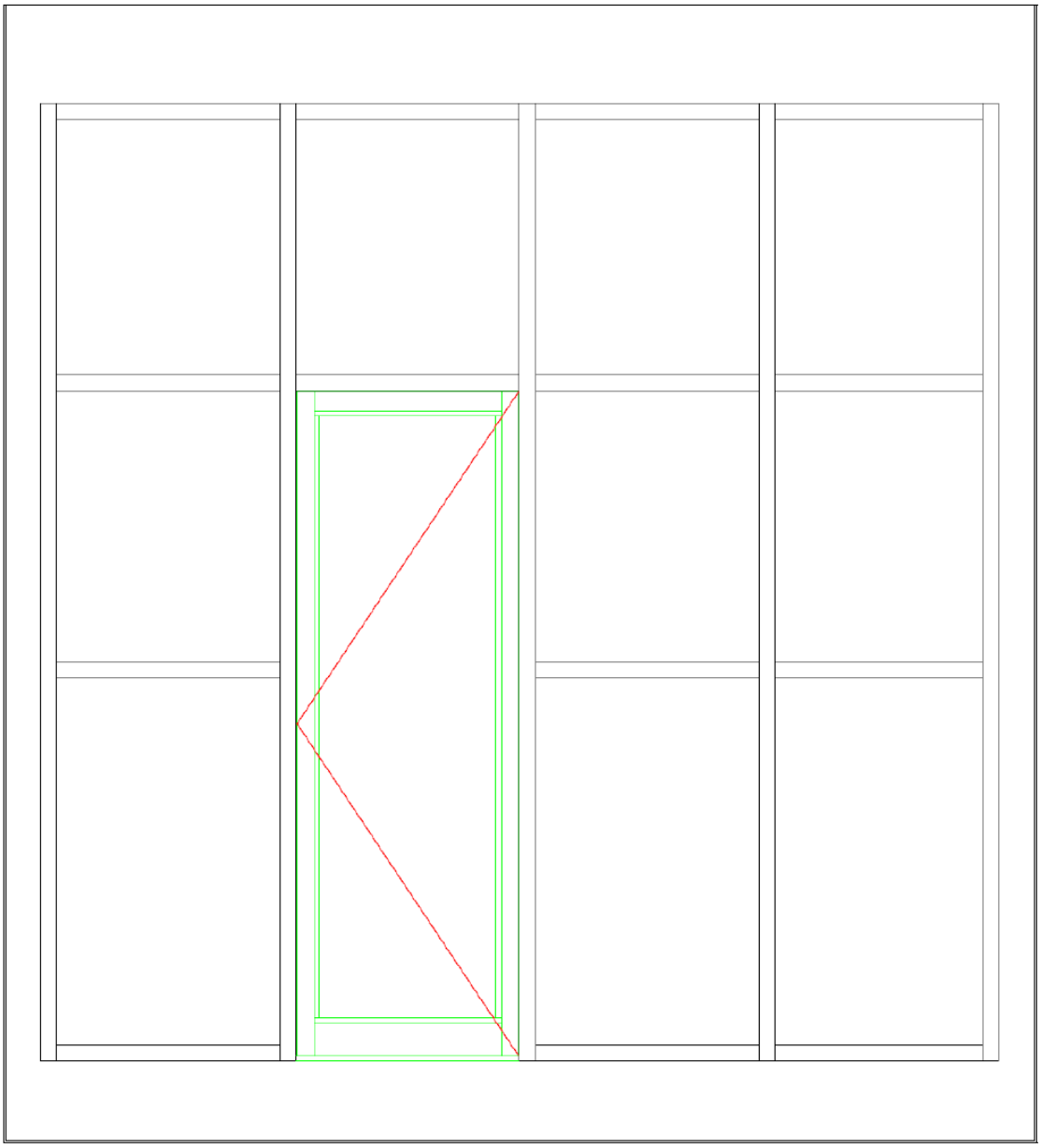


Figure 5-12 – Door Inside Glazed Wall System

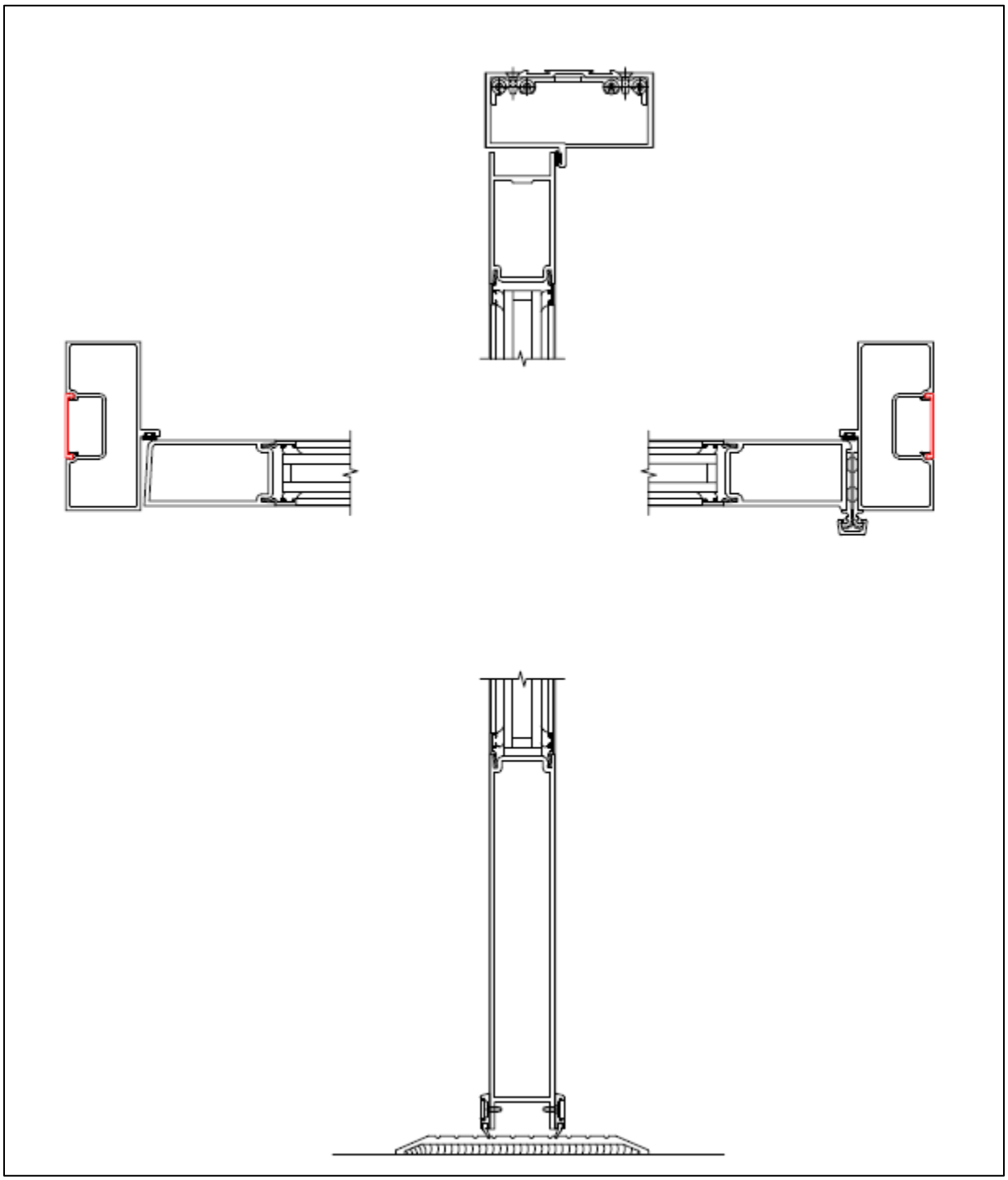
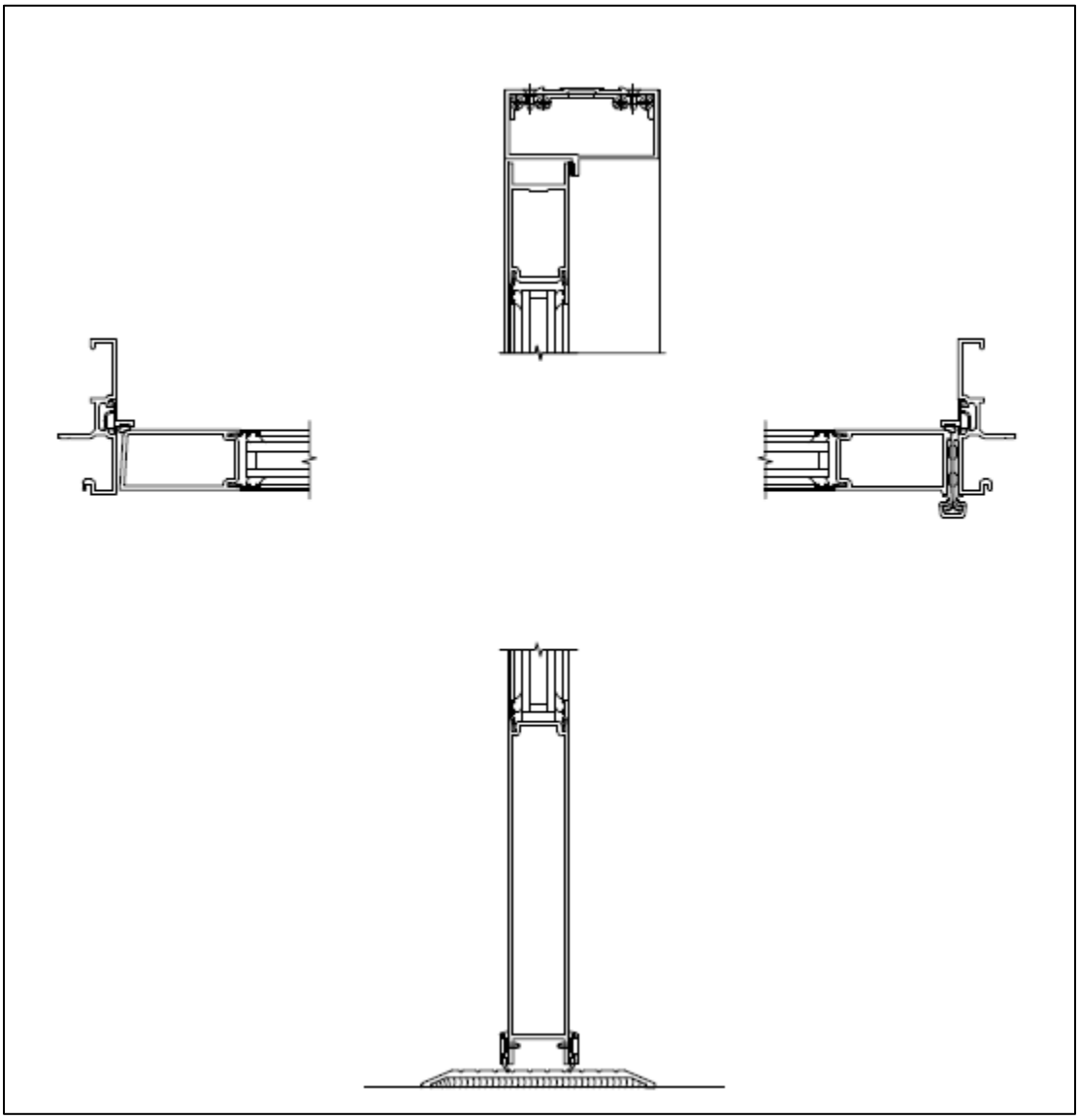


Figure 5-13 – Door Inside Glazed Wall System



5.3 Skylights

5.3.1 Scope

This section presents additional details specific to skylights.

This section presents and references methods for determining specific skylight system heat transfer properties or quantities used in the determination of these properties. At this time, the scope of these properties is limited to the total skylight system U-factor. For additional simulation parameters see Reference 2.

5.3.2 Variations from Standard Product Lines

The method in which skylights are mounted will affect the U-factor of the skylight. Mounting variations include roof mount or inset mount, which shall be different product lines.:

A skylight with an interior diffuser is rated with the interior tube and/or diffuser removed from the assembly. Any solar tracking devices or other auxiliary elements shall also be removed for rating purposes.

5.3.3 Variations from Standard Individual Products

None

5.3.4 Variations from Standard Simulation and Test Conditions

Skylights and other sloped glazing products shall be simulated and rated at a slope of 20º above the horizontal. For determining validation of the baseline product only, skylights and other sloped glazing products shall be simulated and tested in a vertical position. Ratings for test only products shall be converted to the 20º slope from the vertical position by multiplying the tested value at vertical by 1.20.

5.3.5 Calculation of Total Product Rating

The total fenestration product U-factor shall be calculated as outlined in Section 5.1.5.

5.3.6 Figures

None

5.4 Tubular Daylighting Devices (TDD)

5.4.1 Scope

This section presents and references methods for determining specific TDD system heat transfer properties or quantities used in the determination of these properties. At this time, these products can only be rated using the testing alternative procedure (Section 4.1.2).

The specific details for testing TDDs are outlined in Appendix 3 of NFRC 102.

5.4.2 Variations from Standard Product Lines

A TDD product line shall only consist of individual products of the same tube material, exterior dome material, and interior diffuser material.

5.4.3 Variations from Standard Individual Products

None

5.4.4 Variations from Standard Simulation and Test Conditions

5.4.4.1 Orientation

U- TDDs shall be rated with the tube in a vertical orientation (see Figures 5-14a and 5-14b). Therefore, the heat flow shall be in the vertical direction. Standardized rating conditions are defined in Section 5.4.4.4.

5.4.4.1.1 Insulation at Ceiling Configuration

The diffuser is attached to the insulated ceiling. The tubular section is located in the attic space connecting the interior diffuser to the exterior dome. The exterior dome/flashing assembly is mounted to the roof deck.

5.4.4.1.2 Insulation at Roof Configuration

The diffuser is attached to the tubular section which is located in the interior space. The tubular section is connected to the exterior dome. The exterior dome/flashing assembly is mounted to the insulated roof deck.

5.4.4.2 Sizes

The TDD model size listed in Table 4-3 is based on the Thermal Opening Area, as defined in Section 3. For the purpose of testing, this is the interior side of the 254 mm (10 in.) foam panel. The TDD model size is 350 mm +/- 30mm (14 in +/- 1 in) diameter tube opening. The closest production size to the model size shall be tested. In the event that the device is not manufactured in the model size, the production size with the closest area (as defined in 5.4.4.3) shall be used and the result for that unit shall be the product's rating. For TDD products with non-circular

Thermal Opening Area, the product shall use an opening area equivalent to the actual size of the manufactured product as tested. Equation 4-1 shall not be used to adjust the results to model size.

5.4.4.3 Tubular Daylighting Device Area

The U-factor for all TDDs shall be based on the Thermal Opening Area, as defined in Section 3. This area shall be used when calculating the total product U-factor.

