National Fenestration Rating Council

National Fenestration Rating Council Incorporated

NFRC 200-2001: Procedure for Determining Fenestration Product Solar Heat Gain Coefficients at Normal Incidence

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Foreword

This procedure has been developed by the National Fenestration Rating Council (NFRC) to meet the need for a uniform and accurate means for calculating Solar Heat Gain Coefficients (SHGC's) of window systems. The SHGC established by this procedure is determined at a fixed set of environmental conditions and for normal incidence radiation. Consequently, the SHGC determined using this procedure may not be appropriate for directly determining peak solar heat gains for other angles of direct beam incidence, nor for determining the solar heat gain produced by diffuse radiation incident on the fenestration system, nor for directly determining seasonal energy performance.

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1.0 Purpose

To specify a method for calculating Solar Heat Gain Coefficients (SHGC's) at normal (perpendicular) incidence for fenestration products containing glazings with specular optical properties.

Note: This standard specifies a method for calculating the solar heat gain from direct solar radiation through most fenestration products at normal incidence only. This procedure is limited to normal incidence calculations because solar optical data needed for such calculations is typically only available at normal incidence. While solar radiation rarely enters a fenestration product at normal incidence, solar heat gains at near normal angles of incidence (less than 30 degrees off normal) are typically very similar to those at normal incidence; for other angles, the solar heat gain coefficients at normal can be used, to first order, as an indicator of the relative magnitude of solar heat gains.

2.0 Scope

2.1 Fenestration Products Covered by NFRC 200

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

(d) Products of any size;

(e) Products of all glazing materials, tints, and types such as but not limited to clear glass, tinted glass, thin plastic films (internally suspended, internally applied, or externally applied), rigid plastics with or without any solar control, low-E or any other partially transparent coating;

(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, SF6, CO2, 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 designed for installation at any tilt.

2.2 Fenestration Products and Effects Not Covered by NFRC 200

(a) Products with shading systems, either between the glazing or attached to the inside or outside of the fenestration aperture;

(b) Garage doors with or without glazed areas;

(c) Solar heat gain performance changes of a window over the course of time, i.e., long term energy performance;

(d) Issues of water tightness, structure, and air infiltration.

(e) Products with non-specular transmittance and reflectance properties such as translucent fiberglass and glass blocks;

(f) Fenestration systems whose glazings depart from being parallel, such as with curved glass, complete bay windows, corrugated or patterned glass, glass blocks, etc. (Fenestration systems made up of combinations of complete windows or doors each of which individually meet the above requirements can be included by treating each of the components separately); and

(g) Fenestration systems with angular selectivity, that is with optical properties, though specular on the small scale, which produce emerging rays whose angle of transmittance is not equal to the angle of incidence, measured with respect to the normal to the plane of the fenestration aperture.

Note: Many products not covered by this procedure, such as those mentioned in (a), (e), (f), and (g) above, are not included in the scope because their solar heat gain cannot be calculated. It is the intent of this procedure to add those products to the scope once a solar heat gain test procedure and/or advanced calculational methods have been

developed. This may be accomplished through the issuance of a technical interpretation, addendum, and/or by a revision to this document.

3.0 Background

Consumers today have many new energy-saving fenestration product options to choose from. Advances in fenestration product technologies include the use of low-emissivity coatings, selective tints, insulating spacers, and new frame materials and designs. While the use of one or more of these components can improve fenestration product thermal performance it will also increase the complexity of the selection process. This procedure is offered as a uniform means to calculate total fenestration product SHGC's for the class of fenestration products that lend themselves to this calculation. It is hoped that in the future, the scope of this calculational procedure can be extended to include an even greater variety of fenestration products.

This document contains the state-of-the-art procedure at the time of its publication. This procedure will be updated as new research results become available and accepted.

4.0 Definitions

4.1 **Solar Heat Gain Coefficient** (SHGC): the ratio of the solar heat gain entering the space through the fenestration product to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation which is then reradiated, conducted, or convected into the space.

(a) **Frame Solar Heat Gain Coefficient** (SHGCf)*: the solar heat gain through all frame and sash members divided by the total incident solar radiation and the frame area (as defined in Section 4.11).

(b) **Divider Solar Heat Gain Coefficient** (SHGCd)*: the SHGC representative of the divider area, as defined in Section 4.7.

