NFRC 100: Procedure for Determining Fenestration Product U-factors

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Foreword

Consumers today have many energy saving fenestration product options to choose from. Advances in fenestration product technologies include the use of low-emissivity coatings, low-conductivity gas-fills, insulating spacers, and new frame materials and designs. While the use of one or more of these components will improve fenestration product thermal performance, it will also increase the complexity of the selection process.

This procedure has been developed by the National Fenestration Rating Council (NFRC) to meet the need for a uniform and accurate means for evaluating the U-factors of fenestration systems using state-of-the-art simulation procedures validated with physical testing. The U-factors established by this procedure are determined at a fixed set of environmental conditions. Consequently, the U-factors determined using this procedure may not be appropriate for directly determining seasonal energy performance.

This document supercedes and replaces *NFRC 100-91*.

A procedure to evaluate total product solar heat gain coefficients and visible transmittances is addressed in *NFRC 200*; to determine glazing layer optical properties in *NFRC 300* and *NFRC 301*, to determine air leakage rates in *NFRC 400*, and to determine annual energy effects in *NFRC 900*. A procedure to address condensation resistance factors is under development.

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

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Table of Contents

1. Purpose

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

2. Scope

2.1. Fenestration Products Covered by NFRC 100

(a) Products of all frame materials including but not limited to aluminum, steel, thermally broken aluminum, wood, vinyl, reinforced vinyl, fiberglass, and plastic, used singly or in combination;

(b) Products of all operator or unit types including but not limited to vertical sliding windows, horizontal sliding windows, casement windows, projecting windows, fixed windows, non-standard shaped and non-rectangular windows, glazed wall systems, glazings for site built fenestration products, garden or greenhouse windows, bay or bow windows, and skylights;

(c) Single or multiple assemblies of exterior doors *[**Note**: Entry Doors with and without glazed areas are addressed in Reference 1]*;

(d) Products of any size;

(e) Products of all glazing materials, tints, and types such as but not limited to clear glass, tinted glass, stained glass, glass block, thin plastic films (internally suspended, internally applied, or externally applied), rigid plastics, and translucent fiberglass with or without any solar control, low-E or any other partially transparent coating and products with manufactured decorative opaque insulative glazing panels, designed for interchangeability with other glazing options;

(f) Products with any or no gap width between glazing layers;

(g) Products with any gas-fill between glazing layers such as but not limited to air, argon, krypton, SF_6, CO_2, or mixes of these gases.

(h) Products with any spacer or spacer systems between glazings, such as but not limited to metallic, non-metallic, or composite spacers;

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

(j) Products utilizing shading systems between glazing layers limited to those that are an integral, i.e., non-removable, part of the product; and

(k) Products designed for installation at any tilt.

2.2. Fenestration Products and Effects Not Covered by NFRC 100

(a) Products with shading systems other than those listed in 2.1(j);

(b) Thermal performance changes of a fenestration product over the course of time, i.e., long term energy performance; and

(c) Issues of water tightness, structural capacity, and air infiltration.

*[**Note**: Garage doors with or without glazed areas are covered in Reference 1.]*

3. Terminology

U-factor (a.k.a. U-value): a measure of the heat transfer characteristics of a fenestration product under specific environmental conditions. 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 infrared radiation. The U-factor is the heat transmission in a unit time through a unit area of a test specimen and its boundary air films, induced by a unit temperature difference between the environments on each side.

(a) **Frame U-factor (U_f):** the total heat transfer through all frame and sash members divided by the induced temperature difference and the frame area.

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

(c) **Edge-of-glass U-factor (U_e):** the U-factor representative of the edge-of-glass area.

(d) **Divider edge U-factor (U_{de}):** the U-factor representative of the divider edge area.

(e) **Center-of-glass U-factor (U_c):** the U-factor representative of the center-of-glass area.

(f) **Total fenestration product U-factor (U_t):** the U-factor representative of the total fenestration product.

*[**Note:** See figures 1 and 2 for drawings of following definitions]*

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

Divider area (A_d): the projected area in the plane(s) parallel to the fenestration product's glazing of all internal, external, or between glazing dividers (includes dividers for simulated or true divided lites, interior and exterior decorator grilles, and between glass muntin bars).

Edge-of-glass area (A_e): all glazed vision areas within 63.5 mm (2.5 in.) of any part of the frame and sash. The edge-of-glass area shall exclude any divider area contained within the above defined area.

Divider edge area (A_{de}): all glazed vision areas within 63.5 mm (2.5 in.) of any part of a divider area. The divider edge area shall exclude any edge-of-glass area contained within the above defined area.

Center-of-glass area (A_c): all glazed areas except those within 63.5 mm (2.5 in.) of any part of a primary sash and/or frame and/or divider.

Frame area (A_f): the sum of the projected areas of all frame and sash members in the plane(s) parallel to the glazing surface, summed over each glazing plane.