5.4.4.4 Standard Testing Conditions

5.4.4.4.1 Insulation at Ceiling Configuration

A. 750 mm (30 in) shift length (interior ceiling line to exterior roof line);

B. Ceiling insulation shall be represented by a surround panel, 250mm (10 in) in depth;

C. An exterior 13 mm (0.5 in) thick plywood roof deck, painted to limit moisture transfer;

D. ASHRAE attic space boundary conditions on the exposed surface of the vertical shaft material, from the top of the insulation material to the underside of the 13 mm (0.5 in) plywood roof deck;

E. Exterior boundary conditions applied to the exposed surface of the dome; and

F. Bottom of the tubular skylight covered with a light diffusing plate (manufacturer specific).

5.4.4.4.2 Insulation at Roof Configuration

A. 750 mm (30 in) shaft length (from the exterior roof line to the top of the diffuser);

B. Roof insulation shall be represented by a surround panel, 250mm (10 in) in depth;

C. Exterior boundary conditions applied to the exposed surface of the dome; and

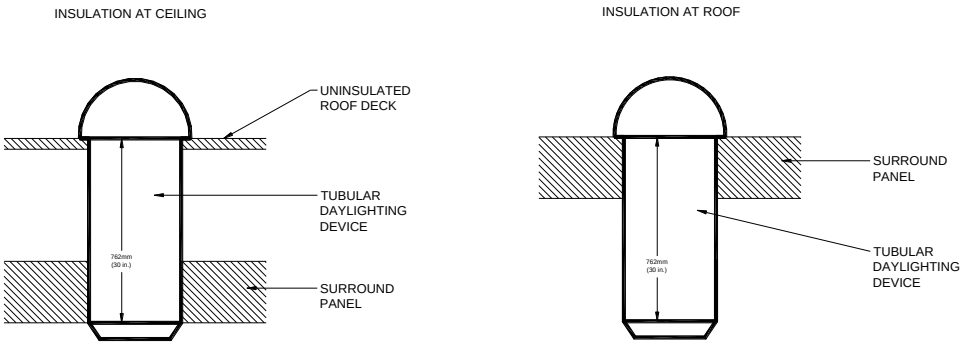
D. Bottom of the tubular skylight covered with a light diffusing plate (manufacturer specific).

5.4.4.5 Calculation of Total Product Rating

The total TDD system U-factor shall be determined as noted in Appendix A3 of NFRC 102.

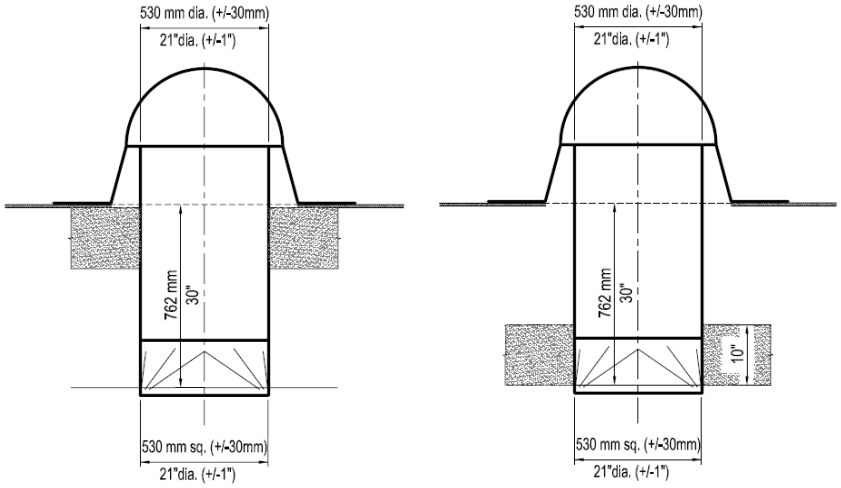
5.4.5 Figures

Figure 5-14a – Tubular Daylighting Device Product Schematic – Vertical Elevation



See Reference 12 for a more detailed drawing of the rough opening and diffuser plate attachment.

Figure 5-14b – Hybrid Tubular Daylighting Device Product Schematic – Vertical Elevation



5.5 Vehicular Access (Garage) Doors

5.5.1 Scope

This section presents and references methods for determining specific garage door system heat transfer properties or quantities used in the determination of these properties. At this time, the scope of these properties is limited to total garage door system U-factor. For additional simulation parameters, see Reference 2.

5.5.2 Variations from Standard Product Lines

A given series of garage door systems defined by skin material, core material, and edge of garage door construction that differ only in:

A. Size;

B. Solid panel and panel cut-out configurations;

C. The replacement of core or a panel area with a glazing system;

D. Center-of-glazing characteristics and edge-of-glazing characteristics, such as glazing types, gap widths, glazing areas, use of dividers, use of spacers, glazing coatings, and/or gas fills;

E. Panel changes where one component of the same physical shape has a thermal conductivity that differs by more than a factor of 10;

F. Jamb track and/or hardware components, variations in panel interior/exterior finish, paint, varnish, or stain; and

G. Variations in end stile design, intermediate stile design, and door bottom edge design.

5.5.3 Variations from Standard Individual Products

An individual product, in a product line, shall be those products that comply with the requirements per Section 5.5.2.

5.5.4 Variations from Standard Simulation and Test Conditions

A. In accordance with validation testing for simulated garage door products, sectional garage doors shall have the U-factor determined using a specimen to fill a 2.13 m (7 ft) wide by 2.13 m (7 ft) tall opening (the aperture is smaller than the test specimen).

B. For doors with glazing options, the glazing shall be per the manufacturer's design. If grids or dividers are normally used in garage door glazing, those grids and dividers shall be included for modeling purposes when glazing is included. The glazed

garage door option which meets the validation sample requirement shall be chosen for testing.

C. Door opening framing and sill shall be included in simulation calculations. The framing (nominal 2 in x 4 in) and the sill (nominal 2 in x 6 in) shall consist of 38 mm (1 1/2 in) wood surrounding the perimeter of the door (See Figures 5-11 through 5-13).

5.5.5 Total Product Rating

The total garage door system U-factor shall be calculated as outlined below:

A. Determine all of the following, as applicable:

i. Top rail (i.e., top edge of door) U-factor using the approved 2-D computational program, including the wood framing in the surround panel,

ii. Bottom rail (i.e., bottom edge of door) U-factor using the approved 2-D computational program, including the wood sill in the surround panel,

iii. End stile (i.e., side edge of door) U-factor using the approved 2-D computational program, including the wood framing in the surround panel,

iv. Meeting rail (i.e. section interface between door panels) U-factor using the approved 2-D computational program,

v. Door panel core U-factor using the approved 2-D computational program (this will only include portions of those top, intermediate, and bottom panels that are not glazed),

vi. Edge-of-glazing U-factor, including the glazing frame, using the approved 2-D computational program,

vii. Center-of-glazing U-factor per the total product height procedure as defined in Reference 2 using the approved center-of-glazing computational program, with input as needed from the approved center-of-glazing conductance test procedure given in Section 4.5.3, and

viii. The component areas in square feet, to the nearest 0.001 m^2 (0.010 ft^2) of:

(a) Top rail area, which includes the greater of 63 mm (2.5 in) or 25 mm (1 in) into a homogeneous area of the door core, measured from the top edge of the wood opening framing,

(b) Bottom rail area, which includes the greater of 63 mm (2.5 in) or 25 mm (1 in) into a homogeneous area of the door core, measured from the bottom edge of the wood opening sill,

(c) End stile area, which includes the greater of 63 mm (2.5 in) or 25 mm (1 in) into a homogeneous area of the door core, measured from the outside edge of the wood opening framing,

(d) Meeting rail area, which for each door panel includes the greater of 63 mm (2.5 in) or 25 mm (1 in) into a homogeneous area of the door core, measured from the interface of the door panels,

(e) Door panel core area,

(f) Edge-of-glazing area,

(g) Center-of-glazing area, and

(h) Projected total exterior door system area (including framing and sill areas);

B. Perform the following calculations as shown in Equation 5-3:

i. Multiply the top rail, bottom rail, end stile, meeting rail, door panel core, edge-of-glazing, and center-of-glazing area U-factors by their corresponding areas,

ii. Total these seven quantities, and

iii. Divide this total by the projected total exterior garage door system area to produce computed total garage door system product U-factors for all the door systems in the matrix of required U-factors.

$$U_t = \left[(U_{tr}A_{tr}) + (U_{br}A_{br}) + (U_{es}A_{es}) + (U_{mr}A_{mr}) + \left(U_{dpc}A_{dpc}\right) + \left(U_{eg}A_{eg}\right) + \left(U_{cg}A_{cg}\right)\right]/A_{pt}$$

Equation 5-3

Where

U_t = Total door system U-factor
U_{tr} = Top rail U-factor
A_{tr} = Top rail area
U_{br} = Bottom rail U-factor
A_{br} = Bottom rail area
U_{es} = End stile U-factor
A_{es} = End stile area
U_{mr} = Meeting rail U-factor
A_{mr} = Meeting rail area
U_{dpc} = Door panel core U-factor
A_{dpc} = Door panel core area

U_{eg} = Edge-of glazing U-factor
A_{eg} = Edge-of-glazing area
U_{cg} = Center-of-glazing U-factor
A_{cg} = Center-of-glazing area
A_{pt} = Projected total door system area

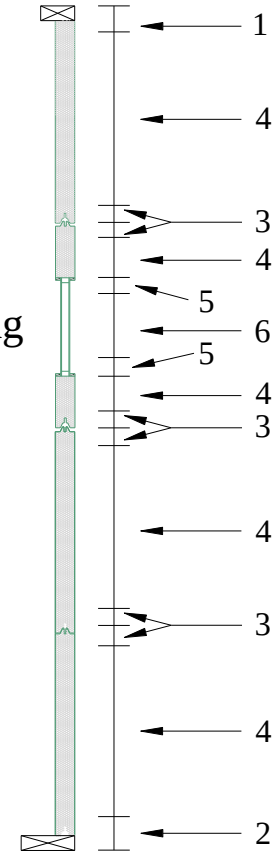
5.5.6 Figures

Figure 5-15 – Garage Door U-factor Area Weighting, Sectional

Legend

1 Top Rail*
2 Bottom Rail*
3 Meeting Rail*
4 Door Panel Core
5 Edge-of-Glazing; 63 mm (2.5 in.) around perimeter, including glazing framing
6 Center-of-Glazing

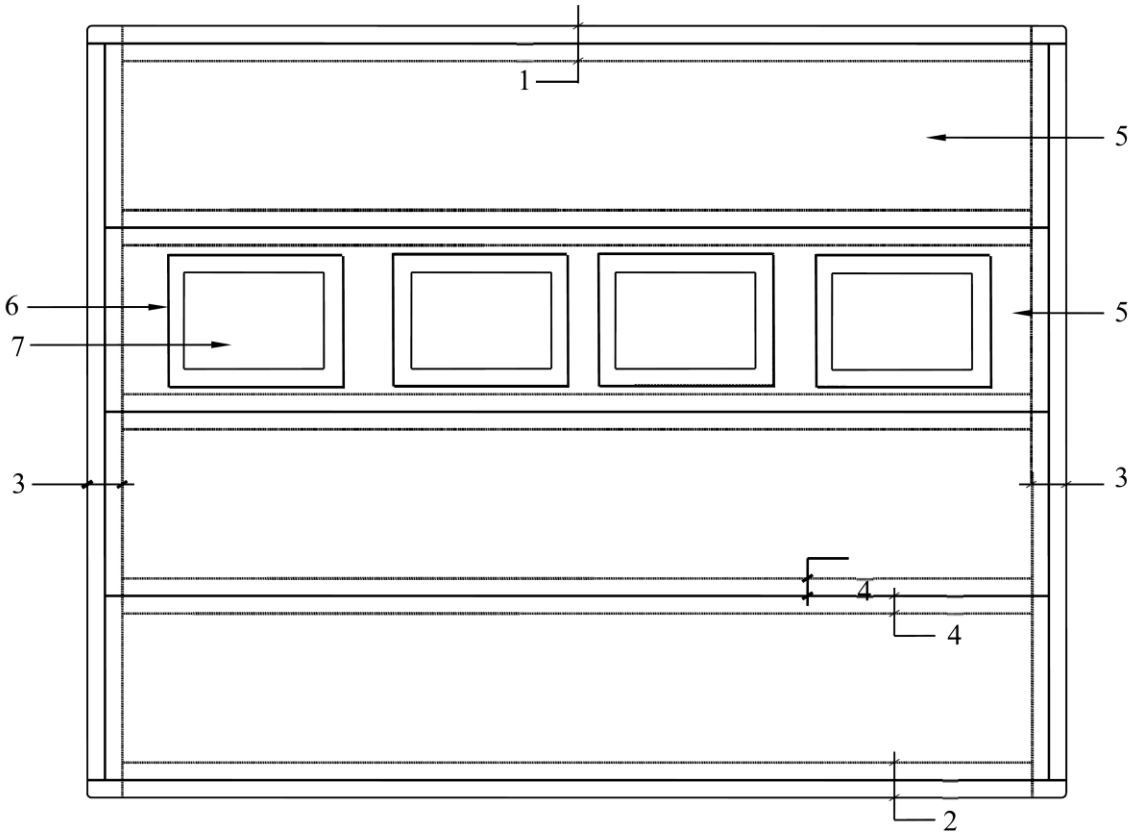
*greater of 63 mm (2.5 in.) or 25 mm (1 in.) into a homogeneous area



Notes

1. Glazing is optional.
2. Number of glazing lites may vary.
3. Glazing locations may vary.

Figure 5-16 – Garage Door U-factor Area Weighting, Front Elevation View

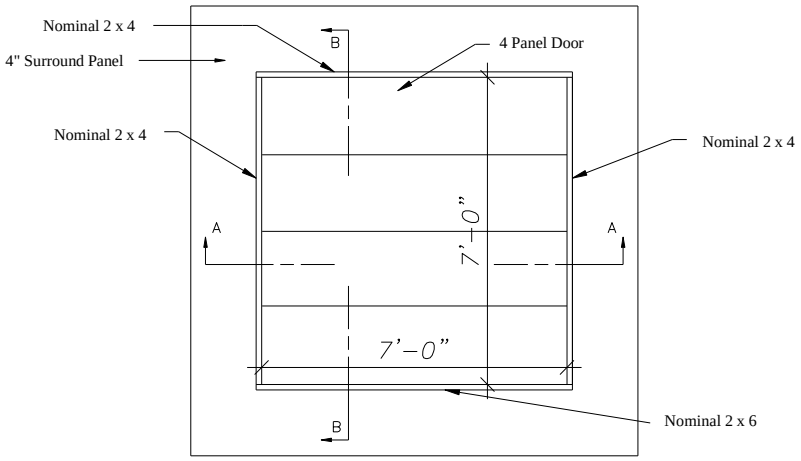


Legend

1 Top Rail*
2 Bottom Rail*
3 End Stile*
4 Meeting Rail*
5 Door Panel Core
6 Edge-of-Glazing; 63mm (2.5 in) around perimeter, including glazing
7 Center-of-Glazing

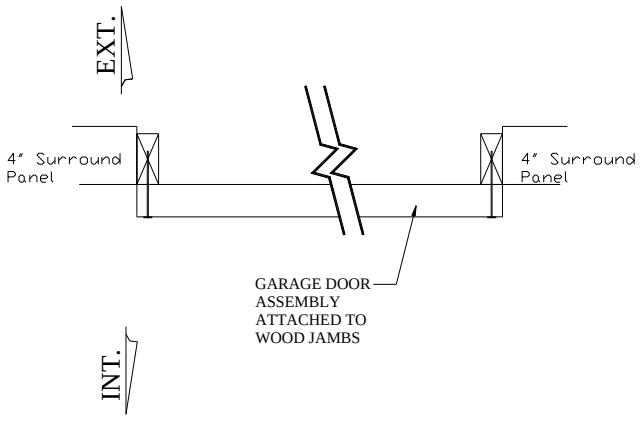
*greater of 63mm (2.5 in) or 25mm (1 in) into a homogeneous area

Figure 5-17 – Garage Door Front Elevation View and Perimeter Details



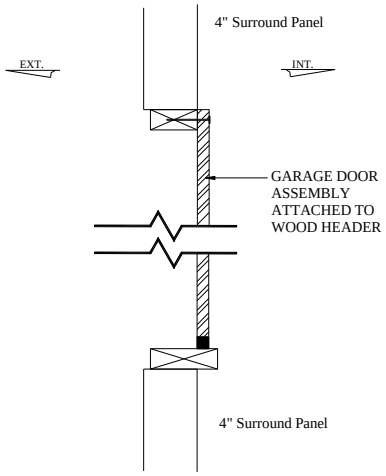
EXTERIOR ELEVATION

N.T.S.