(c) **Edge-of-glass Solar Heat Gain Coefficient** (SHGCe): the SHGC representative of the edge-of-glass area, as defined in Section 4.8.

(d) **Divider edge Solar Heat Gain Coefficient** (SHGCde): the SHGC representative of the divider edge area, as defined in Section 4.9.

(e) **Center-of-glass Solar Heat Gain Coefficient** (SHGCc): the SHGC representative of the center-of-glass area, as defined in Section 4.10.

(f) **Total fenestration product Solar Heat Gain Coefficient** (SHGCt): the SHGC representative of the total fenestration product, as defined in Section 4.12.

4.2 Product line: a given series of fenestration products that differ only in size; center-of-glass characteristics; edge-of-glass characteristics such as glazing types and placement, glazing coatings and placement, gas-fills, gap widths, use of dividers, use of spacers; opening/non opening configurations, e.g., XO vs. XOX*; minor changes to accommodate smaller/larger glazing or IG widths; minor changes to operating hardware to accommodate higher/lower loads and stresses; and 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 interior/exterior appendages added to the main web of the frame that are not exposed after product installation, i.e., nailing fins.

' The SHGC of a frame or divider element is more specifically defined as: $\frac{k*a*U}{h}$

where: k is a factor which accounts for the differences between the surface area and projected area of the frame or divider, equal to 1.0 is this standard
a is the frame or divider absorptance
U is the frame or divider U-factor (sec. 5.4.3)
h is the exterior film coefficient (2.94 Btu/hr -ft2 -cF)

- An "X" denotes an operating panel/sash. An "O" denotes a fixed nor non-operating panel/sash. Combinations of X's and O's denote the appropriate combinations of operating and non-operating panels.

The NFRC Product Line is defined by an operator type and a set of basic frame profiles. The manufacturer must define a **Base Profile** for each frame/sash element. Frame/sash profiles which differ from these **Base Profiles** will be considered to be 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**.

These elements may be incorporated within the Product Line for different installations. Material changes where the conductivity changes by more than a factor of 10 are not part of the same Product Line.

Multipurpose products incorporating identical **Base Profiles** with differences characterized only as lengthening, shortening, expanding or deleting discrete elements thereof can be classified as one NFRC Product line.

4.3 Individual Product: any one specific fenestration product, of any size, within a Product Line specific to center-of-glass and edge-of-glass characteristics, and opening/non-opening configurations, e.g., XO vs. XOX. 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 0.016 in.(0.4 mm), or the solar absorptance by more than 0.30. For the purposes of this procedure only, variations in gap width and/or gas fill do not constitute different individual products.

Hardware, reinforcing, frame component changes, or sill changes are not considered to create a different individual product. Movement of the hardware or components from one side to the other can also be ignored.

For each Product Line, the manufacturer may define a standard glazing divider pattern (which is a standard product offering) and which uses glazing dividers 12" on-center or less. If no standard product offerings exist with glazing divider patterns 12" on-center or less, a glazing divider pattern with an on-center dimension closest to 12" shall be used as the standard glazing divider pattern. All products sold with glazing dividers can than be rated with the SHGC for the standard glazing divider pattern. Manufacturers may rate all individual glazing divider patterns separately.

4.4 *This section intentionally left bank at this time.*

4.5 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.

4.6 Projected fenestration product area (A_{pf}): the area of the rough opening in the wall, for the fenestration product, less installation clearances. See Figures 1 and 2 on pages 11 and 12.

4.7 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). See Figures 1 and 2 on pages 11 and 12.

4.8 Edge-of-glass area (A_e): all glazed vision areas within 2.5 in. (63.5 mm) of any part of the frame and sash. The edge-of-glass area shall exclude any divider area contained within the above defined area. See Figures 1 and 2 on pages 11 and 12.

4.9 Divider edge area (A_{de}): all glazed vision areas within 2.5 in. (63.5 mm) of any part of a divider area. The divider edge area shall exclude any edge-of-glass area contained within the above defined area. See Figures 1 and 2 on pages 11 and 12.

4.10 Center-of-glass area (A_c): all glazed areas except those within 2.5 in. (63.5 mm) of any part of a primary sash and/or frame and/or divider. See Figures 1 and 2 on pages 11 and 12.

