REFERENCE PROCEDURE
FOR SIMULATING SPANDREL U-FACTORS

Fenestration Association of BC (FENBC)
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Acknowledgements

The Fenestration Association of BC (FENBC) gratefully acknowledges RDH Building Science Inc. for undertaking the research and documentation of this Reference Procedure, and the funding support from BC Housing through the Building Excellence Research and Education Grant program.

RDH Building Science Inc. gratefully acknowledges CLEB Building Science for their cooperation in providing spandrel test data for this project

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Table of Contents

Preface

This *Reference Procedure for Simulating Spandrel U-Factors* was developed for voluntary use by fenestration manufacturers and building designers.

Design standards such as ASHRAE 90.1 and NECB require building designers to determine the effective U-factor of opaque wall assemblies clad with spandrel products. Building designers commonly rely on fenestration manufacturers to provide U-factor data for the products they supply.

FENBC member companies found there was insufficient guidance in NFRC 100 for simulating spandrels, and particularly the narrow and interrupted spandrels that are common in large buildings today. The lack of a recognized reference methodology was identified as an impediment to evaluating competing performance claims.

This Reference Procedure was created to allow spandrel U-factor performance claims to be objectively evaluated in a similar way as window U-factor performance claims that are based on NFRC 100 procedures.

While various methods are currently employed to determine spandrel U-factors, including physical testing, 2D simulation and 3D thermal modelling, it was felt that a simulation method based on NFRC 100 and using LBL THERM software would allow industry participants to produce consistent and comparable results more quickly and more economically than using other methods.

The objective of this Reference Procedure differs from the objective of NFRC fenestration product simulations. The Reference Procedure limits itself to the concerns of building designers who are need to determine effective U-factors for opaque walls. The NFRC approach includes the determination of two additional properties that are significant for fenestration assemblies: Solar Heat Gain Coefficient and Condensation Resistance.

The Reference Procedure differs from NFRC 100 in three respects:

1) It increases the panel edge distance from the 63.5 mm (2.5 in.) used for transparent glass to 152.4 mm (6 in.), a dimension found to be more accurate for spandrels

2) It offers three spandrel product configurations, one of which is identical to the curtain wall configuration in NFRC 100. The additional configurations address window wall spandrels interrupted by floor slabs

3) It utilizes an Excel worksheet to perform area-weighting calculations in place of the LBL WINDOW software

Document Organization and Format

Sections 1 through 4 of this Reference Procedure follow the content organization and heading numbering of ANSI/NFRC 100-2014 [E0A1] to help users cross-reference the provisions of this document with that standard. In this Reference Procedure, statements and requirements followed by [NFRC 100] are identical to, or intended to have the same meaning and significance, as in that standard.

This Reference Procedure is intended to be used with the accompanying *User Guide to the Reference Procedure for Simulating Spandrel U-Factors*.

Reference Publications

Name and Version of Publication	Name Used in this Document
ANSI/NFRC 100-2014 [E0A1], Procedure for Determining Fenestration Product U-factors *Published by the National Fenestration Rating Council Inc.*	NFRC 100
THERM 7/WINDOW 7 NFRC Simulation Manual, (Publication Version: July 2017) *Published by the National Fenestration Rating Council Inc.*	NFRC Simulation Manual

1 Purpose

To propose a consistent procedure for determining spandrel U-factors used in opaque wall assemblies. The use of a consistent methodology in construction specifications makes it possible to compare the relative performance claims of proposed assemblies under identical standard conditions that include standard sizes. The proposed methodology also allows values to be scaled to more closely represent project values once specific assemblies have been selected.

The intent of this Reference Procedure is to supplement the existing simulation framework presented in ANSI/NFRC 100-2014 [E0A1], *Procedure for Determining Fenestration Product U-factors* (NFRC 100), by extending familiar methodologies to account for specific challenges when simulating spandrels and in this way, build on the existing tools, skills, and knowledge of fenestration system designers. This procedure is to be used in conjunction with NFRC 100.

Although validation was performed at several stages in the preparation of this methodology, testing and validation of the simulated results is outside of the scope of this procedure.