*[**Note:** Where a fenestration product has glazed surfaces facing in only one direction (typical windows), the sum of the divider-edge area, the edge-area, the divider area, the center-of-glass area, and the frame area will equal the total projected fenestration product area (A_{pf}). 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.]*

Frame and sash: any structural member of the fenestration product, with the exception of muntins or other dividers used to create true or artificial divided lites.

Total fenestration product area: the area of the total fenestration product which includes all frame, divider, edge-of-glass, divider edge, and center-of-glass areas.

4. Product Lines and Individual Products

Under NFRC 100, U-factors are determined for all individual products within a product line. The baseline product is a specific individual product within a product line. This section defines these critical terms.

4.1. Product line

A product line is a given series of fenestration products with the same operator type that differ only in:

(a) size;

(b) center-of-glass and edge-of-glass characteristics such as glazing types, glazing coatings, gas-fills, gap widths, use of dividers, use of spacers;

(c) opening/non opening configurations, e.g., XO vs. XOX*;

(d) minor changes to accommodate smaller/larger glazing unit widths;

(e) minor changes to operating hardware to accommodate higher/lower loads and stresses (including the use of reinforcing in vinyl framed fenestration products);

(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 a factor of 10; and

(g) interior/exterior appendages added to the main web of the frame that are not exposed after product installation, i.e., nailing fins.

A product line is thus defined by an operator type and a set of basic frame profiles. For each frame/sash element, a **base profile** must be defined. Frame/sash profiles which differ from

* An "X" denotes an operating panel/sash. An "O" denotes a fixed or non-operating panel/sash. Combinations of X's and O's denote the appropriate combinations of operating and non-operating panels.

these base profiles are part of the same product line as long as the differences are limited to lengthening, shortening, expanding, or deleting specific elements of the base profile (typically incorporated into the product line for different installations). Such differences in the base profile constitute different individual products within the product line. Material changes where the conductivity changes by more than a factor of 10 are not part of the same product line except for the addition of cladding materials applied to the base profile.

Multipurpose fenestration products incorporating nearly identical frame/sash base profiles can be classified and rated as one product line. The products shall be classified in separate groups by operator type within the product line.

Clad products and unclad products can be incorporated into one product line if and only if the cladding system represents a minor change to the frame/sash base profile. The clad and unclad products would be separate individual products within the product line.

Multiple assemblies, sometimes referred to as combination or composite windows, including more than one operator type, (e.g., a vertical slider over an awning) and multiple assemblies of the same operator type need not be rated in combination. Each operator type may be evaluated separately.

Non-rectangular fenestration products shall be rated as though they are rectangular fenestration products. Identify all the frame cross sections of the non-rectangular fenestration product. Find or develop a product line with the same frame cross sections as the non-rectangular fenestration product, and choose the rectangular sizes closest to residential and nonresidential for simulation and testing. If there are no rectangular sizes available in those ranges, a non-rectangular fenestration product with the same frame cross sections, and the closest possible total area (see Section 5.3) can be used for simulation or testing.

4.2. Individual Product

An individual product is any one specific fenestration product, of any size, within a product line specific to:

(a) center-of-glass and edge-of-glass characteristics;

(b) minor frame differences (variations on the base profile--see Section 4.1);

(c) sealing characteristic variables and elements;

(d) opening/non-opening configurations, e.g., XO vs. XOX; and

(e) operator type.

Variations in frame or sash interior/exterior finish, paint, varnish, or stain do not constitute different products provided that each of these variations do not change the surface emittance by more than 0.1 or overall thickness by more than 0.41 mm (0.016 in.).

Continuous hardware, reinforcing, or other frame component changes to the same base profile are considered different individual products within the same product line.

Individual products where the sill design changes to accommodate different installation requirements but the materials remain the same shall be considered different individual products within the same product line.

Reinforced vinyl products and products without reinforcement with the same base profile are considered different individual products within the same product line.

Inswinging and Outswinging doors with the same base profile are considered different individual products within the same product line.

Products with different glazing divider patterns do not need to be treated as different individual products. The manufacturer may define a standard glazing divider pattern (which is a standard product offering) and which uses glazing dividers 305 mm (12 in.) on-center or less. If no standard product offerings exist with glazing divider patterns 305 mm (12 in.) on-center or less, a glazing divider pattern with an on-center dimension closest to but not greater than 305 mm (12 in.) shall be used as the glazing divider pattern.

Fenestration products which include an outdoor air ventilator assembly (OAVA) are considered to be the same individual product if the OAVA area, expressed as a percentage of the

model size area, is less than the value computed in Equation 1. Products with an area percentage larger than given in Equation 1 are treated as separate individual products.

$$P_{OAVA} = \frac{\left(W_{OAVA} \cdot H_{OAVA}\right)}{\left(W_m \cdot H_m\right)} \cdot 100 \qquad \text{[Equation 1]}$$

Where:

P_{OAVA} = percentage of OAVA rounded up to the nearest 0.5%
W_{OAVA} = width of glazing in mm (in.)
H_{OAVA} = a constant, 44.5 mm (1.75 in.)
W_m,H_m= width, height of model size in mm (in.)