SECTION A-A

N.T.S.



SECTION B-B

N.T.S.

5.6 Non-Residential Products

5.6.1 Scope

Non-residential fenestration systems covered by this method include products that are designed to be field glazed or field assembled units comprised of specified framing and glazing components, including but not limited to:

5.6.1.1 Products and Systems Covered

Transparent and translucent wall systems where the glazing material is glass, plastic, or other light-transmitting panels (including opaque spandrel panels within the system), except those products where no testing or calculation procedure exists

A. Glazed wall support and framing systems;

B. Products of any size and design;

C. Products with single or multiple glazing layers;

D. Products with spacer systems between glazings;

E. Horizontal, vertical and sloped systems;

F. Products that, by design, may have multiple framing components and/or glazing combinations;

G. Fenestration systems using unitized construction, where a system is field assembled from factory assembled sub-units; and

H. Dynamic glazing products.

5.6.2 Variations from Standard Product Lines

If a glazed wall system meets the definition of a curtain wall system, it shall be rated as a curtain wall system, regardless of application. If a glazed wall system meets the definition of a window wall system, it shall be rated as a window wall system, regardless of application.

5.6.3 Variations from Standard Individual Products

None

5.6.4 Variations from Standard Simulation and Test Conditions

5.6.4.1 Rating Configuration for Glazed Wall and Sloped Glazing Systems

These systems are rated using two lites with a single vertical mullion.

A. Curtain Walls shall be simulated and tested with intermediate verticals as jambs and intermediate horizontals as head/sill frame members. Area weight intermediate members based on centerline dimensions.

B. Window walls shall be simulated and tested with intermediate verticals as jambs and standard head and sill members. Area weight intermediate members based on centerline dimensions.

C. Sloped glazing may also be rated based on the centerline dimensions if utilized like a curtain or window wall, except for solariums and sunrooms.

D. Sloped glazing of solariums and sunrooms shall be simulated and tested with standard jamb, head, and sill members (see Section 5.6.4.3).

E. Other sloped glazing, as identified under the "Architectural Skylight Systems" definition, shall also be rated as sloped glazing products based on centerline dimensions. These products shall be simulated and tested with purlins as head and sill and rafters as jambs and vertical mullion.

F. Spandrel panel systems are utilized within glazed walls and therefore shall be simulated with the same modeling rules as indicated in this section for the appropriate product type.

5.6.4.2 Unspecified Product Sample Validation Criteria

If the product to be used for validation purposes is not specified, then the individual product used for validation purposes shall be simulated and tested using the following criteria: The test specimen shall be constructed in such a manner as to be identical to the individual product simulated and have outside dimensions measuring 2000 mm x 2000 mm (79 in x 79 in), having one vertical mullion and two glazed lites. The glazing system configuration for the validation testing shall be nominal 25 mm (1 in) outside dimension insulating glass utilizing two lites of 6 mm (1/4 in)

clear (uncoated glass), a typical dual-sealed aluminum spacer system, and air-filled. There shall be no insulation of any type applied to the test specimen during validation testing. Validation will be achieved per Section 4.7.1

This section is to be used only in those instances where the representative sample for validation purposes has not been prescribed by a specifying authority, such as an architect, project manager, engineering firm, building owner, etc.

For simulating and testing of all other fenestration operator types other than glazed wall systems, sloped glazing, and solarium/sunroom systems model sizes shall be consistent with the sizes listed in Table 4-3 of this standard.

5.6.4.3 Determining the Thermal Transmittance for Solarium/Sunroom Systems

Note: This procedure is to be used when the solarium is glazed on-site. If manufactured window or door systems are used to create the glazed walls in a solarium, the thermal transmittance shall be determined in accordance with Section 4 of this standard.

A. The thermal transmittance of solarium/sunroom systems shall be determined in accordance with Section 4.1 of this standard;

B. For simulating and testing site-built vertical glazed wall sections of solarium/sunroom systems, each product line shall have one baseline product validated in accordance with Section 4.1.1 and 4.3.1, with the following exception--the individual product used for validation purposes shall be simulated and tested using the following criteria: the test specimen shall be constructed in such a manner as to be identical to the individual product simulated and have outside dimensions measuring 2000 mm x 2000 mm (79 in x 79 in), having one vertical mullion and two glazed lites; the glazing system configuration for the validation testing shall be nominal 25 mm (1 in) outside dimension insulating glass utilizing two lites of 3 mm (1/8 in) clear (uncoated glass), a typical dual-sealed aluminum spacer system, and air-filled; and there shall be no insulation of any type applied to the test specimen during validation testing. Validation will be achieved per Section 4.1.1;

C. Sloped glazing systems shall be rated in accordance with Section 4.1 utilizing sample construction as described in Section 5.6.4.3.B; and

D. For simulating and testing all other fenestration operator types other than glazed wall systems and sloped glazing systems, model sizes shall be consistent with the sizes listed in Table 4-3 of this standard with glazing in accordance with Section 5.6.4.3.B.

5.6.5 Calculation of Total Product Rating

Calculation of U-factor of an opaque spandrel panel system cannot be conducted using Berkeley Lab WINDOW. Opaque spandrel panel systems require a 254mm (10 in.) edge-of-glass (panel) U-factor surface tag. Therefore, a specialized spreadsheet shall be used to conduct the proper product area-weighting using equation 5-1 whereas the center-of-glazing is the spandrel system (glass/air/insulated panel) for the variables U_c (derived from THERM) and A_c

5.6.6 Figures

None

5.7 Dynamic Attachment for Swinging Door Products (DASD)

Rating procedures for full and half lite glazed swinging doors shall be used with the dynamic attachment in the “fully open” and “fully closed” positions.

5.7.1 Scope

This section presents additional details specific to DASD. This section presents and references methods for determining specific dynamic attachments for swinging doors U-factor rating.

5.7.2 Methodology

Methodology for rating full and half lite swinging doors can be found in Section 5.2. DASD products will be rated using Reference Swinging Doors (see Table 5-2 and Figures 5-18 and 5-19).

The dynamic attachment for swinging door shall be simulated with the attachment in the “fully open” position.

The DASD shall be tested as a whole product system (attachment and reference door) in the “fully closed” position. Center-of-glazing tests are not acceptable for this purpose.

Individual product ratings shall be determined for each of the four configurations.

5.7.3 Approved Computational Program

The DASD product U-factor shall be determined using approved glazed swinging door simulation. The DASD shall be modeled on the following reference swinging doors.

Table 5-2 – Reference Swinging Doors

3068; Steel skin; wood edge; EPS core door ½" IG Full and Half Lite See Figure 5-18
3068; Fiberglass skin; wood edge; urethane core door ½" IG Full and Half Lite See Figure 5-19

Reference Swinging Door Glazing Detail

The glazing system shall consist of two panes of 3 mm (1/8 in) clear glass with a 1/4 in air gap separated by an aluminum spacer system. For simulation purposes, the 3 mm (1/8 in) clear glass shall be the generic 3mm clear glass file (ID#102) from the approved NFRC spectral data files with the International Glazing Database (IGDB).

5.7.4 Figures

Figure 5-18 – Reference Swinging Door Details

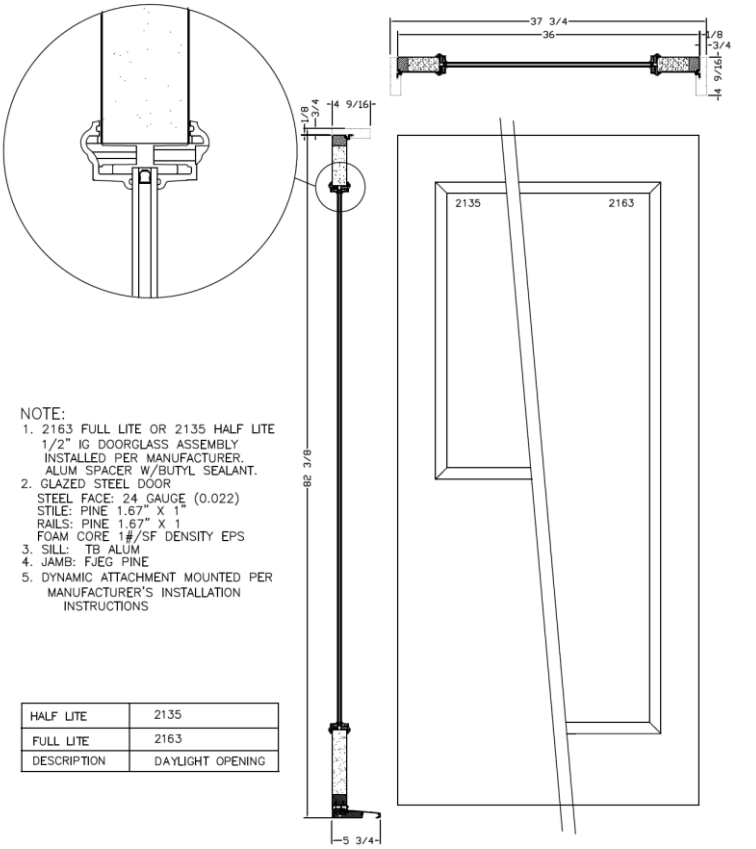
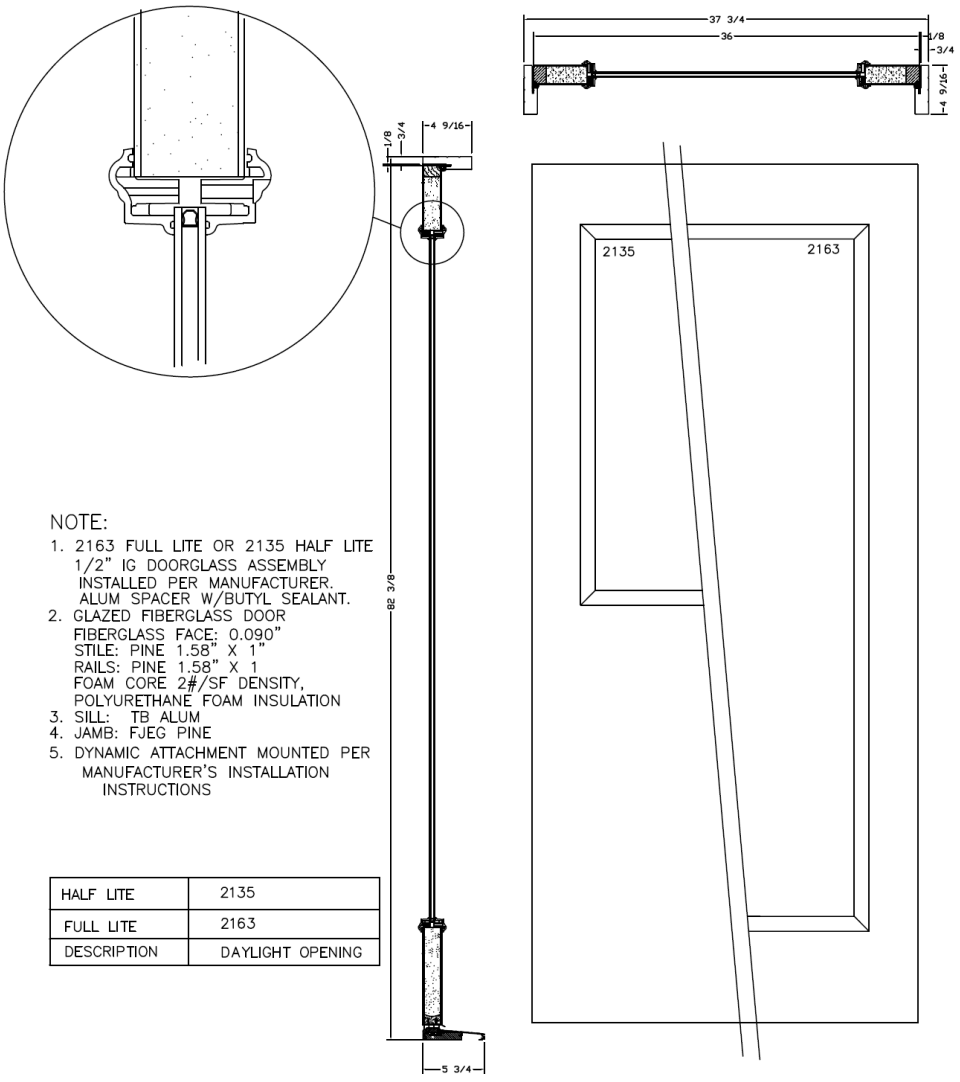


Figure 5-19 – Reference Swinging Door Details



NOTE:

1. 2163 FULL LITE OR 2135 HALF LITE 1/2" IG DOORGLASS ASSEMBLY INSTALLED PER MANUFACTURER. ALUM SPACER W/BUTYL SEALANT.
2. GLAZED FIBERGLASS DOOR
   FIBERGLASS FACE: 0.090"
   STILE: PINE 1.58" X 1"
   RAILS: PINE 1.58" X 1
   FOAM CORE 2#/SF DENSITY, POLYURETHANE FOAM INSULATION
3. SILL: TB ALUM
4. JAMB: FJEG PINE
5. DYNAMIC ATTACHMENT MOUNTED PER MANUFACTURER'S INSTALLATION INSTRUCTIONS

HALF LITE	2135
FULL LITE	2163
DESCRIPTION	DAYLIGHT OPENING

3068 DASD REFERENCE FIBERGLASS DOOR

DRAWING NUMBER 100–002	NFRC 100 REFERENCE DRAWING	REVISIONS
DRAWN: ddb	DYNAMIC ATTACHMENT FOR SWINGING DOORS REFERENCE FIBERGLASS DOOR FOR SIMULATION AND TEST	1. RELEASE FOR PRODUCTION 06 JAN 08 2. REVISED SPACER DETAIL 01 MAY 08 3. ADDED CHART & HALF LITE 08 AUG 09 4. REVISED GLASS SIZE TO BE DAYLIGHT OPENING 27 AUG 12
APPROVED:		
DATE: 06 JAN 08		

5.8 Rolling Doors

5.8.1 Scope

This section presents and references methods for determining specific rolling door system heat transfer properties or quantities used in the determination of these properties. At this time, the scope of these properties is limited to total rolling door system U-factor. For additional simulation parameters see Reference 2.