2 Scope

2.1 Products and Effects Covered

The scope of this Reference Procedure is in general accordance with NFRC 100, but is limited to the determination of spandrel U-factors only. The following products and effects are within the scope of this Reference Procedure:

A) Spandrels of the types listed in Table 4.1

B) Insulation products of all types, including (but not limited to) expanded polystyrene, extruded polystyrene, glass fiber batt, mineral wool, and polyurethane spray foam

C) 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 [NFRC 100][1]

D) Products of all opaque glazing materials, tints, and types, including (but not limited to) manufacturer decorative opaque insulated glazing options [NFRC 100]

E) Products with any or no gap width between glazing or insulating layers [NFRC 100]

F) Products with any spacer or spacer system between glazings, including (but not limited to) metallic, non-metallic, or composite spacers [NFRC 100]

G) Products with any gas-fill between glazing layers, including (but not limited to) air, argon, krypton, or mixes of these gases [NFRC 100]

2.2 Products and Effects Not Covered

The following products and effects are outside of the scope of this Reference Procedure:

A) Determination of solar-optical properties of spandrels

B) Simulation of non-spandrel fenestration products

C) Thermal performance changes of a spandrel product over the course of time, i.e., long-term energy performance [NFRC 100]

D) Issues related to water tightness, structural capacity, and air leakage [NFRC 100]

E) Permanently attached louvers [NFRC 100]

F) Other conduits or ducts penetrating spandrel assemblies

[1] Reference to NFRC 100 in square brackets indicates the preceding attribute is present in NFRC 100.

3 Definitions[2]

Curtain Wall: any building wall, of any material, that carries no superimposed vertical load (a non-bearing wall). [NFRC 100]

Spandrel: the opaque areas of a building envelope that typically occur at locations of the floor slabs, columns, and immediately below roof areas. [NFRC 100]

Window Wall: a type of wall or window system installed between floors or between floor and roof. Also referred to as a "strip window" or "horizontal ribbon window system." [NFRC 100]

[2] For the purposes of this guide, these definitions are understood to be limited to fenestration products and in particular to window and curtain wall spandrels

4 General

4.1 Compliance

Spandrel product ratings shall be determined in general accordance with the procedures outlined in NFRC 100 Sections 4.1 to 4.5. Sections 4.6 *Test Procedures* and 4.7 *Validation* are excluded from this Reference Procedure.

4.2 Product Lines and Individual Products

The definition of product lines and individual products shall conform to Sections 4.2.1 and 4.2.2 of NFRC 100. Grouping of products shall conform to Section 4.2.4 and shall be limited to individual products within the same product line. Groups shall be represented by the group leader (option with the highest U-factor).

4.2.4.6 Insulation Grouping

For the purpose of determining U-factors, insulation groups shall consist only of variations in insulation material. After all insulation options have been identified within a product line, the U-factor shall be simulated for each option. Groups may be represented by a group leader, i.e., reported with the same U-factor as the option with the highest U-factor.

Variations in back pan depth, materials, or geometry shall be simulated as individual products.

4.2.5 General Simulation Rules

A) Non-rectangular spandrel products shall be rated as rectangular spandrel products at the sizes shown in Table 4.2 of this document [NFRC 100]

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; [NFRC 100]

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:

   i. Examples of such elements include (but are not limited to) subsills and frame expanders [NFRC 100], and deflection-compensating accessory profiles

D) For the purpose of determining U-factors, only glazing tint (including obscure glass, or fritted glass) shall be permitted to be assumed to have the same U-factor and do not need to be simulated separately unless this change is associated with a change in coating properties.

4.3 Standard Conditions

Standard simulation conditions, including boundary definitions and material thermophysical properties shall conform to Section 4.3 of NFRC 100. Testing (NFRC 100 Section 4.3.2) is outside of the scope of this Reference Procedure.

The edge-of-spandrel distance shall be 152.4 mm (6 in.) and shall replace all references to a 63.5 mm (2.5 in.) edge distance in the portions of NFRC 100 referred to in this procedure, including edge-of-glazing distance and edge-of-mullion distance. (See User Guide Section 2.3)

All cross sections shall include a minimum of 300 mm of spandrel infill to accommodate the increased spandrel edge dimension distance of 152.4 mm (6 in.).