OAVA's are defined as devices, other than a sash unit, for the purpose of controlling the passage of air through a fenestration product. An OAVA shall not allow outside air access to cavities within the cross-sectional boundaries of the sash, frame, or glazing. Any components that are added to the fenestration product to facilitate the installation of the OAVA shall be considered to be an integral part of the OAVA for the purpose of calculating the total area of the ventilator assembly.

4.3. Baseline product

The **baseline product** is the individual product selected for validation testing (see Section 6.1.1). The individual product selected as the baseline product shall have a simulated U-factor within 0.57 W/m^2-^{o}C (0.1 Btu/hr-ft^2-^{o}F) or 20%* of the lowest simulated U-factor. Size variations are limited to the two representative sizes as defined in Section 5.3 for the given operator or unit type. For product lines which include multiple operator types (see Section 4.1), the baseline product is selected from all operator type groups within that product line.

[***Note:*** *In some product lines, there may be more than one product eligible to be selected as the baseline product. Selecting the individual product with the lowest simulated U-factor as the baseline product is recommended to allow for maximum flexibility when adding individual products in the future.]*

* Whichever is greater

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5. Standard Conditions and Requirements

This section presents standard tests, simulations, and calculations for determining total or component fenestration product U-factors. Read and follow Section 6, Fenestration Product Thermal Properties, before performing any of the tests, simulations, or calculations identified in this section.

5.1. Test Procedures

There are two different test procedures used in NFRC 100. Section 5.1.1 defines the total fenestration product test procedure, its standard conditions, and requirements. The total fenestration product test procedure is used to validate the product line simulations (see Section 6.1.1) and is used under the testing alternative (see Section 6.1.2) which may be used only if the U-factor for the product cannot be simulated in accordance with Section 5.4. Section 5.1.2 defines a center-of-glass component test procedure which may be used only if the U-factor for the center-of-glass cannot be simulated in accordance with section 5.4.

5.1.1. Total Fenestration Product Test Procedure

The NFRC *Test Procedure for Measuring the Steady State Thermal Transmittance of Fenestration Systems* [Reference 2], shall be used to determine tested total fenestration product U-factors. The following conditions also apply:

(a) Fenestration product sizes tested shall be in accordance with Section 5.2;

(b) All products shall be evaluated or tested without screens, removable grilles, or any other applied devices;

(c) All products shall be evaluated or tested in the vertical position. Skylights and other sloped glazing products shall be evaluated in a vertical position until NFRC issues a technical interpretation stating how such products shall be rated at a slope of 20 degrees above the horizontal; and

(d) The fenestration product shall not be modified by the testing laboratory for testing except as allowed in Reference 2 for sealing against air infiltration and as required to meet this section**.**

5.1.2. Center-of-Glass Component Test Procedure

The following procedure shall not be used to obtain a rating for the center-of-glass component if the U-factor for the product can be simulated in accordance with section 5.4. If the U-factor for the product cannot be simulated in accordance with Section 5.4, the methods in references 8, 9 and 10, with the following conditions, may be used to determine the effective center-of-glass conductance:

(a) The center-of-glass component tested shall be the same dimensions, to the nearest 6.4 mm (0.25 in.), as the plates on either side;

(b) The spacer system within the center-of-glass component shall be at least 76 mm (3 in.) from the metering area;

(c) Rubber gaskets with a known thermal conductivity shall be used to separate the surfaces of the center-of-glass component from the plates. The thermal resistance of these gaskets shall be excluded from the calculated effective conductivity. The total thermal resistance of both gaskets shall be less than 0.0352 m^2-^oC/W (0.2 hr-ft^2-^oF/Btu); and

(d) With non-hermetically sealed insulating glass units, the testing process may prevent the transfer of moisture through engineered weep-holes. In such cases, a desiccant may be placed inside the unit to prevent moisture from building up within the test unit. The desiccant must be placed at least 63.5 mm (2.5 in.) from the metering area.

Reference 6 suggests additional appropriate practices.

5.2. Model Product Line Sizes and Configurations for Reporting of U-factors

For each individual product, total fenestration product U-factors shall be reported for the specified configuration in two model sizes (residential and nonresidential), as shown in Table 1. For residential product comparisons, the use of the residential model size is recommended. If, within a product line, there are no individual products smaller than the nonresidential model size, U-factors for the residential model size shall not be required. Similarly, if, within a product line, there are no individual products larger than the residential model size, U-factors for the nonresidential model size shall not be required.