4.11 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 areas defined in 4.7 through 4.11 will equal the total projected fenestration product area (A_{pf}) defined in 4.6. Where a fenestration product has glazed surfaces in more than one direction (e.g., greenhouse/garden, bay/bow windows) the sum of the areas defined in 4.7 through 4.11 will exceed the projected fenestration product area.]*

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

5.0 Standard Conditions & Requirements

This section presents standard calculations for determining total or component fenestration product Solar Heat Gain Coefficient. Read and follow Section 6, Fenestration Product Solar Heat Gain Coefficient, before performing any of the calculations identified in this section.

5.1 Evaluation Conditions:

The total fenestration product Solar Heat Gain Coefficient (SHGCt) shall be determined using the approved Computational Procedure (See Section 5.4) and given the following conditions:

a) A 7.5 mph (3.35 m/s) perpendicular wind on the exterior surface;

b) The exterior air and sky temperatures shall be 89^{o}F (31.7^{o}C) and the interior temperature shall be 75^{o}F (23.9^{o}C) and with 248 Btu/hr•ft2 (783 W/m2) solar radiation;

c) Fenestration product sizes evaluated shall be in accordance with Section 5.2; and

d) All products shall be evaluated without screens, removable grilles, or any other applied devices, and in the vertical position.

5.2 Model Product Line Sizes and Configurations for Reporting of SHGCt

For each Individual Product, total fenestration product SHGC shall be reported for the specified configuration in two model sizes, (Residential and Non-Residential) as shown in NFRC100-Table 1. If, within a Product Line, there are no Individual Products smaller than the Non Residential size, SHGC for the Residential Size shall not be required. Similarly, if, within a Product Line, here are no Individual Products larger than the Residential size, SHGC for the Non Residential size shall not be required. Note that the model sizes vary with operator and unit type. Note that glass thickness varies with the two model sizes. For each individual product, total fenestration product Solar Heat Gain Coefficient shall be reported for the specified configuration in the two model sizes (Residential and Non-Residential) with corresponding model glass thicknesses. The model glass thicknesses are 1/8" double strength for the Residential size and nominal 1/4" glass for the Non-Residential size. Individual products with glass thickness other than 1/8" and 1/4" are represented by one of the two model sizes.

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 by themselves. Each operator type may be evaluated separately.

5.3 *This section intentionally left blank at this time.*

5.4 Computational Procedures

All computational procedures shall comply with the conditions of Section 5.1.

5.4.1 Approved Glazing System Computational Program

WINDOW 4.1 and accompanying documentation or more recent NFRC-approved version [1,2] shall be used. All solar optical property data used with the approved glazing system computational program shall be determined with the most recent NFRC-approved NFRC 300-94: Procedures for Determining Solar Optical Properties of Simple Fenestration Products.

5.4.2 Approved 2-D Heat Transfer Computational Program

FRAME 3.1 and accompanying documentation or more recent NFRC-approved version [3].

5.4.3 Approved Total Fenestration Product SHGC Calculational Procedure

The total fenestration product SHGC shall be calculated as outlined below:

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

(1) Center-of-glass SHGC using the approved glazing system computational program;

(2) Edge-of-glass SHGC, equal to the center-of-glass SHGC value;

(3) Divider SHGC using the approved glazing system computational program (with divider U-values determined by the 2-D heat transfer computational program at the environmental conditions specified in NFRC-100□);

(4) Divider edge-of-glass SHGC, equal to the center-of-glass SHGC value;

(5) Frame SHGC using the approved glazing system computational program (with frame U-values determined by the 2-D heat transfer computational program at the environmental conditions specified in NFRC-100□); and

(6) The component areas in square feet, to the nearest 0.01 ft2 (9.3 cm2), 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 1:

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

(2) Total these five quantities; and

(3) Divide this total by the projected fenestration product area to produce computed total fenestration product SHGC for all the fenestration products in the matrix of required SHGC (see Section 6.0).

$$SHGC_t=[(SHGCf \bullet A_f) + (SHGCd \bullet A_d) + (SHGC_e \bullet A_e) + (SHGC_{de} \bullet A_{de}) + (SHGC_c \bullet A_c)]/A_{pf} \quad \text{[Equation 1]}$$

Where:
$SHGC_t$ =Total Product SHGC
$SHGC_f$ =Frame SHGC-value
A_f =Frame Area
$SHGC_d$ =Divider SHGC
A_d =Divider Area
$SHGC_e$ =Edge-of-Glass SHGC
A_e =Edge-of-Glass Area

$SHGCd_e$ =Divider Edge SHGC
A_{de} =Divider Edge Area
$SHGC_c$ =Center-of-Glass SHGC
A_c =Center-of-Glass Area
A_{pf} =Projected Fenestration Product Area

Note: This calculational sequence is performed by the approved glazing system computational program for virtually all windows.