5.8.2 Variations from Standard Product Lines

A given series of rolling door systems defined by skin material, core material, and edge of rolling door construction that differ only in:

A. Size,

B. Slat changes where one component of the same physical shape has a thermal conductivity that differs by more than a factor of 10,

C. Jamb guide components,

D. Variations in slat ends and guide configurations,

E. Variations in slat interior/exterior finish that changes the surface emittance by more than 0.10, and

F. Variations in top slat and bottom slat/bottom bar designs.

5.8.3 Variations from Standard Individual Products

An individual product, in a product line, shall be those products that comply with the requirements per Section 5.8.2.

5.8.4 Variations from Standard Simulation and Test Conditions

A. In accordance with validation testing for simulated rolling door products, rolling doors shall have the U-factor determined using a specimen to fill a 2.13 m (7 ft) wide by 2.13 m (7 ft) tall opening (the aperture is smaller than the test specimen);

B. Slat height shall be per the manufacturer’s drawing (the bottom slat, the top slat, and the intermediate slats shall be modeled per manufacturer drawings);

C. Slat ends and guide configurations shall be per the manufacturer’s drawing;

D. Rolling door simulations shall not include components and hardware above the top of the opening, e.g. hood, barrel, operator, etc.; and

E. Door opening framing and sill shall be included in simulation calculations. The framing (nominal 2 in x 4 in) and the sill (nominal 2 in x 6 in) shall consist of 38 mm (1.5 in) thick wood surrounding the perimeter of the door (See Figures 5-15 through 5-17).

5.8.5 Total Product Rating

The total rolling door system U-factor shall be calculated as outlined below:

A. Determine all of the following, as applicable:

i. Top rail (i.e., top edge of door) U-factor using the approved 2-D computational program, including the wood framing in the surround panel,

ii. Bottom rail (i.e., bottom edge of door) U-factor using the approved 2-D computational program, including the wood sill in the surround panel,

iii. End stile (i.e., side edge of door) U-factor using the approved 2-D computational program, including the wood framing in the surround panel,

iv. Door core U-factor using the approved 2-D computational program, and

v. The component areas in square feet, to the nearest 0.001 m^2 (0.010 ft^2) of:

(a) Top rail area, which includes the greater of 63 mm (2.5 in) or 25 mm (1 in) into a homogeneous area of the door core, measured from the top edge of the wood opening framing,

(b) Bottom rail area, which includes the greater of 63 mm (2.5 in) or 25 mm (1 in) into a homogeneous area of the door core, measured from the bottom edge of the wood opening sill,

(c) End stile area, which includes the greater of 63 mm (2.5 in) or 25 mm (1 inch) into a homogeneous area of the door core, measured from the outside edge of the wood opening framing,

(d) Door core area, using three slats as the basis for computation, and

(e) Projected total exterior door system area (including framing and sill);

B. Perform the following calculations as shown in Equation 5-4:

i. Multiply the top rail, bottom rail, end stile, and door core U-factors by their corresponding areas,

ii. Total these four quantities, and

iii. Divide this total by the projected total exterior rolling door system area to produce computed total rolling door system product U-factors for all the door systems in the matrix of required U-factors.

$$U_t = [(U_{tr}A_{tr}) + (U_{br}A_{br}) + (U_{es}A_{es}) + (U_{dc}A_{dc})]/A_{pt}$$

Equation 5-4

Where

U_t = Total door system U-factor
U_{tr} = Top rail U-factor
A_{tr} = Top rail area
U_{br} = Bottom rail U-factor
A_{br} = Bottom rail area
U_{es} = End stile U-factor
A_{es} = End stile area
U_{dc} = Door core U-factor
A_{dc} = Door core area
A_{pt} = Projected total door system area

5.8.6 Figures

Figure 5-20 – Rolling Door U-factor Area Weighting - Sectional View

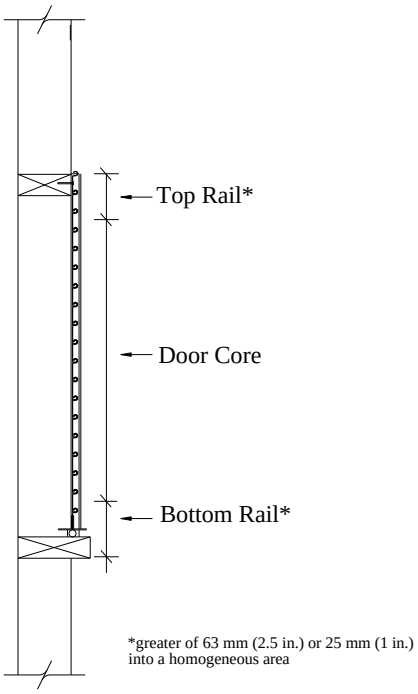
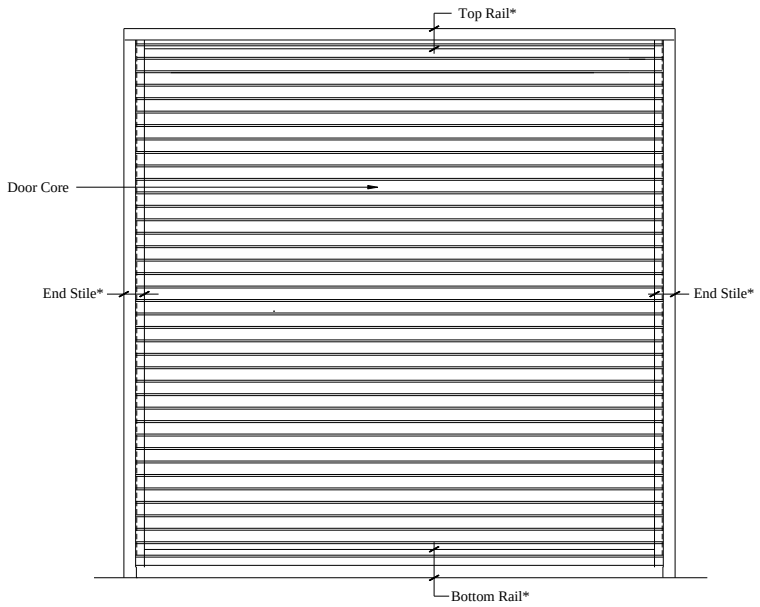
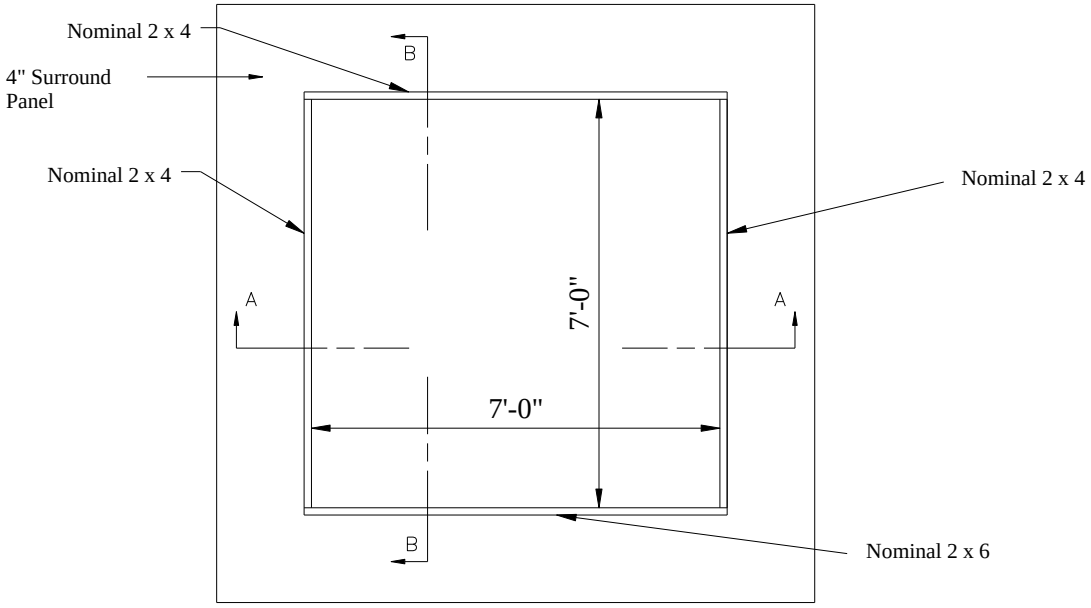


Figure 5-21 – Rolling Door U-factor Area Weighting – Front Elevation View

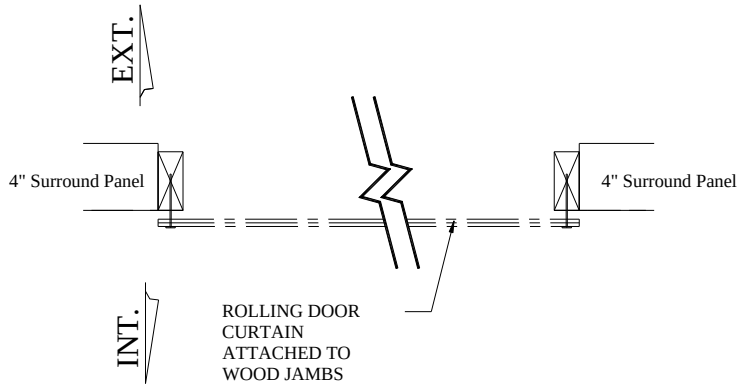


* greater of 63 mm (2.5 in.) or 25 mm (1 in.) into a homogeneous area

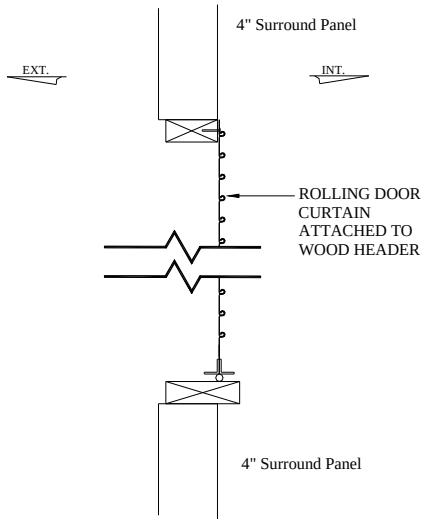
Figure 5-22 – Rolling Door Front Elevation View and Perimeter Details



EXTERIOR ELEVATION
Door not shown N.T.S.



SECTION A-A
N.T.S.



SECTION B-B
N.T.S.

5.9 Component Modeling Approach (CMA) for Non-Residential Products

5.9.1 Scope

This section covers methods for determining fenestration product U-factor (thermal transmittance) for fenestration products using Component Modeling Approach (CMA).

5.9.2 Products and Systems Covered

A. All products listed in Table 4-3 except;

i. Garage Doors;

ii. Greenhouse/garden;

iii. Hybrid tubular;

iv. Jal/jal awning;

v. Tubular daylighting devices

vi. Tropical awning

B. Combination products;

C. Composite products

5.9.3 Standard Simulation and Testing

5.9.3.1 Simulation

All simulations shall be based on computer simulations that comply with Section 4.3.1 and are further based on the CMA modeling procedure (Reference 10).

The CMA procedure is based on modeling frame cross-sections with generic low and high (L/H) conductance center-of-glazing assemblies (L/H COGA) and low and high conductance spacer edge seal assemblies (L/H SESA), collectively known as L/H options. The following are definitions of L/H options.

5.9.3.1.1 Definition of the Low and High (L/H) Options

A total of four configurations are used in the definition of L/H options for insulated glazing. For products without SESA, only two center of glazing assembly configurations are defined for two L/H options. These configurations are assembled from the extreme ends of thermal performance for both COGA and SESA.

A. Insulating glazing: The following thermal performance is used for insulating glazing options:

   i. Low glazing – Double glazed, low-E, with the invented gas fill properties that produces R12.5 insulation value – Ucog = 0.45 W/m^2-K (0.08 Btu/h-ft^2-F)

   ii. High glazing – Double glazed clear air

   iii. Ucog = 2.684 W/m^2-K (0.473 Btu/h-ft^2-F)

B. Single glazing: The following thermal performance is used for single glazing options:

   i. Low glazing – Low-E single glass, with low-E facing indoor side – Ucog = 3.24 W/m2-K (0.57 Btu/h-ft^2-F)

   ii. High glazing Ucog = 5.82 W/m^2-K (1.03 Btu/h-ft^2-F)

C. Glazing for dual window or door and glazing for products with secondary sash or panel, energy panel, or storm panel:

   i. Low glazing – Use a combination of low-E coated glass and invented gas fill from above

   ii. High glazing – Use clear glass (non-coated) for all panes with all glazing cavity with air

D. If the original configuration has any combination of insulated glazings and/or single glazings, low and high glazing configuration should duplicate that;

E. If a product includes SESA, the following low and high spacer details should be used:

   i. Low spacer – generic low conductivity spacer – Keff = 0.01 W/m-K (0.006 Btu/h-ft-F)

ii. High spacer – generic high conductivity spacer – Keff = 10.0 W/(m-K) (5.8 Btu/h-ft-F)

F. SESA height is standardized to 12.7 mm (0.5 in), spacer width is variable in order to match the gap width of L/H COGA;

G. SESA is not applicable to single glazing systems; and

H. Glass thickness is standardized to 3 mm (1/8 in) for residential products and 6 mm (1/4 in) for commercial products. Overall (nominal) thickness of L/H glazing systems should match nominal thickness (± tolerance) of the real glazing systems (i.e. 19.1 mm (3/4 in); 22.2 mm (7/8 in); 25 mm (1 in), etc.) that the simulated product is designed for.

5.9.3.1.2 Reporting Simulation Results

See NFRC 701.03 – Reporting Requirements, Section 1.2.

5.9.3.1.3 Total Product U-factor Calculation

A. Total product U-factor calculation requires the U-factors for frame components frame U-factor (U_f) and edge-of-glass U-factor (U_e), for their representative Low and High options. In addition, projected frame depth (pfd) is required;

B. The following additional calculation results are required for total product U-Factor calculation and these shall be reported for the whole product:

COGA: Uc = W/m2-K (Btu/h-ft2-ºF)

SESA: Keff = W/m-K (Btu/h-ft-ºF)

C. The calculation of total product U-factor for products with a SESA is done using the procedure detailed in Reference 10. For products without a SESA, total product U-factor is calculated by excluding the equations that involve the SESA; and

D. The NFRC-approved CMA Software Tool (CMAST) shall be used to determine total product U-factor for the model size. U-factor ratings for sizes other than the model size can be calculated for informational purposes when applicable.

5.9.3.2 Testing

There is no separate CMA testing procedure for frame components. Testing is done for the whole product, which is the baseline product for the purposes of validation testing and is done to validate a Framing Product Line (FPL).

5.9.4 Validation Testing

Each FPL will require validation testing on a standard baseline product representing the framing product line, using NFRC 102. The following conditions apply:

A. Test specimen size and configuration shall be as defined in Table 4-3 and Section 5.9.6

B. All test specimens shall be tested without removable screens, removable grilles and trims, or any other applied devices;

C. All test specimens shall be tested in the vertical position. For determining validation of the baseline product only, skylights, and other sloped glazing products shall be simulated in a vertical position;

D. The test specimen shall not be modified by the testing laboratory, except as allowed in Reference 1 for sealing against air leakage and as required by this section;

E. The product selected as the baseline product shall have an insulating glass unit(s) with a maximum center-of-glazing U-factor of 0.35, unless the product is not designed for use with insulating glass (i.e. domes, glass block, translucent panels, single glazing, etc.); and

F. The framing product line is validated if the baseline product has a tested U-factor which meets the equivalence criteria in Table 4-4 when simulated in accordance with Section 5.9.3.