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Table 1: Residential and Nonresidential Model Sizes

Operator Type	Opening (X) Non-operating (O) Configuration	Residential Model Size (width x height)	Nonresidential Model Size (width x height)
Vertical Slider[1]	XO or XX[2]	914 mm x 1524 mm (36 in. x 60 in.)	1219 mm x 1829 mm (48 in. x 72 in.)
Horizontal Slider	XO or XX[3]	1524 mm x 914 mm (60 in. x 36 in.)	1829 mm x 1219 mm (72 in. x 48 in.)
Casement	X[4]	610 mm x 1219 mm (24 in. x 48 in.)	762 mm x 1524 mm (30 in. x 60 in.)
Projecting (Awning)	X[5]	1219 mm x 610 mm (48 in. x 24 in.)	1016 mm x 1016 mm (40 in. x 40 in.)
Fixed (includes non-standard shapes)	O[6]	1219 mm x 1219 mm (48 in. x 48 in.)	1219 mm x 1829 mm (48 in. x 72 in.)
Swinging Door(s) with Frame[7]	X, XO or XX[8]	965 mm x 2083 mm or 1829 mm x 2083 mm (38 in. x 82 in. or 72 in. x 82 in.)[9]	965 mm x 2083 mm or 1829 mm x 2083 mm (38 in. x 82 in. or 72 in. x 82 in.)[9]
Sliding Patio Doors with Frames	XO or XX[10]	1829 mm x 2083 mm (72 in. x 82 in.)	1829 mm x 2438 mm (72 in. x 96 in.)
Glazed Wall Systems (Site-Built)	OO[11]	2032 mm x 2032 mm (80 in. x 80 in.)	2032 mm x 2032 mm (80 in. x 80 in.)
Sloped Glazing	OO[12]	2032 mm x 2032 mm (80 in. x 80 in.)	2032 mm x 2032 mm (80 in. x 80 in.)
Skylights	X[14]	1219 mm x 1219 mm (48 in. x 48 in.)[13]	1219 mm x 1219 mm (48 in. x 48 in.)[13]
Greenhouse/Garden	X[14]	1524 mm x 914 mm (60 in. x 36 in.)	1829 mm x 1219 mm (72 in. x 48 in.)
Dual Action	X[15]	914 mm x 1524 mm (36 in. x 60 in.)	1219 mm x 1829 mm (48 in. x 72 in.)
Pivoted	X[16]	1219 mm x 1219 mm (48 in. x 48 in.)	1219 mm x 1829 mm (48 in. x 72 in.)
Sidelites	X[14,17]	406 mm x 2083 mm (16 in. x 82 in.)[18]	406 mm x 2083 mm (16 in. x 82 in.)[18]
Transoms	X[14,19]	965 mm x 356 mm (38 in. x 14 in.)[20]	1880 mm x 356 mm (74 in. x 14 in.)[21]

1 Double hung sash kits shall be rated with one of two options:
Option #1: Double hung sash kits will be simulated and tested for validation in a default frame of similar material and design as proposed installation.
Option #2: Double hung sash kits that are identical in material and design as a manufacturer's double hung product line may use the same ratings provided a simulation laboratory states that the frame qualifies as a default frame per Option #1. See Reference 3.

2 Representative of all vertical sliders and combinations of factory assembled vertical slider(s) and fixed units(s).

3 Representative of all horizontal sliders and combinations of factory assembled horizontal slider(s) and fixed unit(s).

4 Representative of all casements, fixed or operable and combinations of factory assembled casement(s) and fixed unit(s).

5 Representative of all projecting units, fixed or operable and combinations of factory assembled projecting unit(s) and fixed unit(s).

6 Representative of all fixed windows and combinations of factory assembled fixed units.

7 Glazed doors and unglazed doors with the same frame base area profile can be considered as separate individual products within the same product line. In such cases, the procedure presented in Reference 1 shall be used. The single door shall be used to represent all door assemblies (single, double, multiple) unless the manufacturer does not produce a single door; in that case the double door shall be used to represent double and multiple door assemblies.

8 Representative of all swinging doors and combinations of factory assembled swinging doors and fixed unit(s).

9 These sizes represent a 914 mm x 2032 mm (36 in. x 80 in.) door slab.

10 Representative of all sliding patio doors and combinations of sliding patio doors and fixed unit(s).

11 Two lites with one vertical mullion. Curtainwalls shall be simulated and tested with intermediate verticals as jambs and intermediate horizontals as head/sill frame members. Windowwalls shall be simulated and tested with standard jamb, head, and sill members.

12 Two lites with one vertical mullion. Sloped glazing shall be simulated and tested with standard jamb, head, and sill members.

13 Fits over or in a 1181 mm x 1181 mm (46.5 in. x 46.5 in.) opening.

14 If not manufactured, use "O" (fixed unit).

15 Representative of all dual action units and combinations of factory assembled dual action unit(s) and fixed unit(s).

16 Representative of all pivoted windows and combinations of factory assembled pivoted unit(s) and fixed unit(s).

17 Representative of all sidelites and combinations of factory assembled sidelites and fixed unit(s).

18 This size represents a 356 mm x 2032 mm (14 in. x 80 in.) sidelite slab.

19 Representative of all transoms and combinations of factory assembled transoms and fixed unit(s).

20 This size represents a 914 mm x 305 mm (36 in. x 12 in.) transom slab.

21 This size represents a 1829 mm x 305 mm (72 in. x 12 in.) transom slab.

5.3. Representative Product Line Sizes for Testing of Production Line Fenestration Products

For the purposes of testing (see Sections 6.1.1 and 6.1.2), production line units and sizes shall be used. The Residential and nonresidential test samples are therefore defined as the production line sizes with the least deviation (*D*) from the residential and nonresidential model sizes respectively (see Table 1) as shown in Equation 2:

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

[Equation 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 12.7 mm (0.5 in.) in width or 12.7 mm (0.5 in.) in height [25.4 mm (1 in.) for doors] from the reported sizes of the tested products.