In the case of Configurations 2 and 3, where a portion of the floor slab is simulated, the interior surface film coefficients applied to the top and bottom of the floor slab shall correspond to the values found in *ASHRAE Handbook—Fundamentals*, Table 10 Chapter 26, with attention paid to the position of surface and direction of heat flow.

Table 4.1 Interior Surface Film Coefficients for concrete floor slabs

Position of Surface	**Direction of Heat Flow**	**Combined Convective/Radiative Surface Film Coefficient**	
		R_i ($h \cdot ft^2 \cdot {}^\circ F/Btu$)	U_i ($Btu/h \cdot ft^2 \cdot {}^\circ F$)
Indoor, Horizontal	Upward	0.61	1.63
Indoor, Horizontal	Downward	0.92	1.08

Simulations shall be performed according to the NFRC Simulation Manual. The most recent NFRC-approved version of LBL THERM software shall be used.

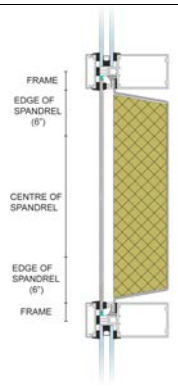
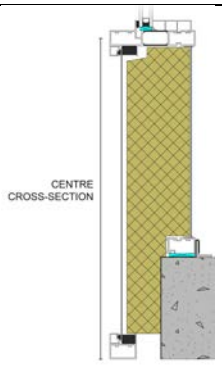
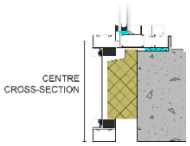
4.4 Simulation Sizes and Configurations

Three spandrel configurations are provided in this procedure. Configuration 1 is identical to the configuration described in Table 4-3 of NFRC 100, representing a spandrel situated beyond the face of a floor assembly and bypassing it. This spandrel configuration is named "uninterrupted". Two additional configurations are presented to address spandrels that partially or fully interrupted by concrete floor slabs, conditions that are characteristic of window wall spandrels. The three configurations are presented in Table 4.2.

To allow for meaningful comparison between spandrel products, spandrel U-factors for each configuration shall be determined and reported at the simulation sizes shown in in Table 4.2.

Compliance with building energy modelling standards and practices may require U-factors to be determined at project sizes. These may be determined according to NFRC 100 Appendix A, Section A.1 *Determination of Project Specific U-Factors.* The calculation methodology in this Reference Procedure and the accompanying area-weighting Calculation Tool support the reporting of spandrel U-factors at both reference simulation sizes and at project sizes.

Table 4.2 Spandrel Configurations and Reference Simulation Sizes

Configuration 1	Configuration 2	Configuration 3
Uninterrupted Spandrel	Partially Interrupted Spandrel	Fully Interrupted Spandrel
		
2000 mm x 1200 mm (79 in x 47 in.)	2000 mm x 1200 mm (79 in x 47 in.)	2000 mm x 203 mm (79 in x 8 in.)

4.5 Simulation Procedure

Simulations shall be performed in general accordance with NFRC 100, except that validation by physical testing is not required.

4.6 Test Procedure

Excluded from this Reference Procedure.

4.7 Validation

Excluded from this Reference Procedure.

