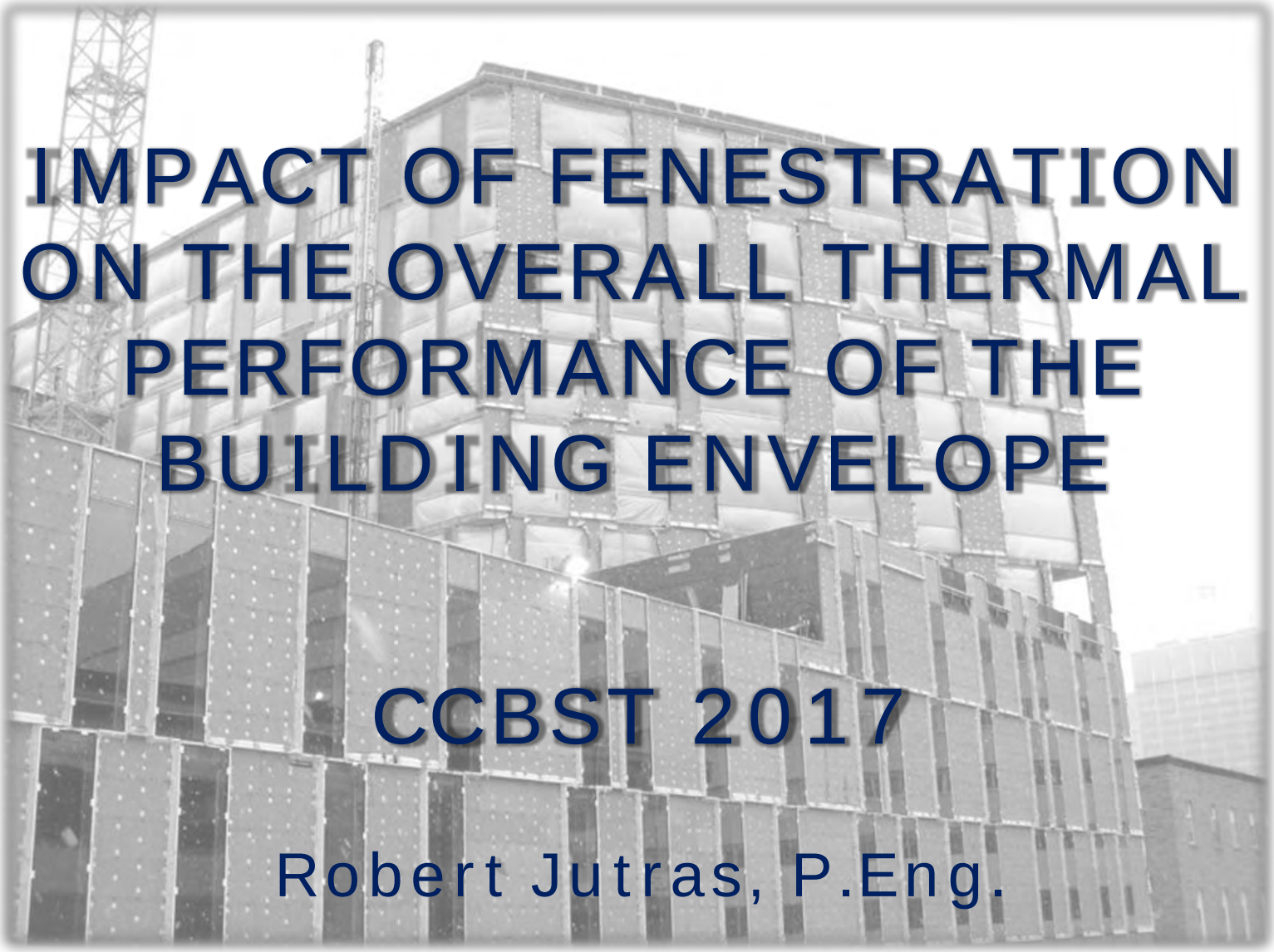


IMPACT OF FENESTRATION ON THE OVERALL THERMAL PERFORMANCE OF THE BUILDING ENVELOPE

CCBST 2017

Robert Jutras, P.Eng.

CLEB
a UL company

OBJECTIVE:

Establish/explain need to consider thermal performance of fenestration

CONTEXT

CURRENT VIEWS

- “architectural glass and curtain wall disease”
  - “..many green buildings don’t save energy. Why? They have too much glass.”
    - “If you want to save serious energy – use less glass; windows and curtain walls provide the worst energy performance..”

EFFECTIVE THERMAL RESISTANCE

- *Effective thermal resistance* (R-value) means the inverse of *overall thermal transmittance* (U-value).

$$R_{eff} = 1/U$$

Overall thermal transmittance (U-value) is a measure of the rate at which heat is transfered through a building <u>assembly</u> subject to a temperature difference (U=1/R).