5.9.5 Simplifications

5.9.5.1 Simplifications to Spacer Components

A. For the purpose of the CMA methodology, each SESA performance shall be provided in terms of its effective conductivity, Keff;

B. The SESA consists of the spacer component, desiccant, and any applicable sealants. Three different paths are provided for the definition of the spacer component and corresponding SESA; and

C. Each spacer component can be submitted by the spacer manufacturer and later made available for SESA under only one path.

Path I – Generic Spacer: (Default Spacer, Default Sealant, Default Geometry)

The Keff is defined based on simple review of spacer drawings.

Group 1 – Spacer containing aluminum

If the spacer uses any aluminum in the design, it shall be assigned a spacer system Keff of 8.0 W/mC (4.622 Btu/h-ft-F).

Group 2 – Spacer containing mild steel (i.e. galvanized steel, tin-plated steel)

If the spacer uses any mild steel in the design, it shall be assigned a spacer system Keff of 3.0 W/mC (1.733 Btu/h-ft-F).

Group 3 – Spacer containing stainless steel

If the spacer uses any stainless steel in the design, it shall be assigned a spacer system Keff of 1.0 W/mC (0.578 Btu/h-ft-F).

Group 4 – Spacer containing all non-metallic materials

If the spacer uses only non-metallic materials in the design, it shall be assigned a spacer system Keff of 0.5 W/mC (0.289 Btu/h-ft-F). If the spacer design incorporates any metal, it shall fall into either Group 1, 2, or 3.

In the event a spacer contains two metals, the higher conductivity metal shall be used in specifying the spacer group, regardless of the amount of that metal present in the spacer.

Path II – Specific Spacer, Default Sealants (Specific Spacer, Default Sealants, Limited Geometry):

The Keff of the spacer edge-seal assembly is defined based on simulation from spacer bar drawings.

A. The spacer manufacturer shall submit drawings to an NFRC-accredited simulator to be evaluated and modeled;

B. The spacer component shall be evaluated by the certified simulator working for an accredited lab and shall be based on the drawings and the bill of materials supplied by the spacer manufacturer;

C. The spacer component is evaluated for each width available for the spacer series, to which spacer component belongs, based on the drawings supplied by the spacer manufacturer at the maximum spacer height available for the spacer series;

D. Modeling of desiccant is applicable to only those spacer systems which separately add desiccant to the spacer bar;

E. The spacer edge seal assembly that is generated from this spacer component shall be evaluated using generic sealant and desiccant materials to cover all sealant and desiccant materials (see table below); and

F. The spacer edge seal assembly with the highest Keff value shall be used to represent all spacer components for this spacer series. Only one Keff for the spacer edge-seal assembly is submitted for inclusion in the CMA database to represent all spacer components for the spacer series.

Table 5-4 – Generic Sealant and Desiccant Material Values

Generic Materials	k (W/m-K)	k(Btu/h-ft-F)
Generic Primary Sealant	0.25	0.144
Generic Secondary Sealant	0.40	0.231
Generic Desiccated Matrix	0.29	0.168
Generic Desiccant Bead	0.03	0.017

Path III – Specific Spacer, Specific Sealants: (Specific Spacer, Specific Sealant, Detailed Spacer Edge-Seal Assembly Geometry)

The Keff of the spacer edge-seal assembly is defined based on simulation from spacer drawings, any applicable desiccant, and any applicable sealants.

A. The spacer manufacturer shall submit drawings to an NFRC-accredited simulator to be evaluated and modeled;

B. The spacer component shall be evaluated by the certified simulator working for an accredited lab and shall be based on the drawings and the bill of materials supplied by the spacer manufacturer;

C. Each spacer component has a unique width and height;

D. The spacer edge-seal assembly, consisting of the spacer component, desiccant, and any sealants, as appropriate, is generated when the spacer edge-seal assembly composition and geometry is known;

E. The effective conductivity of such spacer edge-seal assembly is calculated on demand using the specific spacer component, generic values for desiccant from the Table 5.6.2 and specific values for the primary and secondary sealants, as appropriate, and shall be used in the whole fenestration product calculation; and

F. As an option, the product may be evaluated and modeled with the generic sealant materials defined under Path II to limit the number of system configurations. However, specific sealant geometry shall be used.

5.9.5.2 Simplifications to Frame Component

FPL are not grouped; grouping is done on the basis of frame components (i.e., head cross-sections are compared to head cross-sections, etc.). All applicable frame components shall be members of the same FPL. Membership in the FPL is based on the comparison with the approved framing components used in the standard framing system product.

This section presents additional product line simplification rules specific to frame components.

Frame Grouping

i. All grouping rules contained in Section 4 shall be permitted to be utilized with the calculation procedures of Section 5.9,

ii. In addition, this section presents additional frame grouping rules that shall be permitted to reduce the number of simulations by grouping individual frame components. If this approach is used, the frame U-factors (U_f) calculated in accordance with Section 5.9.5 for the frame group leader shall be used to represent the frame U-factors (U_f) for all individual frame components within that group,

iii. Individual frame components may be grouped based upon the variations listed below; when more than one of these variations is being used for grouping, the priority for determining the frame group leader shall be in the order listed below:

(a) Change in frame length in the direction perpendicular to the fenestration plane,

(b) Emissivity of external and internal frame surfaces,

(c) Glazing inset relative to the exterior,

(d) Projected frame depth (PFD),

(e) Material wall thickness, or

(f) Addition of internal frame web(s) to create additional frame cavities.

iv. The frame group leader shall be determined in accordance with Tables 5-5 to 5-7 based upon the dominant frame material.

Table 5-5 – Frame Group Leader for all Metallic, Aluminum, Thermally-Improved Aluminum, and Thermally-Broken Aluminum Frames

Variation	Group Leader
Change in frame length in the direction perpendicular to the fenestration plane	Maximum length
Surface emissivity	Highest emissivity
Glazing inset relative to the exterior	Glazing location closest to the outside
Change in PFD	Highest PFD
Material wall thickness	Highest wall thickness
Addition of internal frame web(s) to create additional frame cavities	Maximum number of webs

Table 5-6 – Frame Group Leader for Vinyl, Fiberglass, and Composite Frames

Variation	Group Leader
Change in frame length in the direction perpendicular to the fenestration plane	Maximum length
Glazing inset relative to the exterior	Glazing location closest to the outside
Change in PFD	Highest PFD
Material wall thickness	Highest/thickest wall
Addition of internal frame web(s) to create additional frame cavities	Minimum number of webs

Table 5-7 – Frame Group Leader for Wood Frames (either with or without Cladding)

Variation	Group Leader
Change in frame length in the direction perpendicular to the fenestration plane	Minimum length
Glazing inset relative to the exterior	Glazing location closest to the outside
Change in PFD	Highest PFD

5.9.5.3 Modification of Approved Framing Components and Addition of New Framing Components

A. If a framing component within an approved FPL is modified, the modified component becomes a new member of the approved FPL without additional validation testing if the modification is consistent with the definition of framing product line.

B. A new framing component may be added to an approved FPL without additional validation testing if the new framing component is consistent with the definition of FPL.

5.9.6 Total Product Rating

The U-factor of a fenestration product may vary by size. In order to provide a uniform rating procedure for the comparison of fenestration systems, total product U-factor rating is calculated for the model size per Table 4-3 and Table 5-9.

A U-factor rating for sizes other than the model size can be calculated for informational purposes.

5.9.6.1 Reporting of Ratings

The final U-factor shall be reported in IP units (BTU/h·ft^{2}·^{o}F) and rounded to two digits following the decimal point. All variables used in the formula shall be expressed to at least three significant decimal places. If the U-factor is to be reported in SI units as well as IP units, the SI U-factor shall be converted from the IP U-factor following the procedure outlined in NFRC 700, Section 6.5.I.iii.

5.9.6.2 Determining Thermal Transmittance (U-factor) for Sloped Glazing Systems

A. All sloped glazing systems shall be rated for thermal performance characteristics at a slope of 20o above the horizontal (See Section 5.3 [Skylights] for more information); and

B. Sloped glazing systems are validated at vertical position.

5.9.6.3 Complex Product Rating

This section provides the details of additional non-residential product types and their model sizes for rating purposes.

5.9.6.3.1 Spandrel Panel System

Spandrel panel systems shall be rated for U-factor at the model size specified in Table 4-3 if the system can be represented by an approved glazing layer or a # sign glass layer entry from the International Glazing Database (IGDB).

Validation of Spandrel Panel System Products.

If the frame components of the spandrel panel system, with limitation as noted in Section 5.9.6.3.1 above have been validated for any framing product line, no additional validation is required. It is treated as an additional glazing option.

5.9.6.3.2 Combination Products

Individual fenestration products forming the combination product, which can be identified as a product/operator type listed in Table 4-3, will get separate NFRC rating for their individual model sizes.

No separate validation is required for combination products. Frame components of individual units forming the combination product shall be part of a validated Framing Product Line (FPL).

5.9.6.3.3 Composite Products

Individual units forming the composite product, which can be identified as a product/operator type listed in Table 4-3, will be rated at their model size. The centerline of integral mullion will be used to determine the actual sizes of these individual units.

No separate validation is required for composite products. Frame components of individual units forming the composite product shall be part of a validated Framing Product Line (FPL).

5.10 Applied Films

Note: Applied films factory-applied to glazing prior to fenestration product fabrication and installation are already covered as glazing options by ANSI/NFRC 100 and shall not be rated according to the procedure of Section 5.10 below.

5.10.1 Scope

This section presents additional details specific to applied films. This section presents and references methods for determining specific applied films U-factor rating.

5.10.2 Variations from Standard Product Lines

None

5.10.3 Variations from Standard Individual Products

None

5.10.4 Variations from Standard Simulation and Test Conditions

5.10.4.1 Approved Center-of-Glazing Computational Program

Approved center-of-glazing software shall be used to determine U-factor. Applied films shall be from the approved NFRC spectral data files with the International Glazing Database (IGDB). Glazing/applied film assembly shall be constructed in accordance with NFRC 304 procedure.

The following reference glazing systems shall be simulated with and without the film installed:

A. Single 3 mm (1/8 in) Clear;

B. Single 6 mm (1/4 in) Clear;

C. Single 6 mm (1/4 in) Grey;

D. Double 3 mm (1/8 in) Clear/3 mm (1/8 in) Clear: 7 mm (1/4 in) air gap;

E. Double 6mm (1/4 in) Clear/ 6 mm (1/4 in) Clear: 12.7 mm (1/2 in) air gap; and

F. Double 6 mm (1/4 in) Grey/ 6mm (1/4 in) Clear: 12.7 mm (1/2 in) air gap.

The position (surface number) of the film when installed on the glazing system shall be documented (i.e., #1 to #4).

This will yield the matrix in Table 5-8 for each applied film and applied film position.

5.10.5 Calculation of Total Product Rating

The reference fenestration product with applied film U-factor shall be calculated as outlined below.

5.10.5.1 Reference Fenestration Products

Calculate the total fenestration product U-factor for each reference fenestration product with the corresponding applied film according to Section 5.10.5.2. U-factors for reference products are pre-calculated based on the illustrations in Figures 5-23 and 5-24. This will result in the matrix in Table 5-9 for each film product.