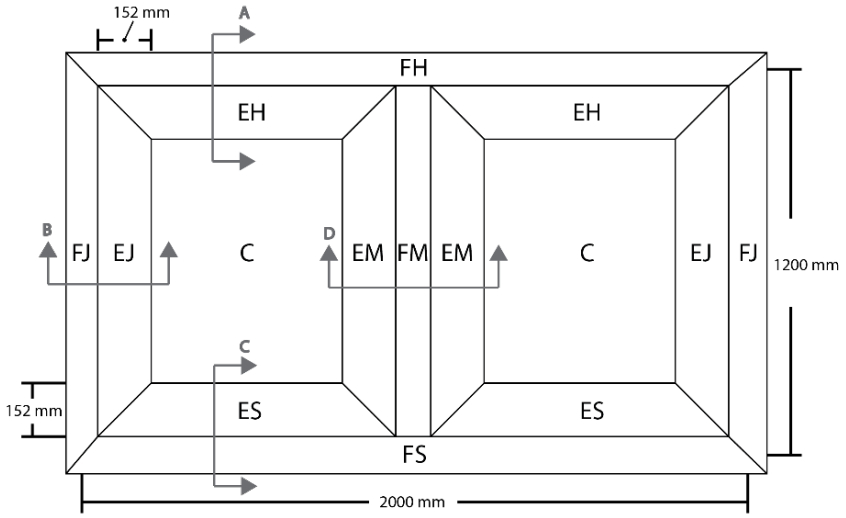
Refer to the User Guide for information about the validation measures undertaken to prepare this procedure.

4.8 Figures

Figures 4.1 to 4.3 illustrate the center-of-spandrel, divider, edge-of-divider, and frame areas for spandrel product Configurations 1 to 3.

Figure 4.1: Areas for a Configuration 1 window or curtain wall spandrel

The sum of the component areas equals the total projected fenestration product area.

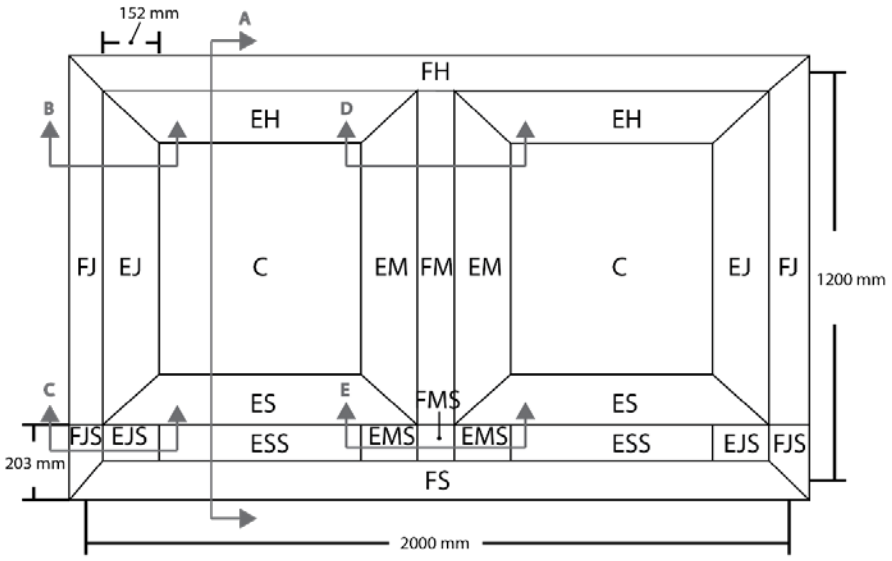


LEGEND

C	Center of Spandrel	EH	Edge-of-Head
FH	Frame (Head)	EJ	Edge-of-Jamb
FJ	Frame (Jamb)	EM	Edge-of-Mullion
FM	Frame (Mullion)	ES	Edge-of-Sill
FS	Frame (Sill)		

Figure 4.2: Areas for a Configuration 2 spandrel

The sum of the component areas equals the total projected fenestration product area.

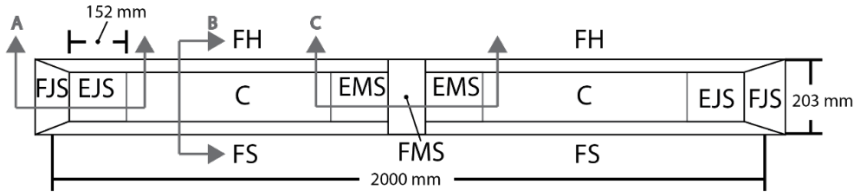


LEGEND

C	Center of Spandrel	EH	Edge-of-Head
FH	Frame (Head)	ES	Edge-of-Sill
FJ	Frame (Jamb)	ESS	Edge-of-Sill at Slab
FJS	Frame (Jamb) at Slab	EJ	Edge-of-Jamb
FM	Frame (Mullion)	EJS	Edge-of-Jamb at Slab
FMS	Frame (Mullion) at Slab	EM	Edge-of-Mullion
FS	Frame (Sill)	EMS	Edge-of-Mullion at Slab

Figure 4.3: Areas for a Configuration 3 spandrel

The sum of these component areas equals the total projected fenestration product area.



