SUPPLEMENT TO DEVELOPMENT OF A PROCEDURE FOR CALCULATING TOTAL WINDOW U-VALUE AND SHGC

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EXECUTIVE SUMMARY

This work was carried out under contract for Energy, Mines and Resources Canada (EMR) as part of the CANMET High-Performance Window Project. This project includes support for the development of window performance standards and labelling procedures.

Window thermal performance standards, under development by the Canadian Standards Association (CSA), include procedures for calculating total window performance from component simulation and tabulated values for a wide range of window types. Procedures are based on two EMR computer programs: VISION, supported by the University of Waterloo, provides thermal analysis of simulated glazing systems, and FRAME, developed and supported by Enermodal Engineering Ltd., is a graphic design tool for thermal analysis of window frames.

This report presents ongoing work for the CSA Subcommittee on Energy Evaluation of Windows and has been useful as input to the energy performance standard.

EMR, Ottawa
March 1992

RÉSUMÉ

Cette étude a été conduite sous contrat avec Énergie, Mines et Ressources Canada (EMR) dans le cadre du projet "Fenêtres performantes" de CANMET. La participation à l'établissement de normes et labels concernant l'efficacité thermique des fenêtres fait partie des objectifs de ce projet.

Des normes d'efficacité énergétique des fenêtres, qui sont actuellement établies par l'Association canadienne de normalisation (Acnor), offrent l'option de calculer l'efficacité de la fenêtre complète à partir d'une simulation des composantes de la fenêtre et de valeurs tabulées pour un large éventail de types de fenêtres. La méthode repose sur deux programmes d'ordinateur de EMR: VISION, de l'Université de Waterloo, qui permet l'étude thermique du vitrage simulé, et FRAME, de Enermodal Engineering Ltée, qui est un outil de conception graphique pour l'analyse thermique des cadres de fenêtres.

Ce rapport reflète les travaux en cours du sous-comité Acnor d'évaluation énergétique des fenêtres et joue un rôle important dans l'établissement d'une norme sur l'efficacité énergétique des fenêtres.

EMR, Ottawa
mars 1992

1.0 INTRODUCTION

In a previous report [Enermodal, 1990, D.S.S. Contract No. 23216-9-9117], the accuracy and suitability of using computer simulation to determine total window U-values was established. That report also presented tables of frame U-values for picture, hinged and sliding windows for seven material constructions. This report expands upon that earlier work and presents tables of frame U-values for patio doors, skylights and glass block.

The window frame U-values given in this report were evaluated using the FRAME 2.2 computer program at the ASHRAE winter design condition. The values are meant to be representative of typical North American window products. The reader is cautioned, however, that there are large variations in window frame U-values between manufacturers especially for aluminum and thermally-broken windows.