6.0 Fenestration Product Solar Heat Gain Coefficient

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

6.1 Total Fenestration Product SHGC 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 SHGC for a given Product Line should be outlined as follows:

	Residential Size	**Non-Residential 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 number of glazing layers, glazing types, glazing coatings, spacer types, and use of dividers. See Section 4.2 for the definition of a Product Line and Section 4.3 for the definition of Individual Products.

Use the approved total fenestration product SHGC calculational procedure (as presented in Section 5.4.3) to calculate total fenestration product SHGC for all entries in the above matrix. These values are to be reported.

Products with integral appendages that extend beyond the rough opening and are not exposed after installation can be assumed to have the same SHGC as identical products without such appendages. Separate calculations on these products is not required.

Once all Individual Products have been identified within a Product Line, the simulation laboratory can determine, and must report the center-of-glass Solar Heat Gain Coefficient (SHGCc) for all individual products. Those products can then be grouped with each group covering a range of no more than 0.05 in SHGCc. Each group can then be represented by an individual product with a SHGCc closest to the mid-point of the group (the Group Representative). If this approach is used, the total window SHGC for the Group Representative shall be used to represent the total window SHGC for all Individual Products within that group. For the purposes of determining SHGCc, groups shall only consist of Individual Product with glazing thickness variations, glazing tint variations, and low-emissivity coating variations.

Manufacturers may simplify the rating for a grouping of products (all or some of the products within a product line) by (1) assuming all frame and divider absorptances are 0.5 and/or (2) assuming the frame U-factors for all products within the grouping are the frame U-factors for the individual product with the lowest center-of-glass U-factor. (If there are several frame profiles within this grouping, all with the lowest center-of-glass U-factor glazing system, use the frame option with the highest frame and edge heat loss), and/or (3) by assuming that all dividers with a projected divider dimension of less than 1.0" are represented by a commercially available divider with a projected divider dimension equal to or closest to 0.75" and that all dividers with a projected divider dimension equal to or greater than 1.0" are represented by a commercially available divider with a projected divider dimension equal to or closest to 1.5".

6.1.1 *This section intentionally left blank at this time.*

6.2 Total Fenestration Product SHGC For Non-Model Sizes

The approved total fenestration product SHGC calculational procedure may be used to evaluate the total fenestration product SHGC for size configurations other than the Residential and Non-Residential Sizes for purposes other than certification.

7.0 References

[1] Lawrence Berkeley Laboratory, Windows and Daylighting Group, 1994. WINDOW 4.1: A PC Program for Analyzing Window Thermal Performance in Accordance with Standard NFRC Procedures, **Lawrence Berkeley Laboratory Report 35298**. Berkeley, CA.

[2] Finlayson, E.U; Arasteh, D.K; Huizensa, C., Rubin, M.D., and Reilly, M.S. 1993. WINDOW 4.0: Documentation of Calculation Procedures. **Lawrence Berkeley Laboratory Report 33943**. Berkeley, CA

[3] Enermodal Engineering Limited, 1993. FRAME: A computer program to evaluate the thermal performance of window frame systems - version 3.1 users manual. Waterloo, Ontario Canada.