LEGEND

C	Center of Spandrel	FJS	Jamb at Slab
FH	Frame (Head)	FMS	Mullion at Slab
FS	Frame (Sill)	EJS	Edge of Spandrel at Slab (Jamb)
		EMS	Edge-of-Mullion at Slab

5 Spandrel Simulation Reference Procedure

5.1 Scope

This Section describes the spandrel simulation procedure. Effort has been made to highlight where this approach differs from the NFRC 100 simulation procedure for fenestration products.

5.2 General Simulation Guidelines

5.2.1 Configuration

All spandrel configurations shall be simulated as two lites separated by a vertical mullion. Window and curtain wall spandrel product U-factors shall be area weighted based on centerline dimensions. Intermediate verticals shall be simulated as jambs and intermediate horizontals as head/sill frame members.

A summary of simulation requirements for the three configurations is provided in Table 5.1.

Table 5.1 Spandrel Simulation Configurations

Configuration	Head	Sill	Jamb	Vertical Mullion	Edge Distance	Floor
Configuration 1: Uninterrupted Spandrel	◒	◓	◑ ◐	●	152.4 mm (6 in.)	N/A
Configuration 2: Partially Interrupted Spandrel	◒	●	◑ ◐	●	152.4 mm (6 in.)	203.2 mm (8 in.) Concrete
Configuration 3: Entirely Interrupted Spandrel	◒	●	◑ ◐	●	152.4 mm (6 in.)	203.2 mm (8 in.) Concrete

Where the reference simulation size is dimensioned to a center line, the entire frame is included in the simulation, but U-factor tags are applied to the center line boundary following the procedure described in the NFRC Simulation Manual.

5.2.2 Center of Spandrel Simulation

The center of spandrel U-factor shall be determined in one of two ways:

→ Simulated directly in THERM (2D), with opaque components drawn and IGU's (if present) imported from WINDOW

→ Simulated in WINDOW with gaps separating solid materials in contact represented by a very thin, highly conductive gas layer, less than 0.001 mm and 9999 W/K·m (see User Guide)

5.2.3 Accessories

Components such as sill flashing and deflection headers are to be excluded from the frame dimensions. Although these accessories typically affect the U-factor of the fenestration product, they are to be excluded from the simulation in the same way NFRC 100 excludes these accessories for fenestration products.

5.2.4 Adjacent System

In the case of Configurations 1 and 2, the spandrel system shall be assumed to be adjacent to another spandrel of the same type being evaluated. For Configuration 3, where this assumption is impractical, an IGU shall be assumed adjacent to the head and sill. The adjacent IG units shall be simulated as a wood panel. For consistency, assume Particleboard, Plywood (500 kg/m^3) with a conductivity of 0.130 W/m^2·K. The thickness of the wood panel shall be the same thickness as the IG unit it is replacing and the simulated height shall be consistent with Section 4.3. The system adjacent to the jambs shall be another spandrel of the same type.

NOTE: It is understood that the choice of adjacent system can have a significant impact on the overall performance of the assembly. Refer to the User Guide for more information.

5.2.5 Non-Continuous Thermal Bridging Elements

Non-continuous thermal bridging elements such as clips, bolts, etc., shall be included as outlined in Section 8.8 of the NFRC Simulation Manual. In brief, this approach requires the user to determine an effective conductivity of the material being thermally bridged using the parallel paths approach.

$$k_{eff} = k_n * F_n + k_b * F_b \quad (1)$$

Where,

k_{eff} = Effective

k_n = Conductivity of the non-thermally bridged cross section

F_n = Fraction of non-thermal bridging

F_b = Fraction of thermal bridging (e.g., bolt head, etc.)

Common non-continuous elements include shear blocks, bolts, clips, and spacers.