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

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

[Equation 3]

Where:

A_{sim} = area of product simulated in mm^2 ($in.^2$)
A_{test} = area of product tested in mm^2 ($in.^2$)
C = a constant, 25.4 mm (1 in.)
W_m,H_m= width, height of model size in mm (in.)

5.4. Simulation Procedures

The requirements of the NFRC *Simulation Manual* [Reference 3] and of Section 5.1.1 shall be used to determine total fenestration product U-factors.

For gas fills other than air, the gas fill percentages used in the simulations shall not exceed the values in Reference 3 for a given filling technique.

Non-continuous elements, including but not limited to screws and bolts in curtainwalls and pour-and-debridge thermal breaks which are not fully debridged, shall be simulated as indicated in Reference 3.

Material conductivities not found in References 3 or 7 or their references shall be determined in accordance with References 4 or 5.

5.4.1. Approved Center-of-Glass Simulation Programs

Approved center-of-glass software shall be used. NFRC approved software is listed in Reference 7.

5.4.2. Approved 2-D Heat Transfer Simulation Programs

Approved 2-D heat-transfer software shall be used. NFRC approved software is listed in Reference 7.

5.4.3. Approved Total Fenestration Product U-factor Calculation Procedure

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

(a) Determine all of the following, as applicable:

(1) Center-of-glass U-factor using an approved center-of-glass simulation program, with input as needed from the approved center-of-glass conductance test procedure given in Section 5.1.2.;

(2) Edge-of-glass U-factor using an approved 2-D heat transfer simulation program;

(3) Divider U-factor using an approved 2-D heat transfer simulation program;

(4) Divider edge U-factor using an approved 2-D heat transfer simulation program;

(5) Frame U-factor using an approved 2-D heat transfer simulation program; and

(6) The component areas, to the nearest 0.001 m^2 (0.01 ft^2), of:

- Center-of-glass area
- Divider area
- Edge-of-glass area
- Divider edge area
- Frame area
- Projected fenestration product area.

(b) Perform the following calculations as shown in Equation 4:

(1) Multiply the center-of-glass, edge-of-glass, divider, divider edge, and frame U-factors by their corresponding areas;

(2) Total these five quantities; and

(3) 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 (see Section 6).

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

Equation 4]

Where:

U_t = Total Product U-factor in W/m^2-^{o}C (Btu/hr-ft^2-^{o}F)
A_{pf} = Projected Fenestration Product Area in m^2 (ft^2)
U_f = Frame U-factor in W/m^2-^{o}C (Btu/hr-ft^2-^{o}F)
A_f = Frame Area in m^2 (ft^2)
U_d = Divider U-factor in W/m^2-^{o}C (Btu/hr-ft^2-^{o}F)
A_d = Divider Area in m^2 (ft^2)
U_e = Edge-of-Glass U-factor in W/m^2-^{o}C (Btu/hr-ft^2-^{o}F)
A_e = Edge-of-Glass Area in m^2 (ft^2)
U_{de} = Divider Edge U-factor in W/m^2-^{o}C (Btu/hr-ft^2-^{o}F)
A_{de} = Divider Edge Area in m^2 (ft^2)
U_c = Center-of-Glass U-factor in W/m^2-^{o}C (Btu/hr-ft^2-^{o}F)
A_c = Center-of-Glass Area in m^2 (ft^2)

5.5. Equivalent

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 given in Table 2.

Table 2: Equivalence

Simulated U-factor	Accepted Difference Between Tested and Simulated U-factor
2.27 W/m^2-^{o}C (0.4 Btu/hr-ft^2-^{o}F) or less	0.227 W/m^2-^{o}C (0.04 Btu/hr-ft^2-^{o}F)
Greater than 2.27 W/m^2-^{o}C (0.4 Btu/hr-ft^2-^{o}F)	10% of Simulated U-factor

6. Fenestration Product Thermal Properties

This section presents and references methods for determining specific fenestration product heat transfer properties or quantities used in the determination of these properties.

6.1. Total Fenestration Product U-factors for Model Sizes

For a given product line, list all individual products and associated model sizes (see Section 5.2). The model size matrix of U-factors for a given product line should be outlined as follows:

	Residential Model Size	Nonresidential Model Size
Individual Product #1		
.		
.		
.		
Last Individual Product		

This matrix shall include all individual products within a product line which 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 4.1 for the definition of a product line and Section 4.2 for the definition of individual products.