2.0 WINDOW FRAME U-VALUES

2.1 Methodology

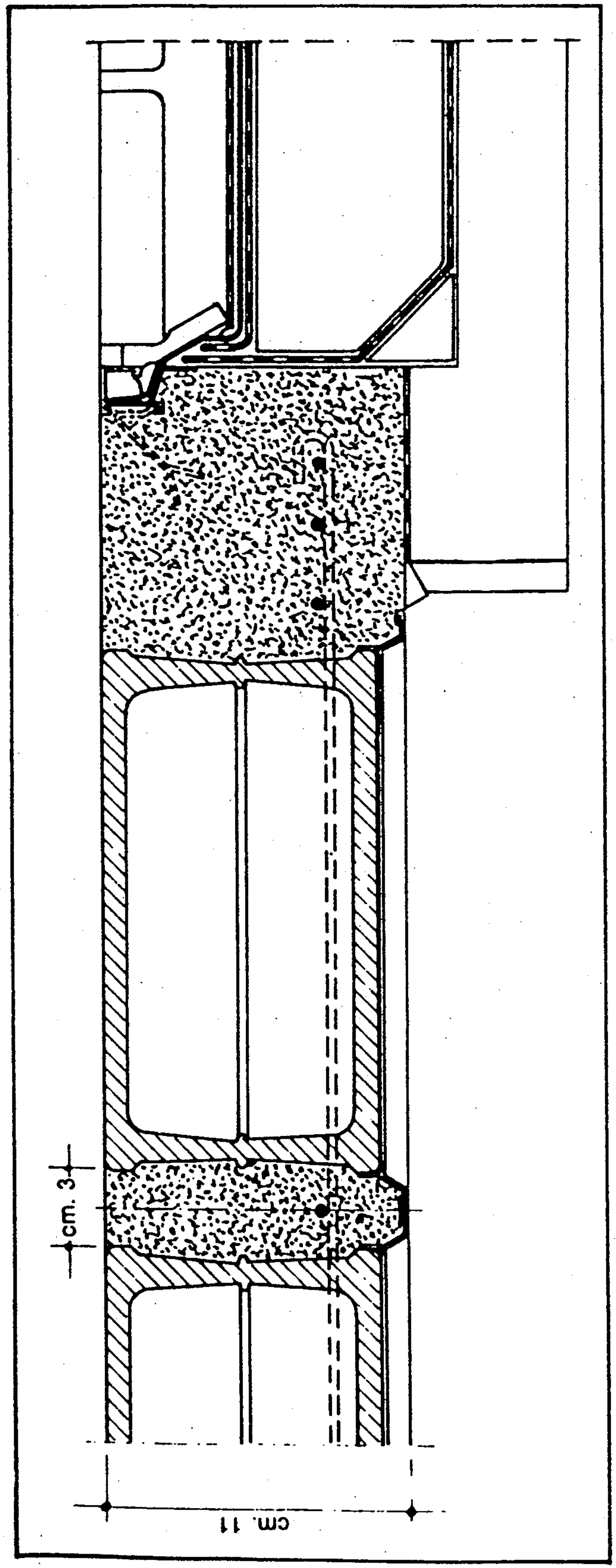
With a few minor exceptions, the approach and methodology is the same as in the earlier report and is not repeated here. Two changes were, however, made to bring the methodology in line with that given in Chapter 27 of the ASHRAE Handbook of Fundamentals [1989]. First, the frame U-values in this report were evaluated with an outside film coefficient of 30 W/m^2*C and the temperature dependent inside film coefficient given in Chapter 27, Table 16 of the Handbook. (The original report used fixed values of 34.48 outside and 7.58 inside.) The thermal resistance of the two film coefficients is, however, very nearly the same, and as such the correction to the values given in the earlier report is small.

Second, the definition of average frame height (i.e., frame and sash height) has been changed. In the first report, the meeting rail was assumed to represent two "frame heights" (i.e., each part of the meeting rail was one frame height). Figure 7 of Chapter 27, defines the meeting rail as one frame height. This is probably more reasonable because the meeting rail is more likely the width of two sashes and the sash is only half of the total frame height. For completeness and ease-of-use, the tables of frame U-values listed in the earlier report have been repeated in Appendix A incorporating these two corrections.

2.2 Glass Block U-Values

Glass block is becoming a popular architectural feature. Although the size and shape varies somewhat, the most commonly used size is 200 mm X 200 mm square by 100 mm thick. The blocks are held together by 3 mm of concrete grouting. The glass block configuration shown in Figure 2.1 was analyzed using the FRAME 2.2 computer program. Definitions of frame, edge-of-glass, and centre glazing are difficult to apply to glass block. As such, only a total U-value was determined to be representative of the heat loss of the assembly. A value of 3.40 W/m^2*C was determined, about 20% higher than the U-value of standard double glazing.

Figure 2.1 Glass Block Configuration



2.3 Patio Door U-Values

Sliding glass patio doors can be treated as if they were a very large horizontal sliding windows. The only question is what size should sliding glass patio doors be evaluated at. Both the National Fenestration Rating Council (NFRC) and the Canadian Standards Association (CSA) have developed procedures for evaluating U-values for sliding glass patio doors [NFRC 1991, CSA 1991]. The two procedures are consistent with the U-value calculations of the earlier report. The CSA procedure defines a size of 1830 mm x 2085 mm (72" x 82") as the size to evaluate sliding glass patio doors, the NFRC defines two sizes, the smaller NFRC size agrees with the CSA size. The CSA size will be used to calculate the average frame heights.