5.2.6 Interior Wall Assemblies

Interior wall assemblies, which are inboard of the spandrel and impact the system performance are not specifically addressed in this procedure, but may be included following the general procedures in the *ASHRAE Handbook—Fundamentals*.

NOTE: Interior wall assemblies inboard of the spandrel can have a significant impact on the thermal performance as well as the condensation resistance of the overall wall assembly and shall be considered where simulation is intended to investigate condensation risk.

5.3 Cross Sections to be Simulated

The total number of cross sections to be simulated will depend on the configuration. Table 5.2 outlines the minimum and maximum number and types of cross sections that need to be simulated for each of the spandrel configurations.

Table 5.2 Spandrel Cross Sections

Configuration	Minimum	Maximum	Cross Sections
Configuration 1: Uninterrupted Spandrel	4 (if left and right jambs and head, and sill are identical)	7	• Head • Sill • Jamb • Vertical Mullion (as a jamb)
Configuration 2: Partially Interrupted Spandrel	5 (if left and right, center of spandrel and jambs are identical)	8	• Center of Spandrel (head/sill/center) • Jamb • Jamb at Slab • Vertical Mullion (as a jamb) • Vertical Mullion at Slab (as a jamb)
Configuration 3: Entirely Interrupted Spandrel	3 (if left and right jambs and head and sill are identical)	5	• Center of Spandrel (head/sill/center) • Jamb • Vertical Mullion (as a jamb)

5.4 Calculation of Total Spandrel U-Factor

Similar to Equation 5-1 in Section 5.1 of NFRC 100, Equation 1 shall be used to determine the total spandrel U-factor.

$$U_t = \frac{\sum U_f A_f + \sum U_e A_e + \sum U_m A_m + \sum U_{me} A_{me} + \sum U_c A_c}{A_{pf}} \quad (1)$$

Where,

U_t = Total spandrel-factor

A_{pf} = Projected frame area of the spandrel

A_f = Frame area (head, sill, jamb)

U_f = Frame U-factor (head, sill, jamb)

A_e = Edge area (head, sill, jamb)

U_e = Edge U-factor (head, sill, jamb)

A_m = Center Mullion area

U_m = Center Mullion U-factor

A_{me} = Edge-of-mullion area

U_{me} = Edge-of-mullion U-factor

A_c = Center of spandrel area

U_c = Center spandrel U-factor

The divider area is replaced by the center mullion frame and edge area. Where dividers are used in the spandrel, they shall be treated as a separate area with corresponding edge distance per the procedure in NFRC 100.

For Configurations 2 and 3, Equation 1 has been modified to include the separate slab areas and to accommodate the complete vertical cross section of the center of spandrel.

$$U_t = \frac{\sum U_f A_f + \sum U_e A_e + \sum U_m A_m + \sum U_{me} A_{me} + \sum U_{cs} A_{cs} + \sum U_s A_s}{A_{pf}} \quad (2)$$

Where,

A_s = Edge-of-slab area (jamb, mullion)

U_s = Edge U-factor (head, sill, jamb)

A_{cs} = Center-of-spandrel vertical section area (head, sill, center-of-spandrel)

U_{cs} = Center-of-spandrel vertical section U-factor (head, sill, center-of-spandrel)

5.4.1 Area Weighting

Corners are bisected for the purpose of area weighting. For example, to apportion area for the frame at the head, draw a diagonal from the edge of the frame to the edge of panel. See figures in Section 4.8 for how the areas are separated.

5.4.2 Excel-based Calculation Tool

To aid in the determination of overall product U-factors, a Microsoft Excel-based calculation tool was developed for use with this procedure. The calculator is designed to accept project-specific or reference-standard dimensions and to perform area-weighted calculations to obtain the overall product U-factor.

Disclaimer: *Every reasonable effort has been made to ensure the accuracy of this tool, however, neither RDH nor FENBC warrant its accuracy and use of the tool is at the user's discretion.*

5.5 Configuration 1 – Uninterrupted Spandrel

The Spandrel product type in NFRC 100 is an uninterrupted spandrel and forms the basis for simulating Configuration 1. Areas are separated as shown in Figure 5.1.