In order to determine total fenestration product U-factors for all the entries in this matrix, use the product line validated simulation procedure, presented in Section 6.1.1. The testing alternative, presented in Section 6.1.2, 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 5.4.

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

6.1.1. Product Line Validated Simulation Procedure

(a) Determine representative size matrix of U-factors. List all individual products and associated representative sizes (see Section 5.3) within a product line. The representative size matrix of U-factors for a product line is given as follows:

	Residential Representative Size	Nonresidential Representative Size
Individual Product #1		
.		
.		
.		
Last Individual Product		

(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 5.4.3), compute the U-factor for the baseline product (see Section 4.3). *[**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 5.1.1.

(d) Validation of simulation procedure. If the simulated and tested U-factors for the baseline product are equivalent, as defined in Section 5.5, then the computational procedure presented in Section 5.4.3 shall be considered as validated for all the products in the product line. The approved total fenestration product U-factor calculation procedure presented in Section 5.4.3 shall then be used to determine U-factors for the model

size matrix of U-factors of Section 6.1. These are the values which are reported.

If the simulated and tested U-factors for the baseline product are not equivalent, as defined in Section 5.5, then the alternative test procedure presented in Section 6.1.2 can be used for all products within the product line with written permission of NFRC.

6.1.2. Testing Alternative

If an individual product cannot be simulated in accordance with Section 5.4, the test procedure found in Section 5.1.1 may be used to determine the U-factors of the individual fenestration product(s), for the residential and nonresidential representative sizes. However, this test procedure may only be used for the reporting of U-factors if all of the following four conditions are met:

(a) The difference between the width of the residential representative size and the width of the residential model size is less than 76 mm (3 in.) or 5% of the width of the residential model size, whichever is less;

(b) The difference between the height of the residential representative size and the height of the residential model size is less than 76 mm (3 in.) or 5% of the height of the residential model size, whichever is less;

(c) The difference between the width of the nonresidential representative size and the width of the nonresidential model size is less than 76 mm (3 in.) or 5% of the width of the nonresidential model size, whichever is less;

(d) The difference between the height of the nonresidential representative size and the height of nonresidential model size is less than 76 mm (3 in.) or 5% of the height of the nonresidential model size, whichever is less.

If these conditions are all met and the individual product cannot be simulated in accordance with Section 5.4, the tested U-factors for the representative sizes of all individual fenestration products in a given product line may be reported as the U-factors for the residential model size and the nonresidential model size.

6.2. Simplifications to a Product Line

This section presents rules which may be used to reduce the number of individual products necessary to represent a product line. These rules may be used either with the product line validated simulation procedure (see Section 6.1.1) or with the testing alternative (see Section 6.1.2).

Products with removable or non-removable dividers applied to the room side and/or exterior side glass surface can be assumed to have the same U-factors as identical products without such dividers.

Products with glazing dividers between lites of insulating glass can be assumed to have the same U-factors as identical products without such dividers, providing there is at least 3.2 mm (0.125 in.) air/gas space between the divider and both glass surfaces.

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

Individual products which differ from another (base) individual product in glazing tint and/or obscurity only can be assumed to have the same U-factor as the base product unless this change is associated with a change in coating properties.

Center-of-glass groupings are allowed as follows. Once all center-of-glass options have been identified within a product line, the center-of-glass U-factor is simulated for each option. These products can then be grouped with each group represented by the center-of-glass group leader which is the center-of-glass option with the highest center-of-glass U-factor. If this approach is used, the total fenestration product U-factor for the center-of-glass group leader shall be used to represent the total fenestration product U-factors for all individual products within that center-of-glass group. For the purposes of determining U-factors, center-of-glass groups shall consist only of variations in glass thickness, gap width, gas fill and low-e coatings.

Frame groupings are allowed follows. Once all frame options have been identified within a product line, the frame and edge-of-glass heat loss is simulated for each option with the lowest

center-of-glass U-factor in the product line. These products can then be grouped with each group represented by the frame group leader which is the option with the highest frame and edge-of-glass 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. For the purposes of determining U-factors, frame groups shall consist only of frame/sash base profile variations consistent with the definition of a product line (section 4.1). Individual products from different product lines cannot be combined using frame groups.

Spacer groupings are allowed as follows. Once all spacer options have been identified within a product line, the frame and edge-of-glass heat loss is simulated for each option using a representative cross-section with the lowest center-of-glass U-factor in the product line. These products can then be grouped with each group represented by the spacer group leader which is the option with the highest frame and edge-of-glass 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 the purposes of determining U-factors, spacer groups shall consist only of variations in spacer assembly materials and shapes.

Divider groupings are allowed as follows. Once all divider options have been identified within a product line, the frame and edge-of-glass heat loss is simulated for each option with the lowest center-of-glass U-factor in the product line. These products can then be grouped with each group represented by the divider group leader which is the divider option with the highest frame and edge-of-glass 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. For the purposes of determining U-factors, divider groups shall consist only of variations in divider materials and shapes.