Table 2.1 lists the values of patio door U-values determined for the CSA size patio door.

Table 2.1 Calculated U-Values for Patio Doors

Frame Design	Thickness IG or TB	Spacer Type	Average Frame Height (mm)	U-Value W/(m²*C)
Aluminum		all	53	12.7
Aluminum with T.B.		alum.	67	6.42
Aluminum with T.B.		ins.	67	6.29
Fibreglass	18 mm	alum.	102	1.89
Fibreglass	18 mm	ins.	102	1.78
Fibreglass	34 mm	alum.	102	1.80
Fibreglass	34 mm	ins.	102	1.63
Vinyl-Rein.	18 mm	alum.	69	2.61
Vinyl-Rein	18 mm	ins.	69	2.44
Vinyl-Rein.	34 mm	alum.	69	2.67
Vinyl-Rein	34 mm	ins.	69	2.33
Wood	18 mm	alum.	88	2.52
Wood	18 mm	ins.	88	2.43
Wood	34 mm	alum.	88	2.42
Wood	34 mm	ins.	88	2.25
Wood-Al Clad	18 mm	alum.	96	3.06
Wood-Al Clad	18 mm	ins.	96	2.97
Wood-Al Clad	34 mm	alum.	96	2.96
Wood-Al Clad	34 mm	ins.	96	2.79

2.4 Skylight U-Values

Determining a representative frame U-value for skylights is complicated because the design and installation detail of skylights vary widely. The National Fenestration Rating Council (NFRC) has developed a procedure for rating skylights to reduce some of this variability and provide consumers with a reasonable measure of comparing skylights performance [NFRC, 1991]. The NFRC procedure is used in this report to determine representative skylight frame U-values and is described below.

Skylights differ from most other windows in that they project out beyond the rough wall or roof opening. Skylight frame U-value can be either normalized to the exposed surface area or a projected area. Although the heat loss is a function of the exposed surface area, a skylight is intended to fill a hole in the roof. Basing the U-value on exposed surface area would unduly penalize those skylights that have a low profile in an attempt to reduce heat loss. For these reasons the NFRC procedure is based on projected surface area.

There are two generic types of skylights: flush-mount and curb-mount. Figure 2.2 shows the typical installation of these two types. In simple terms, the difference between the two types is that the former comes from the factory with the curb attached whereas the curb for the latter is attached in the field. To avoid unfairly penalizing flush-mount skylights, the NFRC procedure calls for curb-mount skylights to be rated with a nominal 2" X 4" curb (38mm X 76mm).

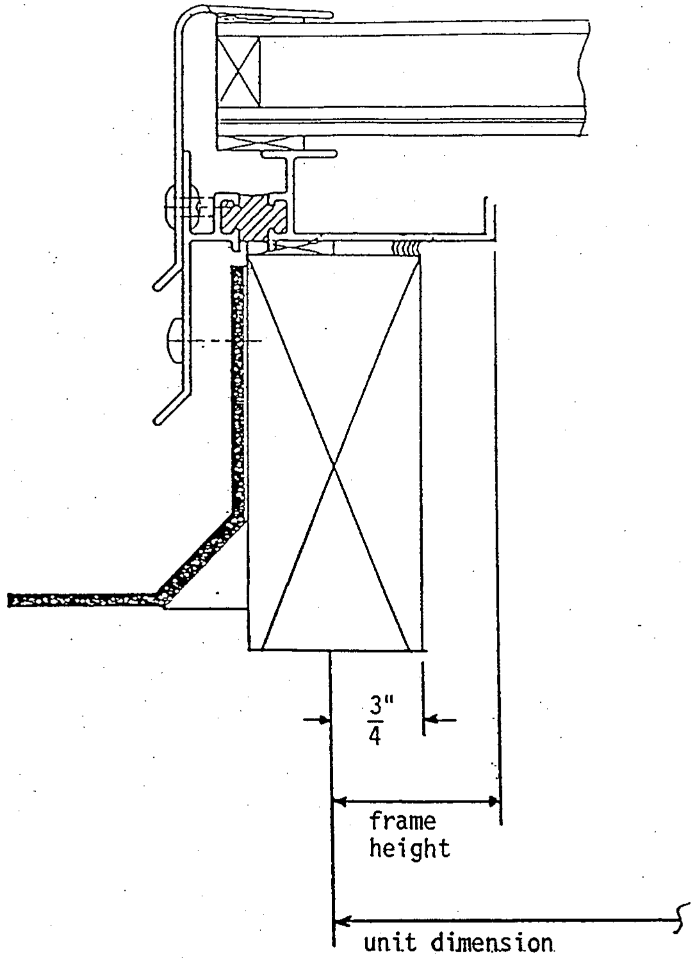
The most difficult (and controversial) aspect of rating skylights is the dimensions to be used for determining the projected area and the frame height. There are three possible dimensions that could be used: rough opening, outside curb and mid-point of the rafters. The rough opening measurement is consistent with how wall-mounted windows are rated but in many cases the projected frame height is zero or negative. Basing the area on the outside dimension of the curb unfairly penalizes flush-mount skylights that have a narrow curb. The NFRC decided that the mid-point of the rafter dimension would provide the fairest method of comparing skylights. This dimension is the same for all skylights and the frame height is always positive. This dimension is also consistent with how the industry labels windows and how building energy analysts model buildings. For example, a 2' X 4' (600mm X 1200mm) skylight is meant to fit on a roof with the centre-line of the rafters 2 feet (600 mm) apart.