07/07/2011

PARALLEL PATH HEAT FLOW METHOD

The overall thermal transmittance **($U_{overall}$)** is the area weighted average of the thermal transmittance of the components of an overall assembly.

The equation for thermal transmittance of an assembly is as follows:

$$U_o = (A_1/R_1 + A_2/R_2 + A_3/R_3 + \ldots)/A_o$$

Where:

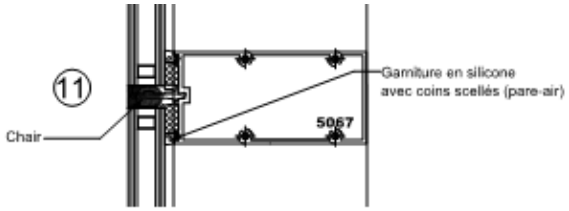
A_1, A_2, A_3, ... = the cross-sectional area of the different elements, such as opaque walls, windows and doors.

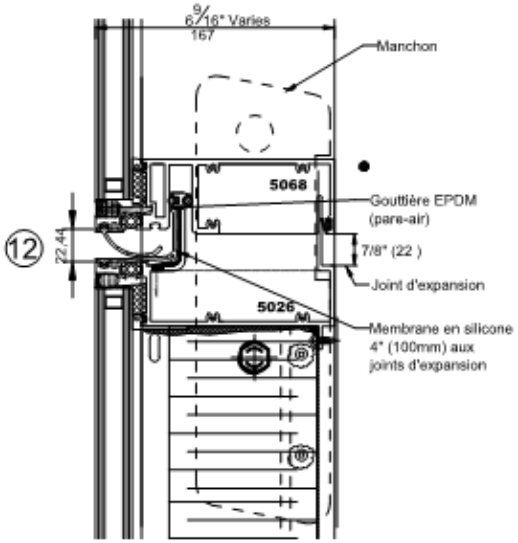
R_1, R_2, R_3, ... = the cross-sectional *R*-value of the different elements.

A_o = the gross area of the element or overall assembly.

The procedure for calculating a total facade heat transfer is to add each of the component heat transfers :