6.3. Additions to a Product Line

The product line validated simulation procedure (see Section 6.1.1) can 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 is not more than 0.57 W/m^2-^oC (0.1 $Btu/hr\text{-}ft^2\text{-}^oF$) or 20%* lower than a previously computed 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. Alternatively, if the new product's simulated U-factor is more than 0.57 W/m^2-^oC (0.1 $Btu/hr\text{-}ft^2\text{-}^oF$) or 20%* lower than the lowest simulated baseline product U-factor, the manufacturer may choose to label the new individual product with the U-factor for a individual product with a higher U-factor.

If a manufacturer introduces a new individual product into multiple product lines (e.g. glazing or spacer options, see section 4.3) which has a simulated U-factor more than 0.57 W/m^2-^oC (0.1 $Btu/hr\text{-}ft^2\text{-}^oF$) or 20%* lower than the simulated baseline product U-factor, only one product line with the new individual product shall be tested. If the simulation of the new baseline product validates, then all other product lines using this option are considered to be validated, and those new individual products can be simulated to obtain U-factors.

* Whichever is greater

6.4. Total Fenestration Product U-factors for Non-Model Sizes

Either the product line validated simulation procedure or the testing alternative may be used to evaluate the total fenestration product U-factor for size configurations other than the residential model size and the nonresidential model size for purposes other than certification.

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7. References

[1] National Fenestration Rating Council. *NFRC 100 Section B: Procedure for Determining Door System Product Thermal Properties (Currently Limited to U-values).* Silver Spring, MD.

[2] National Fenestration Rating Council. *Test Procedure for Measuring the Steady-State Thermal Transmittance of Fenestration Systems*. Silver Spring, MD.

[3] National Fenestration Rating Council. *Simulation Manual*. Silver Spring, MD.

[4] American Society for Testing and Materials. *C177: Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus*. Annual Book of Standards. Philadelphia, PA.

[5] American Society for Testing and Materials. *C518: Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*. Annual Book of Standards. Philadelphia, PA.

[6] Wright, J.L. and Sullivan, H.F*., Glazing System U-factor Measurement Using A Guarded Heater Plate Apparatus*, ASHRAE Transactions, 1988. OT-88-07-3.

[7] National Fenestration Rating Council*. List of Approved Simulation Programs*. Silver Spring, MD.

[8] American Society for Testing and Materials. *C236: Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Guarded Hot Box.* Annual Book of Standards. Philadelphia, PA.

[9] American Society for Testing and Materials. *C976: Standard Test Method for Steady-State Thermal Performance of Building Assemblies by Means of a Calibrated Hot Box.* Annual Book of Standards. Philadelphia, PA.

[10] American Society for Testing and Materials. *C1363: Method of Test for the Thermal Performance of Building Assembiles by Means of a Hot Box Apparatus.* Annual Book of Standards. Philadelphia, PA.

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8. Unit Conversions

The following conversions are used in this document. Values are then rounded to an appropriate number of significant figures. A complete guide to SI and its use may be found in the latest edition of ASTM E380; *Standard Practice for Use of the International System of Units (SI)*.

Measurement	To Convert	To	Multiply by
Length	inch (in.)	millimeter (mm)	25.4
Length	feet (ft)	millimeter (mm)	304.8
Area	square inch ($in.^2$)	square millimeter (mm^2)	645.16
Area	square feet (ft^2)	square meter (m^2)	0.09290
U-factor	$Btu/hr\text{-}ft^2\text{-}^oF$	$W/m^2\text{-}^oC$	5.678
R-value	$hr\text{-}ft^2\text{-}^oF/Btu$	$m^2\text{-}^oC/W$	0.1761
Conductivity	$Btu\text{-}in./hr\text{-}ft^2\text{-}^oF$	$W/m\text{-}^oC$	0.1442
Conductivity	$Btu/hr\text{-}ft\text{-}^oF$	$W/m\text{-}^oC$	1.73

*[**Note**: In this document, the Inch-Pound (IP) unit values were converted to Metric (SI) units. The metric values were then rounded off to the significant digits. Therefore, the user of this document may find slight disagreement in values when converting from SI to IP units. In this event, IP unit values shall be used as it appears in the parentheses.]*