Table 2.2 lists the values of skylight U-values determined in accordance with the NFRC procedure.

Figure 2.2

Skylight Mounting Details

Curb-mount



Flush-mount

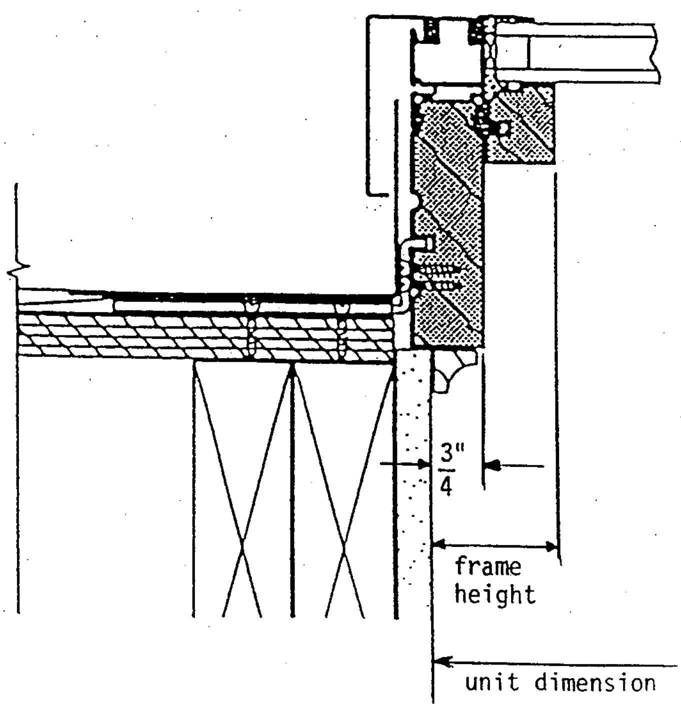


Table 2.2 Calculated U-Values for Skylights

Frame Design	Thickness IG or TB	Spacer Type	Average Frame Height (mm)	U-Value W/(m²*C)
Aluminum		all	19	63.4
Aluminum with T.B.		alum.	19	30.6
Aluminum with T.B.		ins.	19	27.4
Vinyl-Rein.	18 mm	alum.	76	7.89
Vinyl-Rein	18 mm	ins.	76	7.55
Vinyl-Rein.	34 mm	alum.	76	6.42
Vinyl-Rein	34 mm	ins.	76	6.19
Wood	18 mm	alum.	23	11.81
Wood	18 mm	ins.	23	11.52
Wood	34 mm	alum.	23	10.10
Wood	34 mm	ins.	23	9.70
Wood-Al Clad	18 mm	alum.	51	9.71
Wood-Al Clad	18 mm	ins.	51	9.65
Wood-Al Clad	34 mm	alum.	51	8.80
Wood-Al Clad	34 mm	ins.	51	8.80

3.0 REFERENCES

Enermodal Engineering. 1990. "Development of a Procedure for Calculating Total Window U-Value and SHGC." Report prepared for Energy, Mines and Resources Canada by Enermodal Engineering Limited, Waterloo, Ontario, Canada.