$$U_{overall} = \Sigma (U_c A_{pc}) / \Sigma A_{pc}$$





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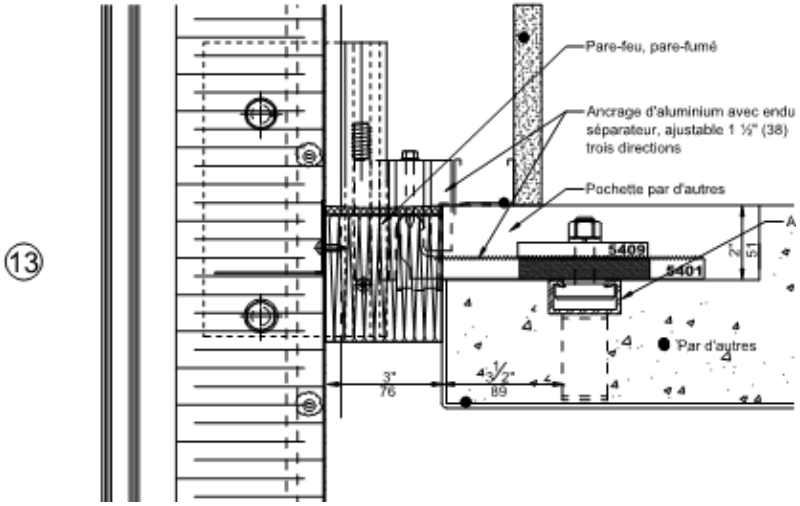