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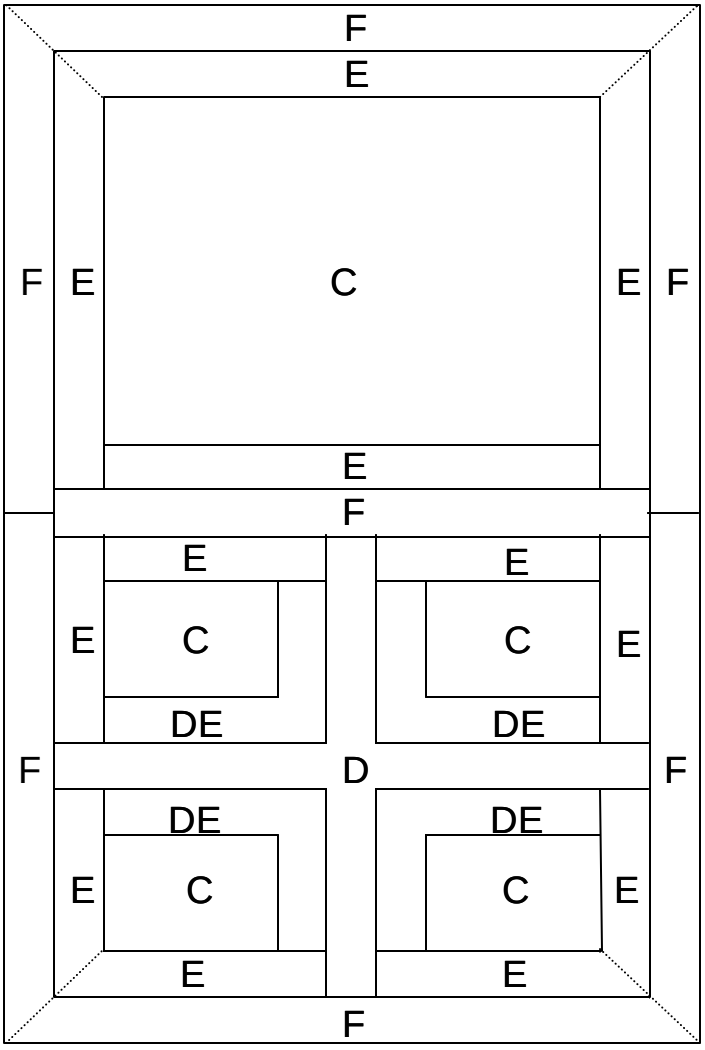
9. Figures

Figure 1: Fenestration Product Schematic - Vertical Elevation



Legend

C	Center-of-Glass
E	Edge-of-Glass
F	Frame
D	Divider
DE	Divider-Edge

Figure 1: Center-of-glass, edge-of-glass, divider, divider-edge, and frame areas for a typical fenestration product. Edge-of-glass and divider edge areas are 63.5 mm (2.5 in.) wide. The sum of these component areas equals the total projected fenestration product area.

Figure 2: Fenestration Product Schematic - Vertical Section

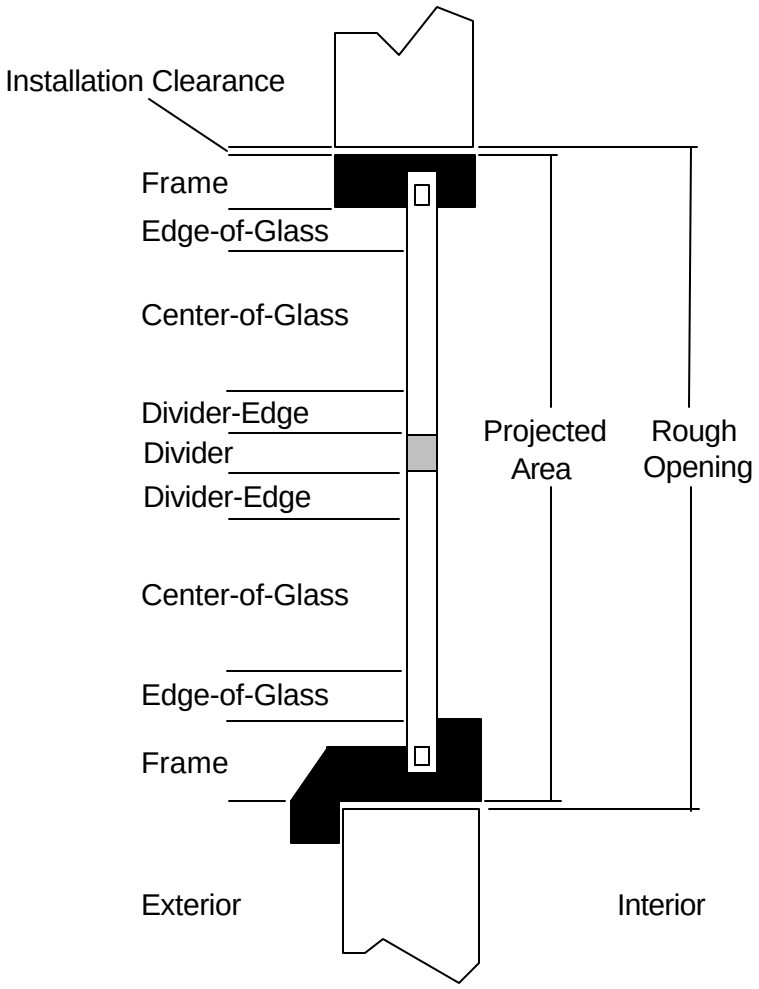


Figure 2: Center-of-glass, edge-of-glass, divider, divider-edge, and frame areas for a typical fenestration product. Edge-of-glass and divider edge areas are 63.5 mm (2.5 in.) wide. The projected fenestration product area is the rough opening area less installation clearances.