5.5.1 Center of Spandrel Simulation

The center of spandrel U-factor shall be determined per Section 5.2.2.

5.5.2 Edge of Spandrel

The edge of spandrel area consists of 4 distinct areas:

- → Edge-of-Head
- → Edge-of-Sill
- → Edge-of-Jamb
- → Edge-of-Mullion

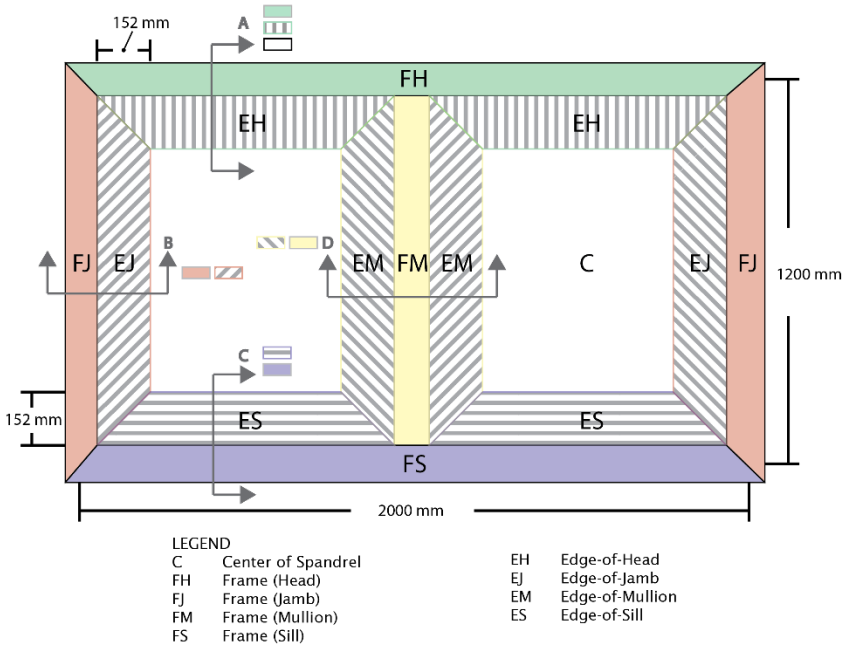
Edge U-factor values shall be obtained from the corresponding cross section using U-factor tags.

5.5.3 Cross Sections

A minimum of 4 cross sections are required: head, sill, jamb and center mullion. Refer to Figure 5.1 for the location of cross sections.

Figure 5.1: Shaded areas for U-factor calculations for a typical Arrangment 1 curtain wall spandrel product

Minimum number of cross sections shown assumes symmetry of the left and the right side of the spandrel.



5.6 Configuration 2 – Partially Interrupted Spandrel

Configuration 2 applies to spandrels which are partially interrupted by a floor (typically a concrete slab). A single vertical cross section shall be used to simulate the full height of the spandrel including the frame at slab, sill and head as well as the spandrel at slab, edge and center. Areas are as shown in Figure 5.2.

5.6.1 Center of Spandrel

The center of spandrel U-factor shall be determined per Section 5.2.2.

5.6.2 Edge of Spandrel

The edge width shall be 152.4 mm (6 in.) and shall extend from the edge of the jambs, head and the concrete slab as opposed to the sill frame.

5.6.3 Interrupting Floor Assembly

An unfinished concrete slab 203.2 mm (8 in.) shall be used to represent the floor interrupting the spandrel. For consistency, the concrete material properties shall be based on the thermophysical properties of concrete – reinforced (2% steel). The concrete floor shall extend towards the interior space for a distance of at least 1000 mm from the innermost protruding

element of the spandrel assembly. Where the floor slab ends, an adiabatic boundary condition is used.