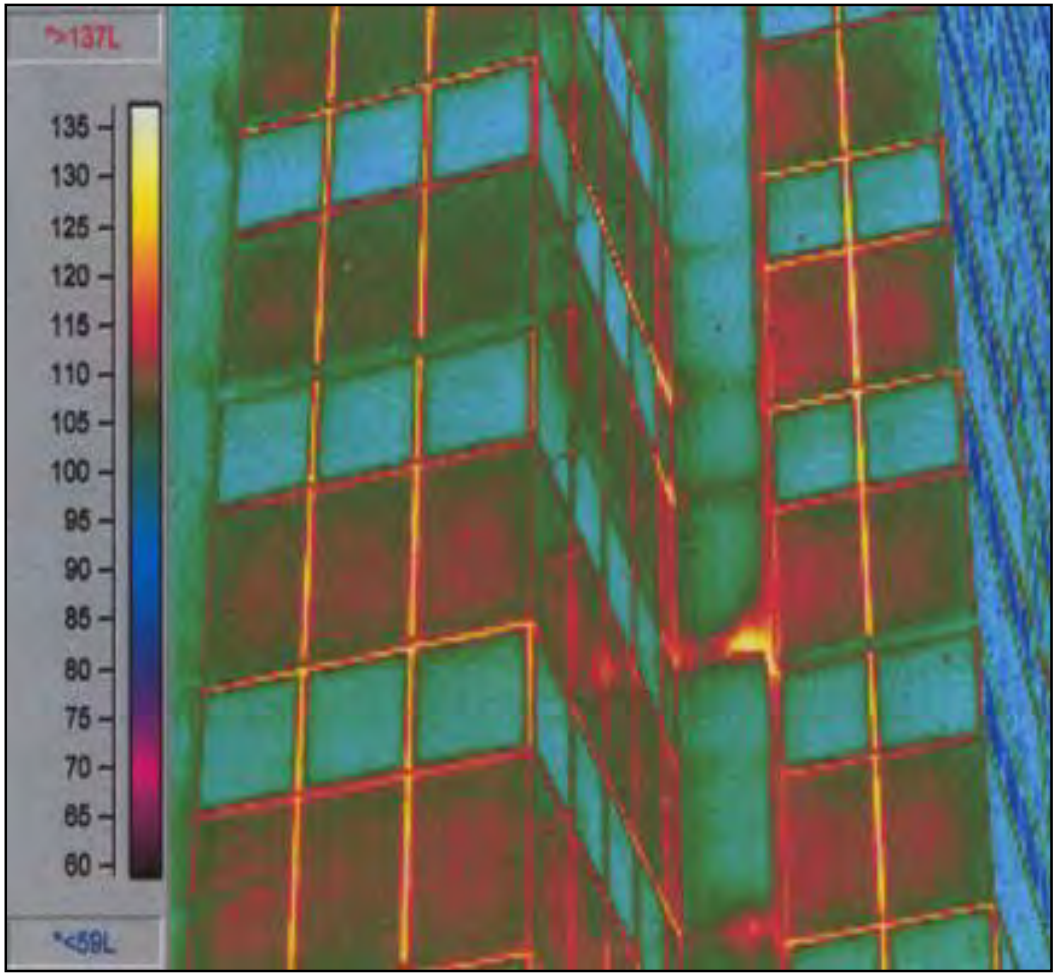
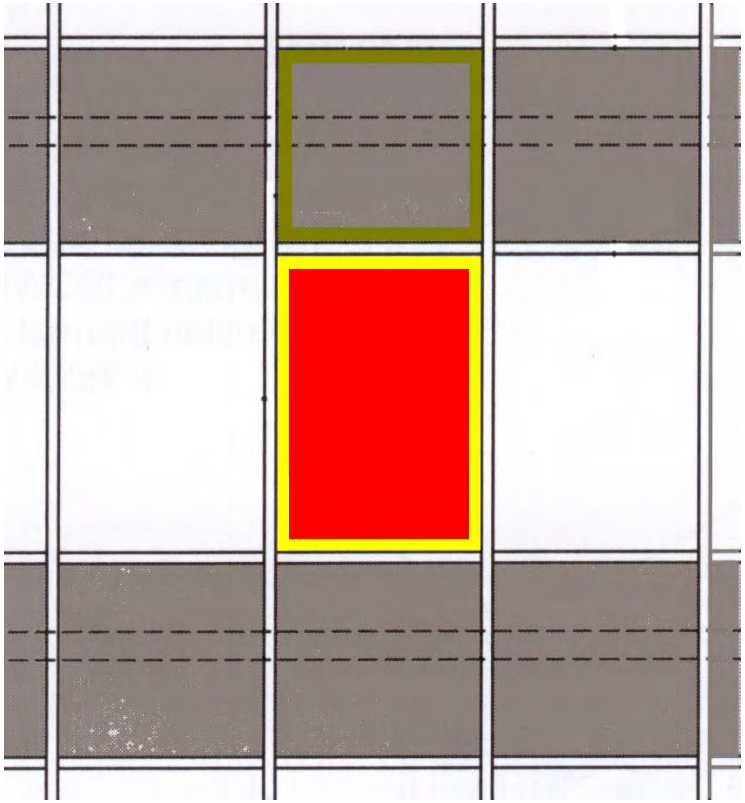
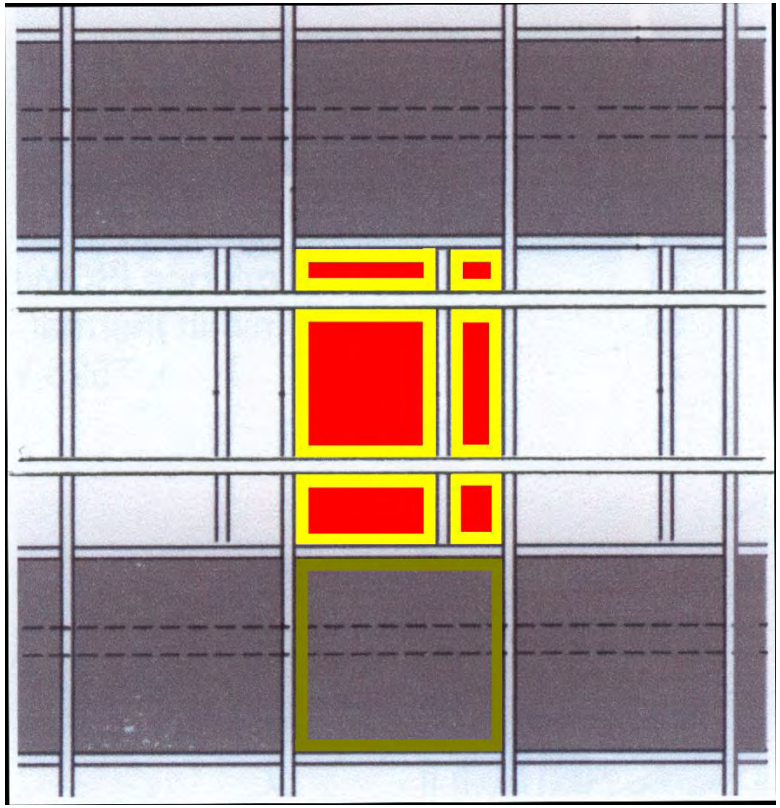