ASHRAE. 1989. ASHRAE Handbook of Fundamentals, Atlanta: American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc.

National Fenestration Rating Council. 1991. NFRC 100-91: Procedure for Determining Fenestration Product Thermal Properties (Currently Limited to U-values).

CSA. 1991. CSA Preliminary Standard A4402, "Methods for Determining the Energy Performance of Windows." Toronto: Canadian Standards Association.

APPENDIX A

Table 8. FRAME Calculated U-Values for Picture Window Frames

Frame Design	Thickness IG or TB[a]	Spacer Type	Percent Frame (%)[b]	Average Frame Height (mm)	U-Value [W/(m²*C)][c]
P1 Aluminum	36 mm	all	11.3	29.9	7.57[d]
P2 Aluminum	104 mm	all	13.0	34.5	14.25
P3 Aluminum with T.B.	5 mm	alum.	13.0	34.5	9.36
P3 Aluminum with T.B.	5 mm	ins.	13.0	34.5	7.88
P4 Aluminum with T.B.	9 mm	alum.	9.5	25.0	6.62
P4 Aluminum with T.B.	9 mm	ins.	9.5	25.0	5.23
P5 Aluminum with T.B.	33 mm	alum.	14.4	38.4	5.09
P5 Aluminum with T.B.	33 mm	ins.	14.4	38.4	3.78
P6 Fiberglass	18 mm	alum.	17.1	46.0	2.29
P6 Fiberglass	18 mm	ins.	17.1	46.0	2.04
P7 Fiberglass	34 mm	alum.	17.1	46.0	1.96
P7 Fiberglass	34 mm	ins.	17.1	46.0	1.57
P8 Vinyl	18 mm	alum.	16.0	42.9	2.46
P8 Vinyl	18 mm	ins.	16.0	42.9	2.08
P9 Vinyl	34 mm	alum.	16.0	42.9	2.49
P9 Vinyl	34 mm	ins.	16.0	42.9	1.86
P10 Vinyl-Rein.	18 mm	alum.	16.0	42.9	2.92
P10 Vinyl-Rein.	18 mm	ins.	16.0	42.9	2.54
P11 Vinyl-Rein.	34 mm	alum.	16.0	42.9	2.78
P11 Vinyl-Rein.	34 mm	ins.	16.0	42.9	2.23
P12 Wood	18 mm	alum.	14.7	39.3	2.75
P12 Wood	18 mm	ins.	14.7	39.3	2.35
P13 Wood	34 mm	alum.	14.7	39.3	2.52
P13 Wood	34 mm	ins.	14.7	39.3	1.87
P14 Wood-Al Clad	18 mm	alum.	14.7	39.3	2.93
P14 Wood-Al Clad	18 mm	ins.	14.7	39.3	2.44
P15 Wood-Al Clad	34 mm	alum.	14.7	39.3	2.65
P15 Wood-Al Clad	34 mm	ins.	14.7	39.3	1.94

Notes:

a. "Thickness" refers to the dimension perpendicular to the plane of the window, and is the thickness of the IG unit (for non-metal frames), the length of the thermal break (in the case of TB aluminum frames), or the thickness of the frame parallel to heat flow (in the case of all-aluminum frames).

b. "Percent frame" is based on a standard 900x1200 mm residential window.

c. All U-values were generated using ASHRAE winter design conditions:
Outside temperature = -18°C, surface coefficient = 34.48 $W/(m^2*C)$
Inside temperature = 21°C, surface coefficient = 7.58 $W/(m^2*C)$

d. U-values for all-aluminum windows show wide variation, depending on the window design, and especially on total surface area of the frame.