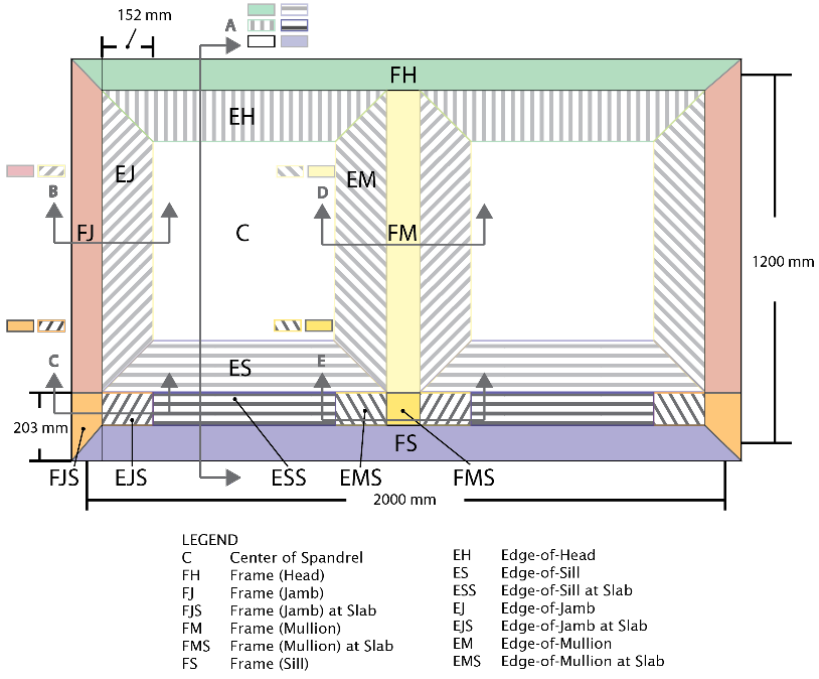
NOTE: A common floor type and size is recommended for ease and consistency of rating. However, design teams may elect to simulate the project's specific floor conditions. In this case, the floor assembly and assumptions shall be clearly indicated in the accompanying simulation report.

5.6.4 Cross Sections

A minimum of 5 cross sections are required: jamb at slab, jamb, center mullion at slab, center mullion, and head to sill. Refer to Figure 5.2 for the location of cross sections.

Figure 5.2: Shaded areas for U-factor calculations for an Arrangment 2 spandrel product

Minimum number of cross sections shown assumes symmetry of the left and the right side of the spandrel.



5.7 Configuration 3 – Fully Interrupted Spandrel

Configuration 3 applies to spandrels which are completely interrupted by a floor (e.g., concrete slab). The methodology for Configuration 3 is to follow the procedure outlined for Configuration 2 except as indicated below.

5.7.1 Center of Spandrel

A single cross section is used to determine the sill, head and center of spandrel U-factors. Areas are separated as shown in Figure 5.3.

5.7.2 Edge of Spandrel

The edge width shall be 152.4 mm (6 in.) and shall extend from the edge of the jambs.

Note: In this configuration, due to the limited height, there is no edge-of-head or edge-of-sill area.

5.7.3 Interrupting Floor

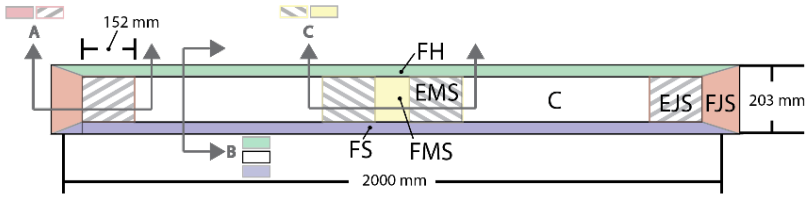
See Section 5.6.3.

5.7.4 Cross Sections

A minimum of 3 cross sections are required: jamb at slab, center mullion at slab, and head to sill. There are no edge of sill or head areas in this simulation. Refer to Figure 5.3 for the location of cross sections.

Figure 5.3: Shaded areas for U-factor calculations for an Arrangment 3 spandrel product

Minimum number of cross sections shown assumes symmetry of the left and the right side of the spandrel.



LEGEND

C	Center of Spandrel	FJS	Jamb at Slab
FH	Frame (Head)	FMS	Mullion at Slab
FS	Frame (Sill)	EJS	Edge of Spandrel at Slab (Jamb)
		EMS	Edge-of-Mullion at Slab