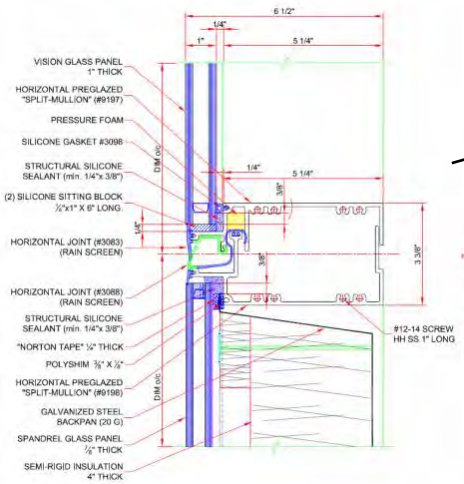
INFRARED ILLUSTRATION OF PARALLEL PATHS

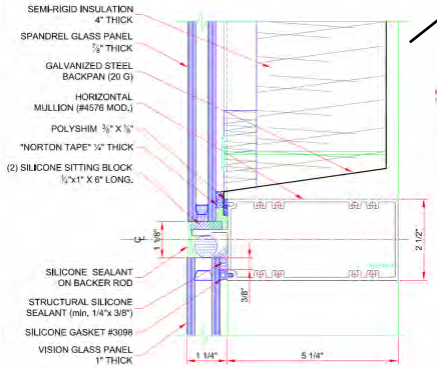
PARTIAL CURTAIN WALL ELEVATIONS SHOWING FRAME INFLUENCE ON PARALLEL PATHS

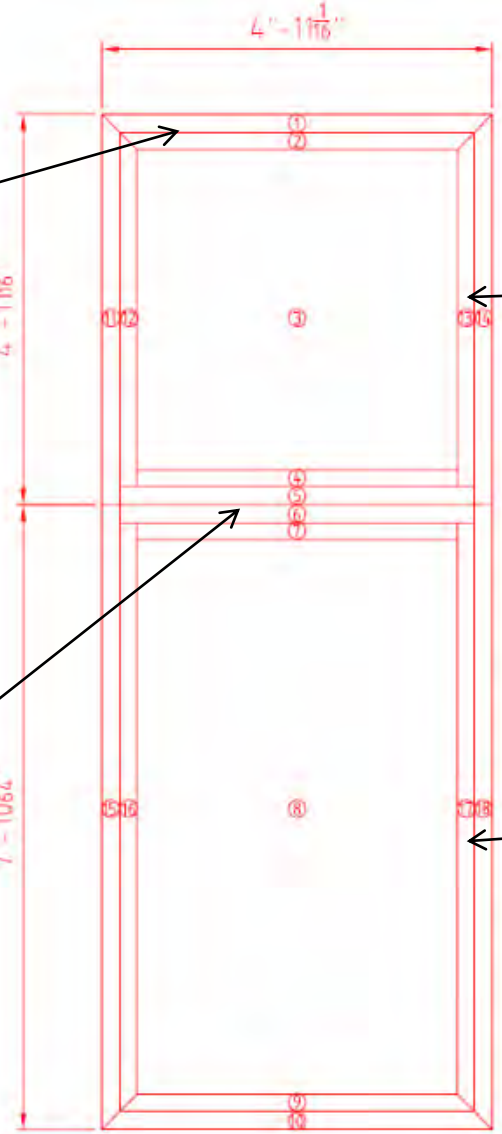




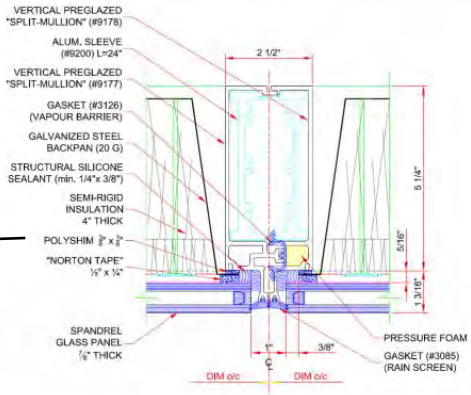
PARALLEL PATHS TO ASSESS OVERALL U-VALUE OF TYPICAL CW MODULE

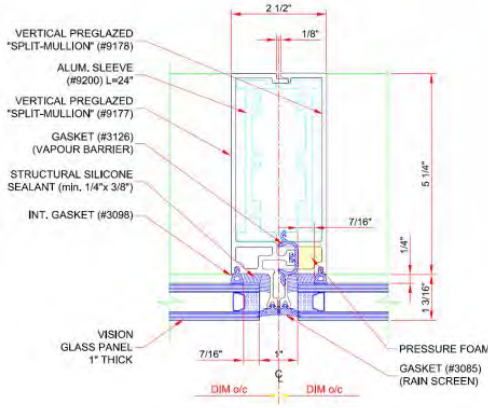






1. DETAIL 100 - FRAME-OF-PANNE
2. DETAIL 100 - EDGE-OF-PANNE
3. CENTRE-OF-PANNE
4. DETAIL 103 - EDGE-OF-PANNE
5. DETAIL 103 - FRAME-OF-PANNE
6. DETAIL 103 - FRAME
7. DETAIL 103 - EDGE-OF-GLAZING
8. CENTRE-OF-GLAZING
9. DETAIL 100 - EDGE-OF-GLAZING
10. DETAIL 100 - FRAME
11. DETAIL 101 - FRAME-OF-PANNE
12. DETAIL 101 - EDGE-OF-PANNE
13. DETAIL 101 - EDGE-OF-PANNE 2
14. DETAIL 101 - FRAME-OF-PANNE 2
15. DETAIL 102 - FRAME
16. DETAIL 102 - EDGE-OF-GLAZING
17. DETAIL 102 - EDGE-OF-GLAZING 2
18. DETAIL 102 - FRAME 2





RESULTS FOR PROPOSED VISION WITH FRAMING

Overall U-factor for Vision with Framing (Project:											
#	Unit	# of Units	Width [inch]	Length [inch]	Area (A) [ft^2]	#*A [ft^2]	U-Factor (U) [Btu/(hr-ft^2-°F)]	#*(AU) [Btu/(hr-°F)]	Overall U-Factor [Btu/(hr-ft^2-°F)]	R-Value [(hr-ft^2-°F)/Btu]	RSI-Value [(m^2-°C)/W]
6	DETAIL 103 - FRAME	1	1,28	59,063	0,50	0,50	1,9155	0,96			
7	DETAIL 103 - EDGE-OF-GLAZING	1	2,50	59,063	0,89	0,89	0,2815	0,25			
8	CENTRE-OF-GLAZING	1	51,49	86,52	30,94	30,94	0,255	7,89		R3.9	
9	DETAIL 100 - EDGE-OF-GLAZING	1	2,50	59,063	0,94	0,94	0,2751	0,26			
10	DETAIL 100 - FRAME	1	1,68	59,063	0,67	0,67	1,6350	1,10			
15	DETAIL 102 - FRAME	1	1,29	94,484	0,84	0,84	1,6668	1,40			
16	DETAIL 102 - EDGE-OF-GLAZING	1	2,50	94,484	1,57	1,57	0,2623	0,41			
17	DETAIL 102 - EDGE-OF-GLAZING 2	1	2,50	94,484	1,57	1,57	0,2624	0,41			
18	DETAIL 102 - FRAME 2	1	1,28	94,484	0,83	0,83	1,6817	1,40			
	Total	9				38,75		14,1	0,3634	2,75	0,48