Figure 5-23 – Residential Fixed Window Reference Product

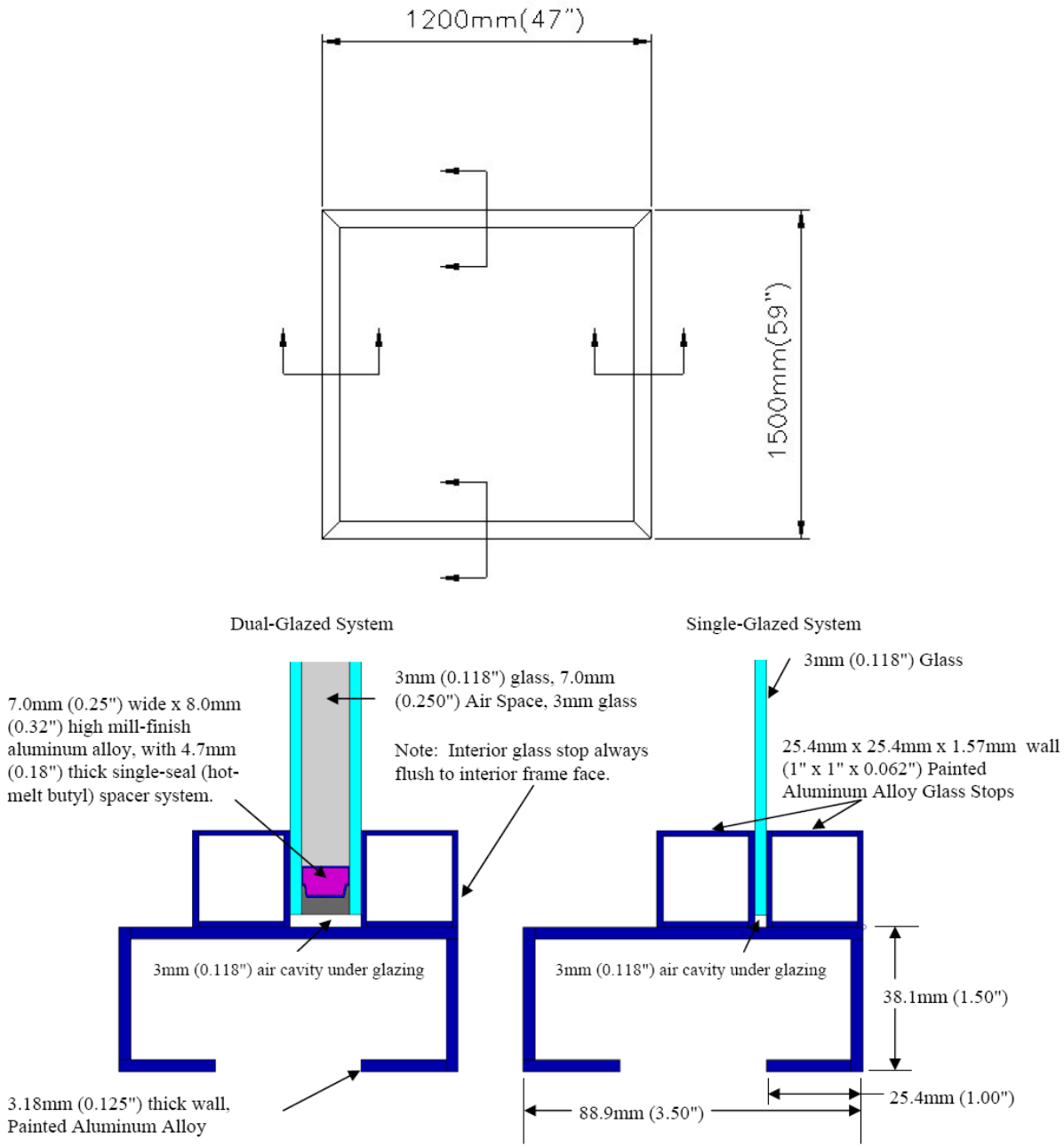
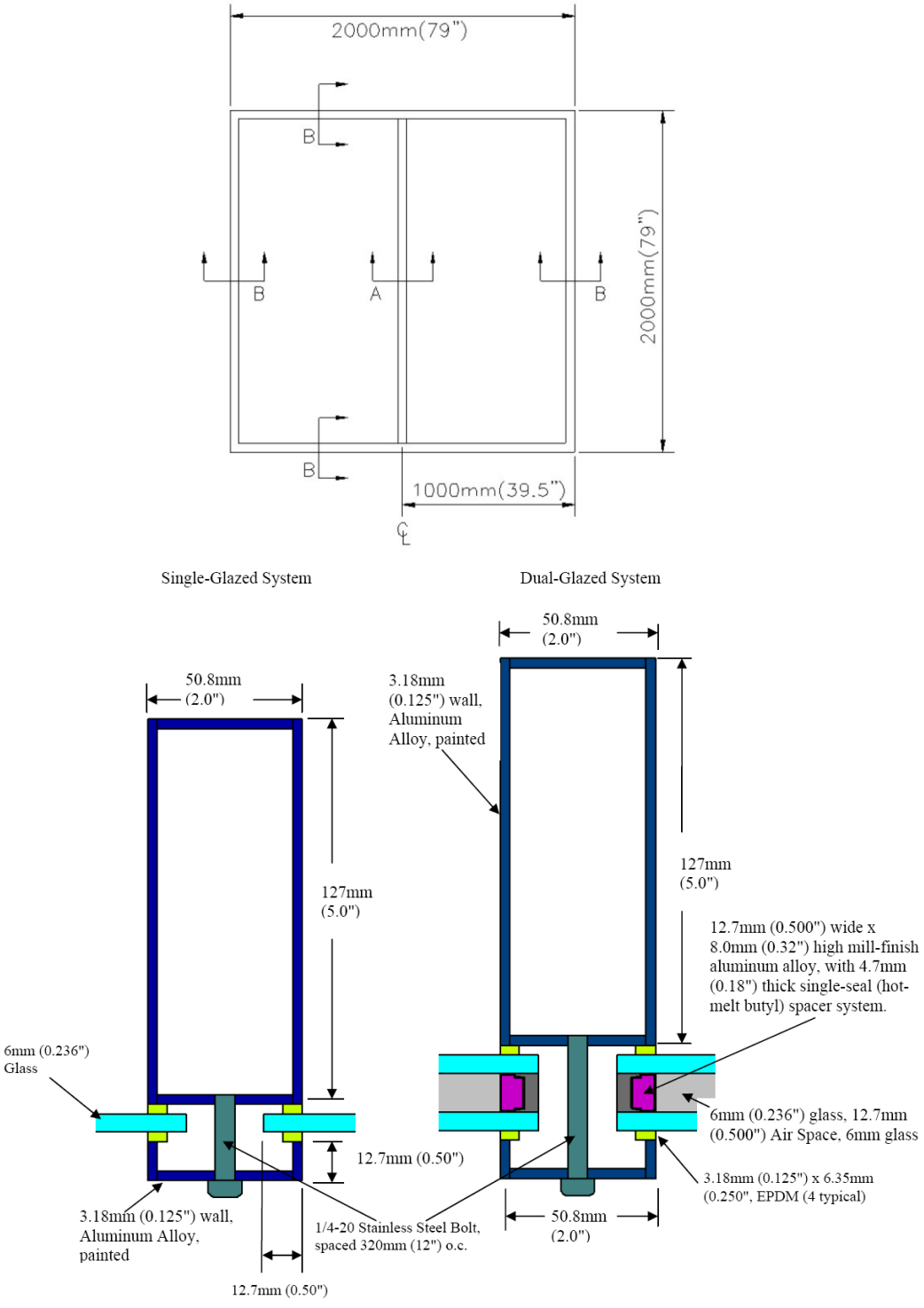
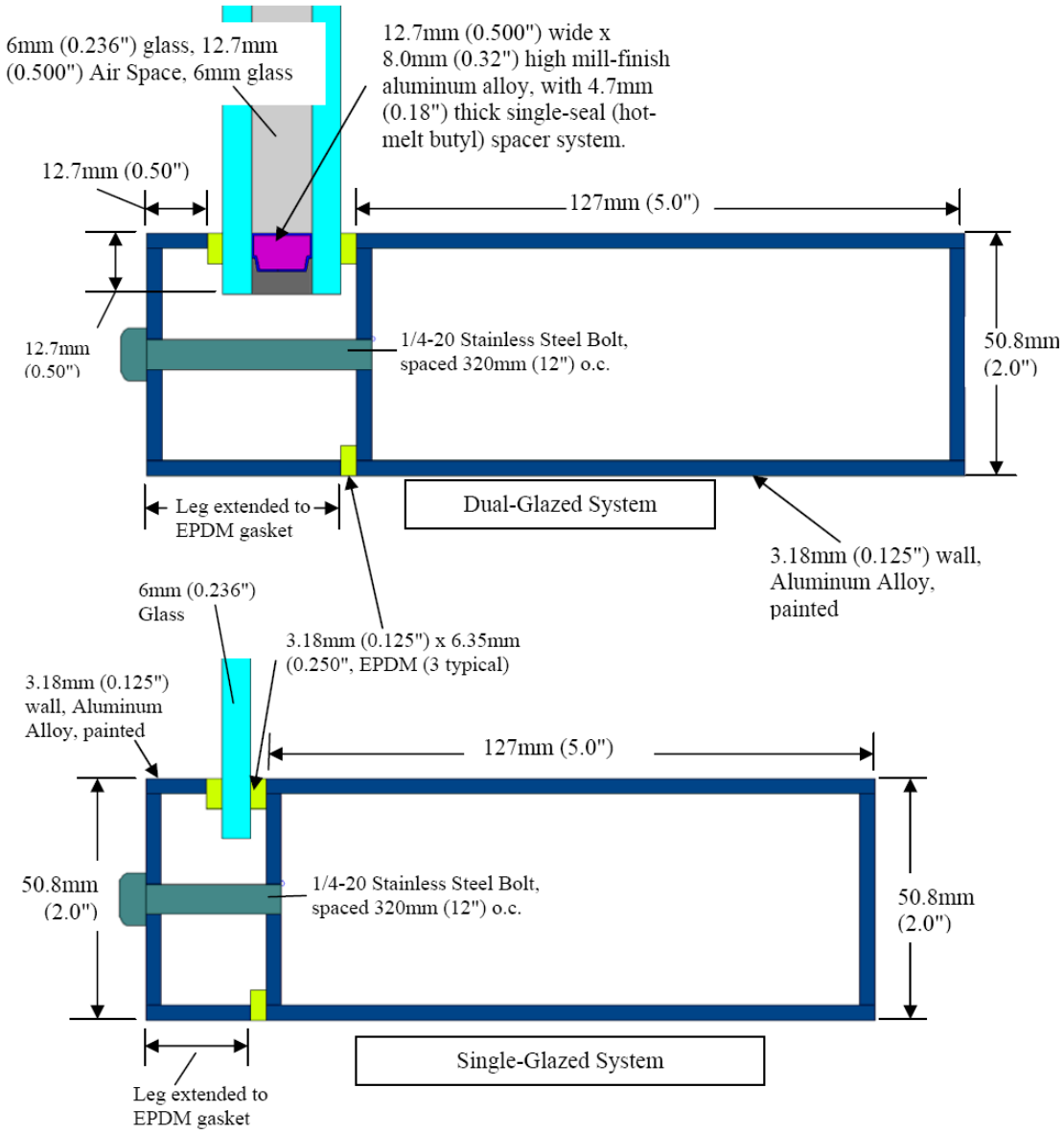


Figure 5-24 – Non-Residential Window-Wall Reference Product





5.10.5.2 Total Fenestration Product U-factor

Calculate the total fenestration product U-factor for each reference fenestration product and corresponding reference product with applied film using the following equation:

$$U_t = \left[\Sigma\left(U_f A_f\right) + \Sigma(U_e A_e) + \Sigma(U_c A_c)\right]/A_{pf} \qquad \text{Equation 5-5}$$

Where:

U_t = *Total product U-factor, W/m²K, (Btu/h-ft²-ºF)*
A_{pf} = *Projected fenestration product area, m² (ft²)*
U_f = *Frame U-factor, W/m²K , (Btu/h-ft²-ºF)*
A_f = *Frame area, m² (ft²)*
U_e = *Edge-of-glazing U-factor, W/m²K, (Btu/h-ft²-ºF)*
A_e = *Edge-of-glazing area, m² (ft²)*
U_c = *Center-of-glazing U-factor, W/m²K, (Btu/h-ft²-ºF)*
A_c = *Center-of-glazing area in ft² (m²)*

To three significant figures

Table 5-8 – Center-of-Glazing Values U_c

Reference Glazing System	Without Film	With Film	
	U_c Btu/h·ft²·ºF	**Film Position**	**U_c* Btu/h·ft²·ºF**
3 mm (1/8 in) clear	1.04	Interior	
6 mm (1/4 in) clear	1.02	Interior	
6 mm (1/4 in) grey	1.02	Interior	
3 mm (1/8 in) clear 3 mm (1/8 in) clear 7mm (1/4 in) gap	0.55	Interior	
6 mm (1/4 in) clear 6 mm (1/4 in) clear 12.7mm (1/2 in) gap	0.47	Interior	
6mm (1/4 in) grey 6 mm (1/4 in) clear 12.7mm (1/2 in) gap	0.47	Interior	

* U_c 'with Film' shall be calculated using reference glazing with film to be rated.

Table 5-9 – Values of U-factor for Reference and Applied Films

Reference Product			U-factor Btu/h·ft²·ºF	
Operator Type	Reference Frame	Reference Glazing	no film	with film*
Residential Fixed	Aluminum	3mm (1/8 in) clear	1.081	
Non-Residential Window-wall	Aluminum	6mm (1/4 in) clear	1.021	
		6mm (1/4 in) grey	1.021	
Residential Fixed	Aluminum	3mm (1/8 in) clear 3mm (1/8 in) clear 7mm (9/32 in) gap	0.700	
Non-Residential Window-wall	Aluminum	6mm (1/4 in) clear 6mm (1/4 in) clear 12.7mm (1/2 in) gap	0.588	
		6mm (1/4 in) grey 6mm (1/4 in) clear 12.7mm (1/2 in) gap	0.588	

* 'with film' shall be calculated using reference glazing with film to be rated.

5.10.6 Testing

If a reference product with applied film cannot be simulated in accordance with Section 5.10.5, the center-of-glazing test procedure in Section 5.10.6.1 shall be used to determine the U-factor of the applied film glazing system.

5.10.6.1 Center-of-Glazing Component Test Procedure

The center-of-glazing U-factor (Uc) for corresponding reference product glazing system with applied film shall be tested in accordance with Section 4.6.2.1.

5.10.6.2 Total Fenestration Product Test Procedure

Using center-of-glazing U-factor (Uc) determined in accordance with Section 5.10.6.1 with applicable reference product framing system shall be simulated to calculate total fenestration product U-factor.

5.11 Trendline Approach

5.11.1 Scope

This section covers methods for determining fenestration product U-factor (thermal transmittance) for fenestration products using a trendline calculation approach.

5.11.2 Products and Systems Covered

Product lines that are comprised of only the following product types: a fully glazed stile and rail hinged doors, lift and slide doors, folding doors, and products listed in Table 4-3 except for the following:

A. Garage (Vehicular Access)/Rolling Door;

B. Greenhouse/Garden;

C. Non-full lite Door Sidelite;

D. Non-full lite Side-Hinged Exterior Door;

E. Non-full lite Door Transom; and

F. Tubular Daylighting Device

5.11.3 Variations from Standard Product Lines

None

5.11.4 Variations from Standard Simulation and Test Conditions

5.11.4.1 Trendlines

Grouping criteria referenced in Section 4.2.4 shall be applied prior to calculating the whole product U-factor using a trendline calculation. After applying Section 4.2.4 grouping of products, separate trendlines are generated based on a product's characteristics.

Each trendline represents a specific categorization of individual product options for which there is a linear relationship between the center-of-glass U-factor (U_{cog}) and the total product U-factor (U_{tot}). The linear relationship is used to generate the U_{tot} from any individual product option's Ucog that falls within the categorized specifications.

The accuracy of the trendline relationship is affected by certain characteristics of the individual product options and is independent of other characteristics. For example, a data group containing both argon-filled and krypton-filled glazings will produce an accurate trendline; whereas,

introducing different gaps widths will greatly reduce the accuracy.

Research has produced a list of known characteristics that affect trendline accuracy. By categorizing individual product options per these factors, the result produces accurate trendlines for any product options that fall within that category.

5.11.4.1.1 Categorizing Product Options for a Trendline

Available individual product options shall be separated into product groupings (categories) per a combination of the characteristics listed below. A category need only be created for those options available for a given product line.

A trendline per section 5.11.4.1.2 will be created for each category of the following characteristics:

A. IGU characteristics:

B. glass types – monolithic or laminate

C. cavity width size;

D. spacer system;

E. number of glazing layers;

F. Interior surface low-e;

G. grids or true divided lites; and

H. dynamic glazing products

I. Frame characteristics

J. reinforcement material and locations;

K. frame cavity fill material and locations;

L. sightline

NOTE: Refer to NFRC LEAFF Simulation Manual to develop trendlines.

5.11.4.1.2 Establishing Trendline Endpoints

The categorization of a trendline per section 5.11.4.1.1 will set the glazing options. The following explains the process to set the three points used for a trendline. A category with less than three glazing options shall not be permitted to use the trendline methodology.

A. Each trendline shall be established with a minimum of three (3) points: the two endpoints and one midpoint.

B. Glazing (i.e., center-of-glass) options for the endpoints shall be the best and worst performing (Uc-min and Uc-max, respectively) options in the available category options.

C. Glazing selection for each trendline COG midpoint (Uc-mid) shall be the closest COG of the average of the Uc-min and Uc-max. For trendlines where there are only three glazing options, the three options will be the Uc-min, Uc-mid, and Uc-max.

D. The determined Uc-min, Uc-mid, and Uc-max shall be used to develop trendlines per Section 5.11.4.1.3.

5.11.4.1.3 Development of a Trendline

For each category established in 5.11.4.1.1, a trendline shall be created from the three points selected in 5.11.4.1.2.

A. Each of the point glazing configurations shall be simulated with the category frame and spacer options, per NFRC RCBC Simulation Manual.

B. The resulting whole product (U_{tot}) and COG (U_c) U-factors of each trendline point shall be plotted as a line graph, as specified below, using NFRC's Trendline Excel file.

C. The values of U_c are plotted against the horizontal (X) axis.

D. The values of U_{tot} are plotted against the vertical (Y) axis.

E. The linear equation coefficients, "m" and "b", for this category, as well as the R^2 value, shall be computed from the modeling results.

F. The m and b coefficients define the trendline and are used to calculate U_{tot} from U_c.

G. The R^2 coefficient of determination is a measure of the linearity of the trendline points. Its value shall be greater than 0.990.

H. If the trendline's R^2 evaluation does not meet linearity standards, the results shall require the re-simulation of the existing points or the re-categorization of the trendline per 5.11.4.1.1.

5.11.5 Total Fenestration Product U-factor Rating

A. Develop a matrix of all individual product options according to the trendline category.

B. To determine the total fenestration product U-factors for all entries in the trendline matrix, use the values from the slope intercept formula y=mx+b.

i. The "m" is the slope

ii. The "b" is the intercept

iii. The "x" is the individual product option's center-of-glass U-factor$_{(cog)}$.

iv. The "y" is the whole product total U-factor$_{(tot)}$.