Figure 1.
Window Area Schematic: Vertical Elevation

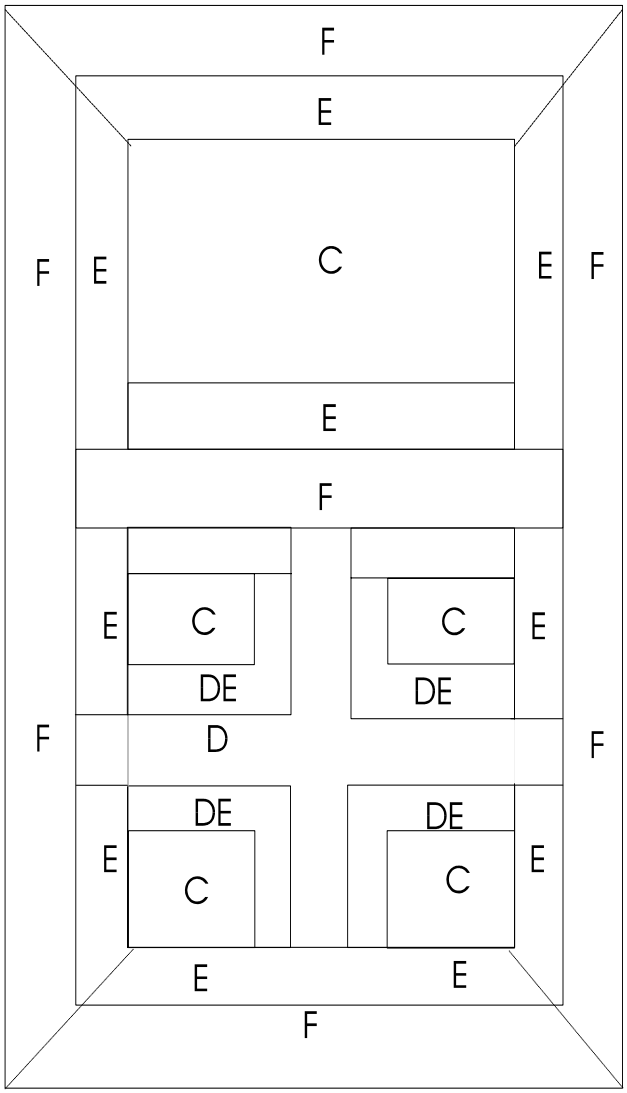

Figure 1: Center-of-glass (C), edge-of-glass (E), divider (D), divider-edge (DE), and frame (F) areas for a typical fenestration product. Edge-of-glass and divider edge areas are 2.5 in. wide. The sum of these component areas equals the total projected fenestration product area.

Figure 2.
Window Area Schematic Horizontal Section

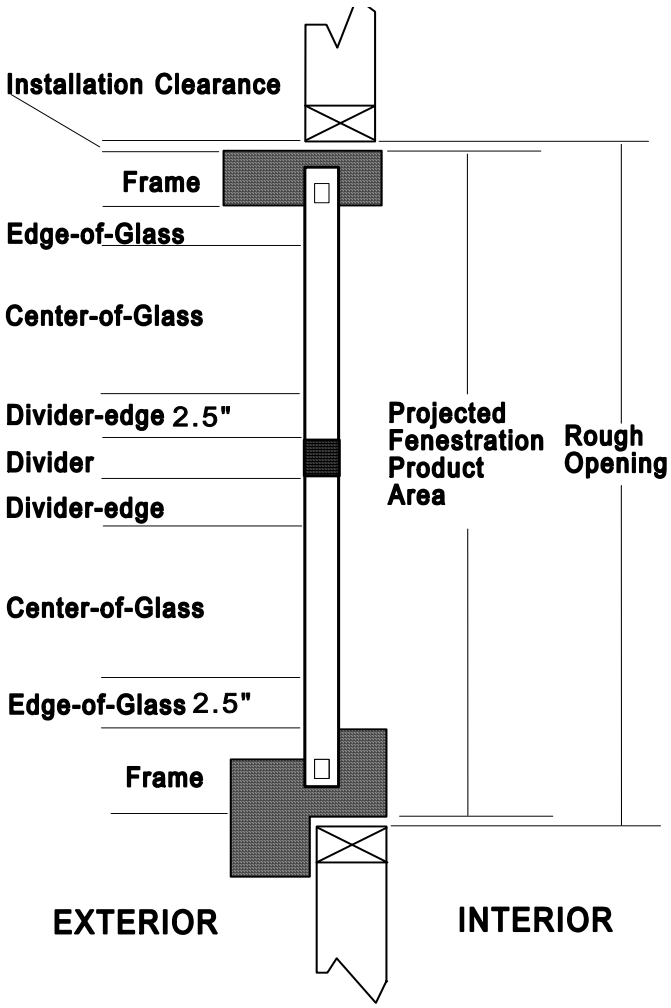

Figure 2: Center-of-glass, edge-of-glass, divider, divider edge, and frame areas for a typical fenestration product. Edge-of-glass and divider edge areas are 64 mm

(2.5 in.) wide. The Projected Fenestration Product Area is the rough opening area less installation clearances