RESULTS FOR PROPOSED SPANDREL WITH FRAMING

Overall U-factor for Proposed Spandrel with Framing (Project:											
#	Unit	# of Units	Width [inch]	Length [inch]	Area (A) [ft^2]	#*A [ft^2]	U-Factor (U) [Btu/(hr-ft^2-°F)]	#*(AU) [Btu/(hr-°F)]	Overall U-Factor [Btu/(hr-ft^2-°F)]	R-Value [(hr-ft^2-°F)/Btu]	RSI-Value [(m^2-°C)/W]
1	DETAIL 100 - FRAME-OF-PANNE	1	1,67	59,063	0,67	0,67	0,9331	0,63			
2	DETAIL 100 - EDGE-OF-PANNE	1	2,50	59,063	0,94	0,94	0,2866	0,27			
3	CENTRE-OF-PANNE	1	51,56	51,14	18,31	18,31	0,0490	0,90		R20.4	
4	DETAIL 103 - EDGE-OF-PANNE	1	2,50	59,063	0,90	0,90	0,2794	0,25			
5	DETAIL 103 - FRAME-OF-PANNE	1	1,25	59,063	0,49	0,49	1,0410	0,51			
11	DETAIL 101 - FRAME-OF-PANNE	1	1,25	59,063	0,51	0,51	1,3188	0,67			
12	DETAIL 101 - EDGE-OF-PANNE	1	2,50	59,063	0,95	0,95	0,3050	0,29			
13	DETAIL 101 - EDGE-OF-PANNE 2	1	2,50	59,063	0,95	0,95	0,3112	0,30			
14	DETAIL 101 - FRAME-OF-PANNE 2	1	1,25	59,063	0,51	0,51	1,3115	0,66			
	Total	9				24,22		4,5	0,1845	5,42	0,95

RESULTS FOR PROPOSED VISION AND SPANDREL WITH FRAMING

Overall U-factor for a Typical Unit with Proposed Spandrel (Project: 150 Slater Street, Ottawa)											
#	Unit	# of Units	Width [inch]	Length [inch]	Area (A) [ft^2]	#*A [ft^2]	U-Factor (U) [Btu/(hr-ft^2-°F)]	#*(AU) [Btu/(hr-ft^2-°F)]	Overall U-Factor [Btu/(hr-ft^2-°F)]	R-Value [(ft^2-°F)/Btu]	RSI-Value [(m^2-°C)/W]
1	DETAIL 100 - FRAME-OF-PANNE	1	1,67	59,063	0,67	0,67	0,9331	0,63			
2	DETAIL 100 - EDGE-OF-PANNE	1	2,50	59,063	0,94	0,94	0,2866	0,27			
3	CENTRE-OF-PANNE	1	51,56	51,14	18,31	18,31	0,0490	0,90			
4	DETAIL 103 - EDGE-OF-PANNE	1	2,50	59,063	0,90	0,90	0,2794	0,25			
5	DETAIL 103 - FRAME-OF-PANNE	1	1,25	59,063	0,49	0,49	1,0410	0,51			
6	DETAIL 103 - FRAME	1	1,28	59,063	0,50	0,50	1,9155	0,96			
7	DETAIL 103 - EDGE-OF-GLAZING	1	2,50	59,063	0,89	0,89	0,2815	0,25			
8	CENTRE-OF-GLAZING	1	51,49	86,52	30,94	30,94	0,255	7,89			
9	DETAIL 100 - EDGE-OF-GLAZING	1	2,50	59,063	0,94	0,94	0,2751	0,26			
10	DETAIL 100 - FRAME	1	1,68	59,063	0,67	0,67	1,6350	1,10			
11	DETAIL 101 - FRAME-OF-PANNE	1	1,25	59,063	0,51	0,51	1,3188	0,67			
12	DETAIL 101 - EDGE-OF-PANNE	1	2,50	59,063	0,95	0,95	0,3050	0,29			
13	DETAIL 101 - EDGE-OF-PANNE 2	1	2,50	59,063	0,95	0,95	0,3112	0,30			
14	DETAIL 101 - FRAME-OF-PANNE 2	1	1,25	59,063	0,51	0,51	1,3115	0,66			
15	DETAIL 102 - FRAME	1	1,29	94,484	0,84	0,84	1,6668	1,40			
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17	DETAIL 102 - EDGE-OF-GLAZING 2	1	2,50	94,484	1,57	1,57	0,2624	0,41			
18	DETAIL 102 - FRAME 2	1	1,28	94,484	0,83	0,83	1,6817	1,40			
	Total	18				62,98		18,6	0,2946	3,39	0,60