C. Apply the slope intercept formula representing the "x" for each corresponding individual product option's center-of-glass U-factor$_{(cog)}$ listed in the matrix. The resulting "y" is the individual product's total U-factor$_{(tot)}$ rating.

5.11.6 Validation

The baseline product option selected per Section 4.2.6 criteria shall be modeled and shall be an option in the trendline.

5.11.7 Adding Individual Product Options to Existing Trendlines

A. Addition of new individual product options where the U_{cog} falls inside an existing trendline's endpoint range, shall be permitted to use that existing trendline.

B. Addition of new individual product options where the Ucog falls outside an existing trendline's endpoint range, shall not use that existing trendline and shall create a new trendline per section 5.11.4.1 for new individual product options.

5.12 Commercial Trendline Approach

5.12.1 Scope

This section covers methods for determining commercial fenestration product U-factor (thermal transmittance) using the Commercial Trendline Approach (CTA).

5.12.2 Products and Systems Covered

A. All products listed in Table 4-3 except

1. Garage (Vehicular Access)/Rolling Door;
2. Greenhouse/Garden;
3. Tubular daylighting devices
4. Tropical awning
5. Non-full lite Door Sidelite;
6. Non-full lite Side-Hinged Exterior Door, and;
7. Non-full lite Door Transom

B. Combination products (refer to NFRC 715);

C. Composite products (refer to NFRC 715)

5.12.3 Variations from Standard Product Lines

None (see Section 4.2.1)

5.12.4 Commercial Trendlines

Grouping criteria referenced in Section 4.2.4 shall be applied prior to calculating the total product U-factor using the CTA. After applying Section 4.2.4 grouping of products, a minimum of two trendlines are generated based on a product's characteristics.

These trendlines represent a specific product grouping of individual product options for which there is a linear relationship between the glazing system (center-of-glass U-factor (U_{cog}) and the total product U-factor (U_{tot}). The linear relationship is used to generate the U_{tot} from any individual product option's U_{cog} and spacer system that falls within the product grouping specifications for the trendline.

5.12.5 Standard Simulation

All simulations shall be based on computer simulations that comply with Section 4.3.1 and use NFRC approved software.

The CTA uses aspects of the Trendline Approach (LEAFF Methodology) per section 5.11 with specific alterations indicated

herein. The CTA requires modeling the product line's frame cross-sections with the best, mid and worst center-of-glazing (COG) assemblies to establish trendline points and using only a default low and default high spacer system to develop two product trendlines for each product grouping, described further in 5.12.5.1. Any individual product options, within their respective product grouping, U-factor can be determined within these two trendline boundaries.

When the individual product options do not meet the CTA requirements for trendline generation these option(s) shall be simulated per section 4.3.1.

5.12.5.1 Categorizing Product Options for a Trendline

All of the product line's individual product options shall be separated into product groupings per a combination of the characteristics listed below.

A trendline will be created for each product grouping with the following characteristics:

A. Nominal IGU accommodations;

(changes in nominal IGU width or main frame changes to accommodate the IGU)

NOTE: Nominal IGU width may be comprised of characteristic options containing different glass and gap thickness. Products with secondary sash or panel, energy panel, or storm panel fall into a separate trendline category.

Interior surface low-e glass can be within the same trendline for U-factor ratings only. To determine CI per ANSI/NFRC 500, separate CI trendlines would be required for products with and without interior surface low-e glass.

B. Number of glazing layers (e.g. double glazed IGU, triple glazed IGU);

C. Grids or true divided lites;

D. Dynamic glazing products, and;

E. Any product changes per Section 4.2.2, which have not been grouped per Section 4.2.4.

5.12.5.2 Establishing Trendline U_{cog} Points

The development of a trendline per section 5.12.5.1, will establish the individual glazing options and results in a minimum of two trendlines for each product grouping.

A. Determining Trendline Point Glazing Options

This section explains the process to establish the three points used for the trendlines.

A product grouping with less than three glazing options shall not be permitted to use the CTA.

i. The trendlines for each product grouping shall be established with three (3) points: the two endpoints and one midpoint.

ii. Glazing (i.e., center-of-glass) options for the endpoints shall be the best and worst performing ($U_{c\text{-}min}$ and $U_{c\text{-}max}$, respectively) options; the same endpoints shall be used for both the spacer trendlines.

(a) The $U_{c\text{-}max}$ shall be constructed using only clear glass layer(s) and use an air-filled gap.

(b) The $U_{c\text{-}min}$ shall be the best center-of-glass option and at a minimum include a low-e glass layer.

iii. Glazing selection for each trendline COG midpoint ($U_{c\text{-}mid}$) shall be the individual option with the closest U_{cog} to the average of the $U_{c\text{-}min}$ and $U_{c\text{-}max}$. For trendlines where there are only three glazing options, these three options will be used for the points (e.g. $U_{c\text{-}min}$, $U_{c\text{-}mid}$, and $U_{c\text{-}max}$).

B. Establishing Trendline Spacer Systems

It is required to use two default spacer systems when using the CTA to establish the minimum two trendlines required; the spacer system composition and geometry shall be based on a solid material with 13mm (0.50”) height and the conductivity set to:

i. Default low spacer system conductivity = 0.01 W/m-K (0.006 Btu/h-ft-F)
ii. Default high spacer system conductivity = 10.0 W/m-K (5.8 Btu/h-ft-F)

5.12.5.3 Development of a Trendline

For each category established in 5.12.5.1, trendlines shall be generated from the three U_{cog} points selected in

5.12.5.2.A and the two default spacer systems in 5.12.5.2.B.

A. Each of the U_{cog} glazing configurations ($U_{c\text{-}min}$, $U_{c\text{-}mid}$, and $U_{c\text{-}max}$) shall be simulated with the product grouping frame and the high default spacer system and the low default spacer system to generate six total product U-factor ratings.

B. The total product U-factor ratings U_{tot} is plotted against the vertical (Y) axis with the glazing configurations U_{cog} plotted against the horizontal (X) axis to generate two trendlines.

   i. Trendline U_b = total product U-factor trendline using the low default spacer system
   ii. Trendline U_w = total product U-factor trendline using the high default spacer system

C. The linear equation coefficients, Slope, Intercept, and R^2 values, will be computed from the modeling results for each trendline.

   i. The slope and intercept coefficients define the trendline and are used to calculate U_{tot} from U_{cog}.

   ii. The R^2 coefficient of determination is a measure of the linearity of the trendline points. Its value shall be greater than 0.980.

D. If the trendline's R2 evaluation does not meet linearity standards of 0.980, the results shall require the re-simulation of the existing points or the re-grouping of the trendline per 5.12.5.1.

5.12.6 Default and Specific Spacer Systems

The CTA methodology requires each spacer system performance to be provided in terms of effective conductivity, k_{eff} when calculating total product U-Factor after Trendline U_w and Trendline U_b are generated. A default or specific spacer system shall be used to calculate the total product performance ratings. The spacer system consists of the spacer component, desiccant, and any applicable sealants and specified sealant thickness / height.

5.12.6.1 Default Spacer System

The default spacer system contains a spacer component and default sealant(s) geometry and is based on a default total height of 13mm (0.50”).

The default spacer system k_{eff} to be used is found in Table 5-10 and is based on the composition and shape of the spacer within the spacer system. In the event a spacer contains two metals, the higher conductivity metal shall be used in specifying the spacer system class, regardless of the amount of that metal present in the spacer.

Table 5-10 – Default Spacer System Performance

Spacer System Class	Spacer System Class k_{eff} W/m-K (Btu/h-ft-F)	Spacer Composition (Highest Conductivity)	Spacer Shape
Class 1	8.0 (4.6)	Aluminum	Box Spacer
Class 2	3.0 (1.7)	Mild Steel	Box Spacer
Class 3	1.0 (0.58)	Stainless Steel	Box Spacer
		Aluminum or Mild Steel	Hybrid, Composite, U-shaped, or Thermal Break Spacer
Class 4	0.5 (0.29)	Non-metallic	Any
		Stainless Steel	Hybrid, Composite, U-shaped, or Thermal Break Spacer

The following definitions apply for Table 5-10:

- Box spacers have a hollow cross-sectional profile with two members that traverse from one side to the other side.
- Hybrid spacers have a geometry similar to a box spacer but have metal present on only one side-to-side path and use a separate, low conductance material <0.5 W/m-K to complete the spacer profile, forming the second side-to-side path.
- Composite spacers have a solid cross-section, and for the purposes of Table 5-10 have no more than one metal member that traverses from one side to the other side.
- U-shaped spacers have a cross-sectional profile with only one member that traverses from one side to the other side.

- Thermal Break spacers have an insulating bridge <0.52 W/m-K of at least 1.6mm connecting two metal profiles.
- Metalized polymer materials (a polymer substrate with a vacuum deposited metal layer) are considered non-metallic for this categorization.
- Mild Steel can be galvanized, tin-plated, etc.

5.12.6.2 Specific Spacer Systems

The Specific spacer system contains detailed and specific sealant(s), geometry, and based on the specific spacer system nominal height.

Determining the k_{eff} of the spacer system:

A. Composition and geometry shall be based on the drawings and the bill of materials supplied by the spacer manufacturer;

B. Modeled by a LEAFF certified simulator with an NFRC accredited simulation laboratory (ASL) in accordance with the NFRC Simulation Manual and reviewed and authorized by an NFRC licensed inspection agency (IA) ;

C. Every unique spacer system type and size shall obtain a k_{eff} or follow this simplification method to obtain k_{eff}. For simplification, spacer system trendlines may be generated so all configurations do not require individual modeling. This is accomplished by modeling the widest spacer system, mid-width spacer system, and narrowest spacer system for all unique spacer system types determined in 5.12.5.1. These spacer system points will be used to generate spacer system trendlines, for each specific spacer system, and allow for the effective conductivity (k_{eff}) determination of any width spacer system between endpoints selected;

   i. The nominal height of the spacer system must be identical for the points used to generate spacer system trendlines;

   ii. The spacer system k_{eff} from the corresponding spacer systems are plotted against the vertical (Y) axis with the spacer system width plotted against the horizontal (X) axis.

5.12.7 Total Fenestration Product U-factor Rating

This section defined the calculation to determine the total product U-factor for each individual option within a product grouping using the CTA approach.

5.12.7.1 U-Factor Range Determination

The total U-Factor for the low default (U_b) and high default (U_w) spacer systems for an individual glazing option in the product grouping shall be determined using the center-of-glass U-factor (U_{cog}) and the two U-factor trendlines, determined in 5.12.5.3.

Equation 5-6:

$$U_w = Intercept_w + Slope_w \, x \, U_{cog}$$

Equation 5-7:

$$U_b = Intercept_b + Slope_b \, x \, U_{cog}$$

Where:

U_w = U-factor using the default high spacer system trendline

U_b = U-factor using the default low spacer system trendline

U_{cog} = individual glazing options center-of-glass U-factor

5.12.7.2 Total U-factor (U_{tot})

To determine the total product U-factor (U_{tot}) for the individual glazing option is determined using Equation 5-8.

Equation 5-8:

$$U_{tot} = U_b + \frac{(U_w - U_b) \cdot (\ln(k_{eff}) - \ln(k_{eff}b))}{\ln(k_{eff}w) - \ln(k_{eff}b)}$$

Where:

U_w = U-factor using the default high spacer system trendline and the individual glazing option center-of-glass U-factor

U_b = U-factor using the default low spacer system trendline and the individual glazing option center-of-glass U-factor

U_{tot} = total product U-factor for the individual glazing option

k_{eff} = use either a Default or Specific spacer system conductivity

(i) Default k_{eff} for the spacer system per Section 5.12.6.1; or
(ii) Specific k_{eff} for the specific spacer system option k_{eff} per Section 5.12.6.2.
(iii) k_{eff} is limited between $k_{eff}b$ and $k_{eff}w$

$k_{eff}b$ = k_{eff} of low default spacer system from trendline U_b

$k_{eff}w$ = k_{eff} of high default spacer system from trendline U_w

The U-factor of a fenestration product may vary by size. In order to provide a uniform rating procedure, as well as size specific information, the CTA as described in this section shall be used as the primary method. For the comparison rating of commercial fenestration systems, the U-factor rating for model size per Table 4-3 is calculated. U-factor ratings for sizes other than model size can be calculated for informational purposes when applicable. The projected frame depth (PFD) is required for calculation of specified sizes; refer to Appendix A Aspect Ratio Calculation.

5.12.8 Reporting Simulation Results

See NFRC 701.03 – Reporting Requirements.

5.12.9 Validation Testing

The baseline product option selected per Section 4.2.6 criteria shall be modeled and shall be an option in the commercial trendline.

The following conditions apply:

A. Test specimen size and configuration shall be as defined in Table 4-3.

B. All test specimens shall be tested without removable screens, removable grilles and trims, or any other applied devices;

C. All test specimens shall be tested in the vertical position. For determining validation of the baseline product only, skylights,

and other sloped glazing products shall be simulated in a vertical position;

D. The test specimen shall not be modified by the testing laboratory, except as allowed in Reference 1 for sealing against air leakage and as required by this section;

E. The product is validated if the baseline product has a tested U-factor which meets the equivalence criteria in Table 4-4 when simulated in accordance with Section 5.12.5.

5.12.10 Calculating Individual Product Options to Existing Trendlines

Calculation of new individual product options where the categorization falls within the existing trendline range, shall be permitted to use the existing trendlines.

6. REFERENCES

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APPENDIX A (NON-MANDATORY INFORMATION)

This section includes methods that can be used to calculate fenestration U-factor performance based on the specified size(s). This data can be used to provide more accurate inputs to building energy simulations to support more effective HVAC equipment sizing and better estimations of peak loads, annual energy use estimations and thermal comfort. These U-factor values shall not be used on NFRC labels, nor shall they be included in the NFRC Certified Products Directory (CPD).

A.1 Determination of Skylight U-factors at Non-Standard Slopes

A U-factor-rating matrix that is slope-specific may be developed in accordance with ANSI/NFRC 100 procedures and requirements. A matrix shall only be developed for those product lines and individual products of a product line that have been submitted to an NFRC-licensed independent certification and Inspection Agency (IA) for certification authorization purposes at the standard 20° slope from horizontal. Products that have previously received certification authorization may also have a matrix developed. Each matrix shall be specific to an individual product and glazing type within a product line.

The matrix shall include the standard slope rating and ratings at other slopes that are defined by the manufacturer.

Calculation shall use the following Convective Surface Heat Transfer Coefficients, for any of the listed slopes:

Table A-2: Convective Surface Heat Transfer Coefficients, hc, in for Skylights at Different Incidence Angles ($W/m^{2}\cdot{}^{o}K$)

Frame Type	Angle of Incidence from Horizontal (degrees)									
	0	10	15	20	30	45	60	70	85	90
Wood/ Vinyl	3.147	3.147	3.095	3.090	3.042	2.798	2.357	2.405	2.441	2.443
T/B Al	4.147	4.147	4.096	4.091	4.043	3.801	3.088	2.953	2.997	2.999
TI Al	4.373	4.373	4.322	4.317	4.270	4.029	3.316	3.071	3.117	3.120
Al	4.710	4.710	4.659	4.654	4.606	4.366	3.657	3.244	3.292	3.295

Table A-3: Convective Surface Heat Transfer Coefficients, hc, in for Skylights at Different Incidence Angles (Btu/h^2·ft$^{2.o}$F)

Frame Type	Angle of Incidence from Horizontal (degrees)									
	0	10	15	20	30	45	60	70	85	90
Wood/ Vinyl	0.554	0.554	0.545	0.544	0.536	0.493	0.415	0.424	0.430	0.430
T/B Al	0.730	0.730	0.721	0.720	0.712	0.670	0.544	0.520	0.528	0.528
TI Al	0.770	0.770	0.761	0.760	0.752	0.710	0.584	0.541	0.549	0.549
Al	0.829	0.829	0.821	0.820	0.811	0.769	0.644	0.571	0.580	0.580

Coefficients for any slopes not listed can be calculated using linear interpolation between the two closest angles.