Table 9. FRAME Calculated U-Values for Hinged Window Frames

Frame Design	Thickness IG or TB[a]	Spacer Type	Percent Frame (%)[b]	Average Frame Height (mm)	U-Value [W/(m²*C)][c]
H1 Aluminum	-	all	22.9	62.6	13.16[d]
H2 Aluminum with T.B.	5 mm	alum.	37.4	107.1	4.40
H2 Aluminum with T.B.	5 mm	ins.	37.4	107.1	4.26
H3 Aluminum with T.B.	9 mm	alum.	24.6	67.6	4.12
H3 Aluminum with T.B.	9 mm	ins.	24.6	67.6	3.61
H4 Aluminum with T.B.	18 mm	alum.	26.2	72.4	3.60
H4 Aluminum with T.B.	18 mm	ins.	26.2	72.4	3.40
H5 Fiberglass	18 mm	alum	25.4	70.0	2.45
H5 Fiberglass	18 mm	ins.	25.4	70.0	2.15
H6 Vinyl	18 mm	alum.	25.1	69.1	2.01
H6 Vinyl	18 mm	ins.	25.1	69.1	1.77
H7 Vinyl	34 mm	alum.	25.1	69.1	1.86
H7 Vinyl	34 mm	ins.	25.1	69.1	1.52
H8 Vinyl-Rein.	18 mm	alum.	25.1	69.1	2.33
H8 Vinyl-Rein.	18 mm	ins.	25.1	69.1	2.09
H9 Vinyl-Rein.	34 mm	alum.	25.1	69.1	2.14
H9 Vinyl-Rein.	34 mm	ins.	25.1	69.1	1.83
H10 Wood	18 mm	alum.	28.1	78.1	2.31
H10 Wood	18 mm	ins.	28.1	78.1	2.07
H11 Wood	34 mm	alum.	28.1	78.1	2.01
H11 Wood	34 mm	ins.	28.1	78.1	1.65
H12 Wood-Al Clad	18 mm	alum.	28.1	78.1	2.34
H12 Wood-Al Clad	18 mm	ins.	28.1	78.1	2.08
H13 Wood-Al Clad	34 mm	alum.	28.1	78.1	2.06
H13 Wood-Al Clad	34 mm	ins.	28.1	78.1	1.68

Notes:

a. "Thickness" refers to the dimension perpendicular to the plane of the window, and is the thickness of the IG unit (for non-metal frames) or the length of the thermal break (in the case of aluminum frames).

b. "Percent frame" is based on a standard 900x1200 mm residential window.

c. All U-values were generated using ASHRAE winter design conditions:
Outside temperature = -18°C, surface coefficient = 34.48 W/(m²*C)
Inside temperature = 21°C, surface coefficient = 7.58 W/(m²*C)

d. U-values for all-aluminum windows show wide variation, depending on the window design, and especially on total surface area of the frame.

Table 10. FRAME Calculated U-Values for Sliding Window Frames

Frame Design	Thickness IG or TB[a]	Spacer Type	Percent Frame (%)[b]	Average Frame Height (mm)	U-Value [W/(m^2*C)][c]
S1 Aluminum	-	all	25.0	56.7	15.99[d]
S2 Aluminum with T.B.	20 mm	alum.	24.0	54.3	5.38
S2 Aluminum with T.B.	20 mm	ins.	24.0	54.3	4.89
S3 Fiberglass[e]	18 mm	alum	33.6	78.4	2.50
S3 Fiberglass[e]	18 mm	ins.	33.6	78.4	2.22
S4 Vinyl	18 mm	alum.	31.8	73.7	3.25
S4 Vinyl	18 mm	ins.	31.8	73.7	2.89
S4 Vinyl-Rein.	18 mm	alum.	31.8	73.7	3.51
S4 Vinyl-Rein.	18 mm	ins.	31.8	73.7	3.17
S5 Wood	18 mm	alum.	29.9	68.9	3.34
S5 Wood	18 mm	ins.	29.9	68.9	3.02
S6 Wood	34 mm	alum.	29.9	68.9	3.03
S6 Wood	34 mm	ins.	29.9	68.9	2.52
S7 Wood-Al Clad	18 mm	alum.	29.9	68.9	3.50
S7 Wood-Al Clad	18 mm	ins.	29.9	68.9	3.12
S8 Wood-Al Clad	34 mm	alum.	29.9	68.9	3.21
S8 Wood-Al Clad	34 mm	ins.	29.9	68.9	2.62