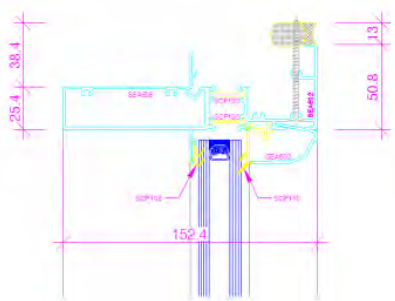
R20.4

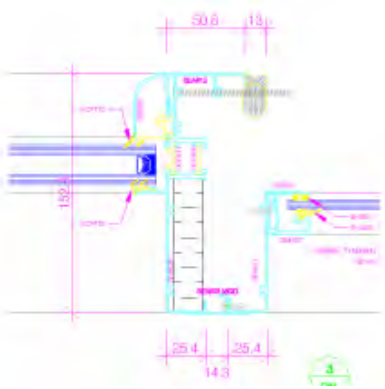
R3.9

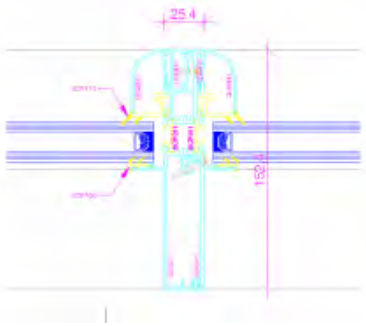
3.39

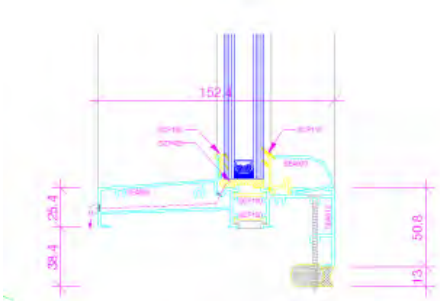
TYPICAL EFFECTIVE THERMAL RESISTANCE VALUES FOR WINDOWS

	R Value
Aluminum framed window with conventional thermal break and doubled glazed IGU composed of clear glass, metallic spacer and 12mm air space;	2.0
Aluminum framed window with conventional thermal break and doubled glazed IGU composed of clear glass with a high performance soft coat low-e, non-metallic spacer and 12mm agron filled air space;	3.0
Aluminum framed window with high performance thermal break and doubled glazed IGU composed of clear glass with a high performance soft coat low-e, non-metallic spacer and 12mm agron filled air space;	3.2
Aluminum framed window with high performance thermal break and tripled glazed IGU composed of clear glass with a high performance soft coat low-e on two surfaces, non-metallic spacer and two 12mm agron filled air spaces;	3.5
PVC framed window and doubled glazed IGU composed of clear glass with a high performance soft coat low-e, non-metallic spacer and 12mm agron filled air space;	3.5
PVC framed window and tripled glazed IGU composed of clear glass with a high performance soft coat low-e on two surfaces, non-metallic spacer and two 12mm agron filled air spaces;	5.7
Wood framed widow and doubled glazed IGU composed of clear glass with a high performance soft coat low-e, non-metallic spacer and 12mm agron filled air space;	3.3
Wood framed window and tripled glazed IGU composed of clear glass with a high performance soft coat low-e on two surfaces, non-metallic spacer and two 12mm agron filled air spaces;	5.2
Fiberglas framed window and doubled glazed IGU composed of clear glass with a high performance soft coat low-e, non-metallic spacer and 12mm agron filled air space;	3.5
Fiberglas framed window and tripled glazed IGU composed of clear glass with a high performance soft coat low-e on two surfaces, non-metallic spacer and two 12mm agron filled air spaces	5.7
Energy star web site searches base on: Quebec, Operable casement.	