Skylights that are approved for use at slopes within 15° of vertical under the manufacturer's standard instructions may be entitled to dual U-factor ratings. Consult with the NFRC-licensed independent certification and Inspection Agency (IA) for further determination.

Note: Until such time that a certification change is made in the NFRC 700: Product Certification Program, the thermal performance parameters that are determined at slopes other than the standard slope are for informational purposes only.

Table A-4: Skylight U-factors Slope Table (Example Only)

	Roof Slope (degrees above horizontal)						
	0	15	20	40	60	75	85
U-Factor	0.52	0.50	0.49	0.47	0.45	0.43	0.42

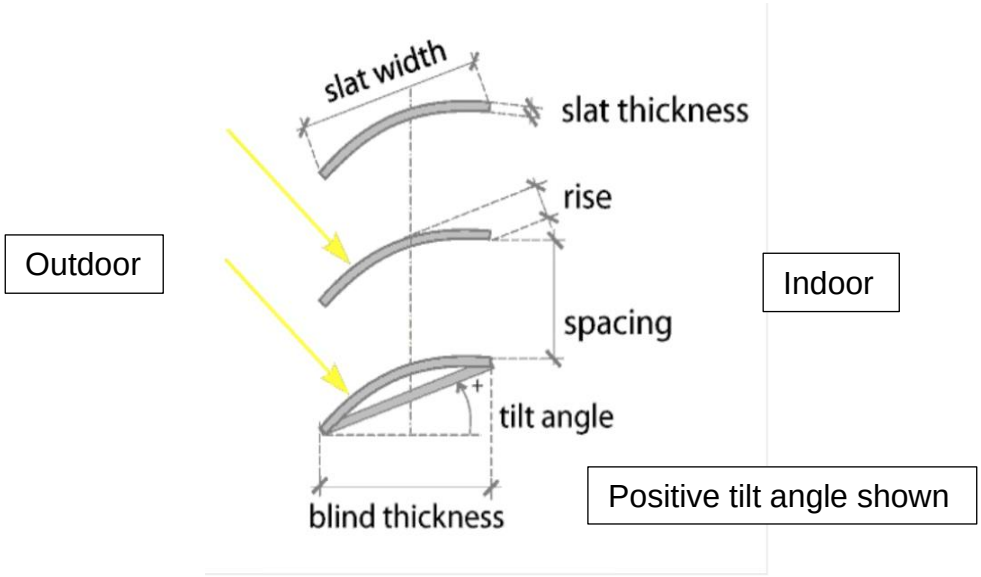
Shaded column indicates ANSI/NFRC 100 standard slope ratings for certification purposes.

The values stated (other than the identified standard ratings) in the matrix above are for informational purposes only and have not been authorized for certification. The standard slope ratings are also shown on the label or certificate to which this matrix is attached. For additional information, contact the IA stated on the label certificate.

A.2 Determination of U-factors for Dynamic Glazing Products at additional slat angles

Determination of U-factors for Dynamic Glazing Products with slatted blinds between glass shall be permitted at slat tilt angles other than Fully ON/CLOSED and Fully OFF/OPEN. Additional slat angles of -45º and +45º shall also be permitted as optional ratings that may be added to the CPD.

See figure below for angle descriptions.



A.3 Determination of U-factor at Specified Sizes using Aspect Ratio Calculation

The U-factor of a fenestration product may vary by size. In order to provide a uniform rating procedure for the comparison of fenestration systems, total product U-factor rating is calculated for the model size per Table 4-3.

Specified size U-factors can be calculated for informational purposes. All products in Tabel 4-3 except greenhouse/garden windows, non-full lite side-hinged exterior doors (single or double), non-full lite sidelites, non-full lite transoms, garage (vehicular access)/rolling doors, tubular daylighting devices, and spandrel panel systems can be calculated using the procedures outline in Section 4.6.3, and if applicable, Section 5.11 and Section 5.12. Total product U-factor results for the specified size product can be calculated from Equation 1 and Equation 2.

Equation 1:

$$U_{f-NFRC} = \frac{(U_{t-NFRC} * A_{pf-NFRC}) - (U_{c-NFRC} * A_{c-NFRC}) - (U_{e-NFRC} * A_{e-NFRC}) - (U_{d-NFRC} * A_{d-NFRC}) - (U_{de-NFRC} * A_{de-NFRC})}{A_{f-NFRC}}$$

Where:

$U_{t\text{-}NFRC}$ = total product U-factor for the individual glazing option at model size per Table 4-3

$U_{c\text{-}NFRC}$ = individual glazing options center-of-glass U-factor

$U_{d\text{-}NFRC}$ = individual glazing option divider U-Factor, assumed to equal U_c

$U_{e\text{-}NFRC}$ = individual glazing option edge-of-glazing U-factor, assumed to be equal to U_c

$U_{de\text{-}NFRC}$ = individual glazing option edge-of-divider U-factor, assumed to be equal to U_c

$A_{pf\text{-}NFRC}$ = total projected fenestration product area at model size per Table 4-3

$A_{c\text{-}NFRC}$ = center-of-glazing vision area at model size per Table 4-3

$A_{d\text{-}NFRC}$ = divider area at model size per Table 4-3

$A_{e\text{-}NFRC}$ = individual glazing option edge-of-glazing area

$A_{de\text{-}NFRC}$ = individual glazing option edge-of-divider area

$A_{f\text{-}NFRC}$ = frame area at model size per Table 4-3

Assume:

$U_{c\text{-}NFRC} = U_{d\text{-}NFRC} = U_{e\text{-}NFRC} = U_{de\text{-}NFRC}$

$A_{g\text{-}NFRC}$ = Total glazing area = $A_{c\text{-}NFRC}+A_{d\text{-}NFRC}+A_{e\text{-}NFRC}+A_{de\text{-}NFRC}$

Then Equation 1 becomes:

Equation 1.1

$$U_{f-NFRC} = \frac{(U_{t-NFRC} * A_{pf-NFRC}) - (U_{c-NFRC} * A_{g-NFRC})}{A_{f-NFRC}}$$

Equation 1.2

$$A_{pf\text{-}NFRC} = W * H$$

Where:

W = width of the model size from Table 4.3 (mm)

H = height of the model size from Table 4.3 (mm)

1) When the projected frame height (PFD) of each modeled section is known and A_f can be calculated:

Equation 1.3

$$A_{g\text{-}NFRC} = A_{pf\text{-}NFRC} - A_{f\text{-}NFRC}$$

2) When the projected frame height (PFD) is not known an average projected frame height ($\overline{H_{fr}}$) shall be calculated and used to determine A_g, A_c, and A_f shall be calculated based on A_c as follows:

Equation 1.4

$$A_{c-NFRC} = \frac{VT_{t-NFRC} * A_{pf-NFRC}}{VT_{c-NFRC}}$$

Where:

$VT_{t\text{-}NFRC}$ = total product visible light transmission for the individual glazing option at model size per Table 4-3.

$VT_{c\text{-}NFRC}$ = individual glazing options center-of-glass visible light transmission

$VT_{f\text{-}NFRC}$ is assumed to be zero

For Rectangular Products:

Equation 1.5

$$\overline{H_{fr}} = \frac{(2 * W + 2 * H - E) - \sqrt{(2 * W + 2 * H - E)^2 - 16 * ((W * H) - A_{c-NFRC} - D)}}{8}$$

Where:

Equation 1.6

$$A_{g-NFRC} = \left(W - 2 * \overline{H_{fr}}\right) * \left(H - 2 * \overline{H_{fr}}\right)$$

Equation 1.7

$$A_{d-NFRC} = D - (E * \overline{H_{fr}})$$

Equation 1.8

$$D = (W * H_d * N_h + H * H_d * N_v - H_d^2 * N_h * N_v)$$

Equation 1.9

$$E = (2 * H_d * N_h + 2 * H_d * N_v)$$

For Horizontal two-lite Products:

Equation 1.10

$$\overline{H_{fr}} = \frac{(2 * W + 3 * H - E) - \sqrt{(2 * W + 3 * H - E)^2 - 24 * ((W * H) - A_{c-NFRC} - D)}}{12}$$

Where:

Equation 1.11

$$A_{g-NFRC} = \left(W - 3 * \overline{H_{fr}}\right) * (H - 2 * \overline{H_{fr}})$$

Equation 1.12

$$A_{d-NFRC} = D - (E * \overline{H_{fr}})$$

Equation 1.13

$$D = (W * H_d * N_h + H * H_d * N_v - H_d^2 * N_h * N_v)$$

Equation 1.14

$$E = (3 * H_d * N_h + 2 * H_d * N_v)$$

For Vertical two-lite Products

Equation 1.15

$$\overline{H_{fr}} = \frac{(3 * W + 2 * H - E) - \sqrt{(3 * W + 2 * H - E)^2 - 24 * ((W * H) - A_{c-NFRC} - D)}}{12}$$

Where:

Equation 1.16

$$A_{g-NFRC} = \left(W - 2 * \overline{H_{fr}}\right) * (H - 3 * \overline{H_{fr}})$$

Equation 1.17

$$A_{d-NFRC} = D - (E * \overline{H_{fr}})$$

Equation 1.18

$$D = (W * H_d * N_h + H * H_d * N_v - H_d^2 * N_h * N_v)$$

Equation 1.19

$$E = (2 * H_d * N_h + 3 * H_d * N_v)$$

Where:

$A_{g\text{-}NFRC}$ = visible glass area and the divider area at model size per table 4-3

$A_{d\text{-}NFRC}$ = divider area at model size per table 4-3

$\overline{H_{fr}}$ = the average projected frame height for the product

H_d = divider PDF, divider $<$ 1” H_d =19mm, divider $\geq$ 1” H_d = 38mm

N_h = number of horizontal dividers in rated product

N_v = number of vertical dividers in rated product

Equation 1.20

$$A_{f\text{-}NFRC} = A_{pf\text{-}NFRC} - A_{g\text{-}NFRC}$$

Assume:

$U_{f\text{-}NFRC} = U_{f\text{-specified size}}$

$U_{c\text{-}NFRC} = U_{c\text{-specified size}}$

Equation 2:

$$U_{t-\text{specified size}} = \frac{(U_{f-\text{specified size}} * A_{f-\text{specified size}}) + (U_c * A_{g-\text{specified size}})}{A_{pf-\text{specified size}}}$$

Where:

$U_{t\text{-specified size}}$ = total product U-factor for the individual glazing option at the specified size

$U_{f\text{-specified size}}$ = frame U-factor for the specified size product

U_c = individual glazing options center-of-glass U-factor

$A_{f\text{-specified size}}$ = frame area at the specified size

$A_{g\text{-specified size}}$ = vision and divider area at specified size

$A_{pf\text{-}specified\ size}$ = total projected fenestration product area at the specified size

Equation 2.1

$$A_{pe\text{-}specified\ size} = W' * H'$$

Where:

H' = height of the specified size product (mm)

W' = width of the specified size product (mm)

1) When the projected frame height (PFD) of each modeled section is known and $A_{f\text{-}specified\ size}$ can be calculated:

Equation 2.2

$$A_{g\text{-}specified\ size} = A_{pf\text{-}specified\ size} - A_{f\text{-}specified\ size}$$

2) When the projected frame height (PFD) is not known $A_{g\text{-}specified\ size}$ shall be calculated based on the average projected frame height ($\overline{H_{fr}}$) and $A_{f\text{-}specified\ size}$ shall be calculated based on $A_{g\text{-}specified\ size}$ as follows:

For Rectangular Products

Equation 2.3

$$A_{g-specified\ size} = \left(W' - 2 * \overline{H_{fr}}\right) * \left(H' - 2 * \overline{H_{fr}}\right)$$

For Horizontal Two-lite Products

Equation 2.4

$$A_{g-specified\ size} = \left(W' - 3 * \overline{H_{fr}}\right) * \left(H' - 2 * \overline{H_{fr}}\right)$$

For Vertical Two-lite Products

Equation 2.5

$$A_{g-specified\ size} = \left(W' - 2 * \overline{H_{fr}}\right) * \left(H' - 3 * \overline{H_{fr}}\right)$$

Equation 2.6

$$A_{f\text{-}specified\ size} = A_{pf\text{-}specified\ size} - A_{g\text{-}specified\ size}$$

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APPENDIX C: Delegation of Rulemaking Authority for Efficiency Standards for Residential Windows, Doors and Skylights, May 13, 2025.

COLORADO
Department of Public Health & Environment

MEMORANDUM

DATE: May 13, 2025

TO: Michael Ogletree, Director of the Air Pollution Control Division, Colorado Department of Public Health and Environment

FROM: Jill Hunsaker Ryan, MPH, Executive Director, Colorado Department of Public Health and Environment

RE: Delegation of Rulemaking Authority for Efficiency Standards for Residential Windows, Doors and Skylights

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Effective immediately, and pursuant to my authority under §§ 6-7.5-105(5)(j)(2); 6-7.5-102(25); 24-4-103, C.R.S. I am hereby delegating authority as detailed below. This memorandum supersedes previous delegations of authority relevant to matters contained herein, and shall remain in full force and effect until withdrawn.

I am hereby delegating the following authority to **Michael Ogletree**:

DUTY	**AUTHORITY**
Determining whether the efficiency standard set by HB23-1161 for residential windows, doors and skylights cannot reasonably be met by manufacturers.	§ 6-7.5-105(5)(j)(II), C.R.S.
Consideration of a request for rulemaking for adoption of 5 CCR 1004-2 Water and Efficiency Standards, to create an alternative standard for residential windows, doors and skylights.	§ 24-4-103, C.R.S.
Conducting a rulemaking hearing to consider adoption of an alternative standard for residential windows, doors, and skylights.	§ 6-7.5-105(5)(j)(II), C.R.S.; § 24-4-103, C.R.S.
Taking and considering testimony, evidence, and comments during the rulemaking process.	§ 24-4-103, C.R.S.
Deliberating over all evidence presented during the rulemaking process.	§ 24-4-103, C.R.S.
Adopting 5 CCR 1004-2 Water and Efficiency Standards, concerning an alternative standard to the standard set by HB23-1161 for residential windows, doors, and skylights.	§ 6-7.5-105(5)(j)(II), C.R.S.; § 24-4-103, C.R.S.

If Michael Ogletree is not available due to unforeseen circumstances, signatory authority will automatically revert back to me, Jill Hunsaker Ryan.

* *In performing the duties delegated to Michael Ogletree, Michael Ogletree is acting as the Executive Director Designee, a neutral hearing officer, and not as the Director of the Air Pollution Control Division.*

Jill Hunsaker Ryan, MPH
Executive Director
Colorado Department of Public Health and Environment