Table 11. FRAME Calculated U-Values for Semi-sashless Sliding Window Frames

Frame Design	Thickness IG or TB[a]	Percent Frame (%)[b]	Average Frame Height (mm)	U-Value [W/(m^2*C)][c]
S9 Aluminum	-	31.7	73.5	7.48[d]
S9 Aluminum with T.B.	10 mm	31.7	73.5	4.78
S10 Aluminum with T.B.	33 mm	24.1	54.5	3.83
S11 Aluminum with T.B.	50 mm	18.1	40.2	3.69
S12 Fiberglass	18 mm	23.7	53.6	3.24
S13 Wood/PVC	18 mm	16.9	37.4	2.00
S14 Wood/PVC	34 mm	16.9	37.4	1.18
S15 Wood/PVC-Al Clad	18 mm	16.9	37.4	2.02
S16 Wood/PVC-Al Clad	34 mm	16.9	37.4	1.20

Notes:

a. "Thickness" refers to the dimension perpendicular to the plane of the window, and is the thickness of the IG unit (for non-metal frames) or the length of the thermal break (in the case of aluminum frames).

b. "Percent frame" is based on a standard 900x1200 mm residential window.

c. All U-values were generated using winter design conditions:
Outside temperature = -18°C, surface coefficient = 34.48 W/(m^2*C)
Inside temperature = 21°C, surface coefficient = 7.58 W/(m^2*C)

d. U-values for all-aluminum windows show wide variation, depending on the window design, and especially on total surface area of the frame.

e. Frame cavities filled with fibreglass insulation.

APPENDIX B
TOTAL WINDOW U-VALUE and SHGC CALCULATION SHEET

STEP 1 WINDOW U-VALUE

I Centre of Glass U-value from Table 5

Centre of Glass U-value ________

II Edge of Glass U-value Constants from Table 6

A = ______, B = ______, C = ______

$U_{eg} = A + B * U_{cg} + C * U_{cg}^2 =$ ________

III Frame U-value from Tables 8 through 11

Metal Spacer ________

Insulating Spacer ________

Glass Spacer $0.50 * U_{metal} + 0.50 * U_{insul} =$ ________

Metal + Insul. Spacer $0.15 * U_{metal} + 0.85 * U_{insul} =$ ________

IV Component Fractions

Frame Height and Window Width and Height [mm]

Window Width, W = ______, Height, H = ______

Frame Height = ______, from Tables 8 through 11

Fraction Frame

Picture and Hinged Windows

$F_{fr} = [(W * H) - (W - 2 * H_{fr}) * (H - 2 * H_{fr})] / (W * H)$ ________

Vertical Sliding Windows

$F_{fr} = [(W * H) - (W - 2 * H_{fr}) * (H - 3 * H_{fr})] / (W * H)$ ________

Horizontal Sliding Windows

$F_{fr} = [(W * H) - (W - 3 * H_{fr}) * (H - 2 * H_{fr})] / (W * H)$ ________

Fraction Centre of Glass

Picture and Hinged Windows

$F_{cg} = [(W - 2 * H_{fr} - 127) * (H - 2 * H_{fr} - 127)] / (W * H)$ ________

Vertical Sliding Windows

$F_{cg} = [(W - 2 * H_{fr} - 127) * (H - 3 * H_{fr} - 254)] / (W * H)$ ________

Horizontal Sliding Windows

$F_{cg} = [(W - 3 * H_{fr} - 254) * (H - 2 * H_{fr} - 127)] / (W * H)$ ________

Fraction Edge of Glass

$F_{eg} = 1 - F_{cg} - F_{fr}$ ________

V Window U-value

$U_{total} = U_{cg} * F_{cg} + U_{eg} * F_{eg} + U_{fr} * F_{fr}$ ________

STEP 2 SHGC CALCULATION

I Centre of Glass SHGC from Table 14

$SHGC_{cg}$ ________

II Frame SHGC

$SHGC_{fr} = 0.015 * a_{fr} * U_{fr} =$ ________

III Window SHGC

$SHGC_{total} = SHGC_{cg} * F_{cg} + SHGC_{eg} * F_{eg} + SHGC_{fr} * F_{fr} =$ ________