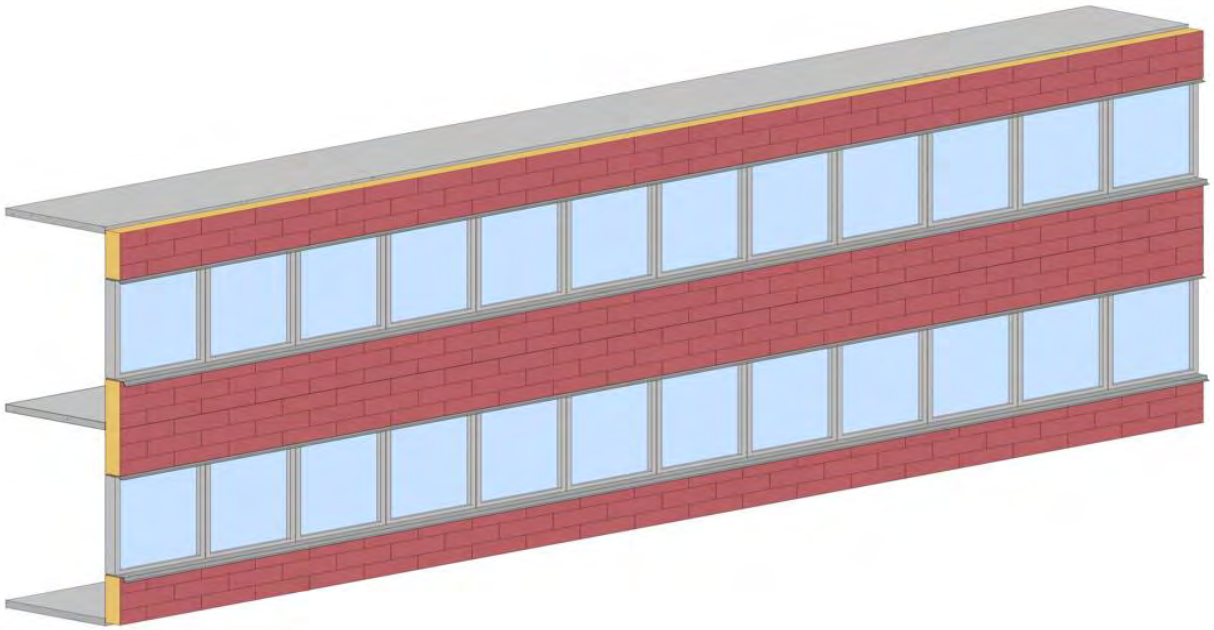








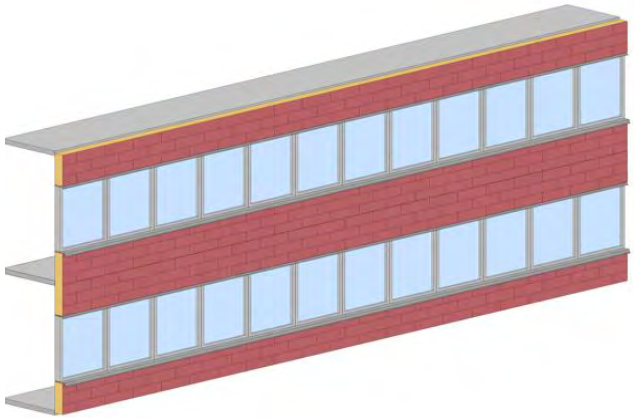
FENESTRATION TO WALL RATIO



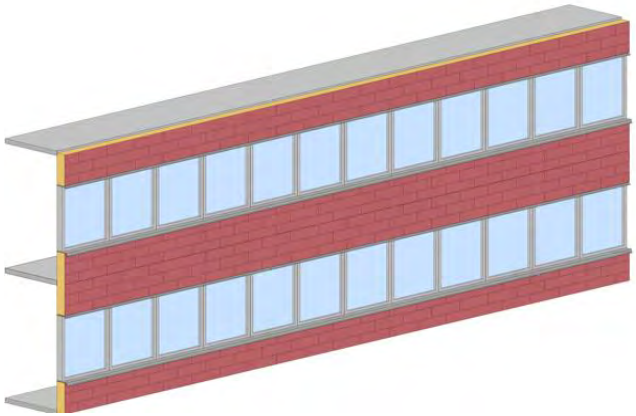
50% fenestration	R2
50% wall	R20
Average thermal resistance:	(R2+R20) = **R11**
But does NOT equal:	
Effective Thermal resistance:	[(1/R2 * 0.5) + (1/R20 * 0.5)] / 1 = **R3.6**

EXAMPLE FOR TWO IDENTICAL BUILDINGS

A



B



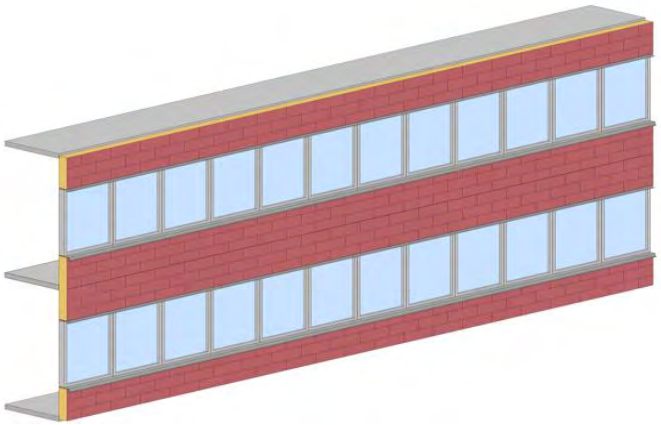
50% fenestration (R2)

50% wall (R20)

R_{eff}: R3.6

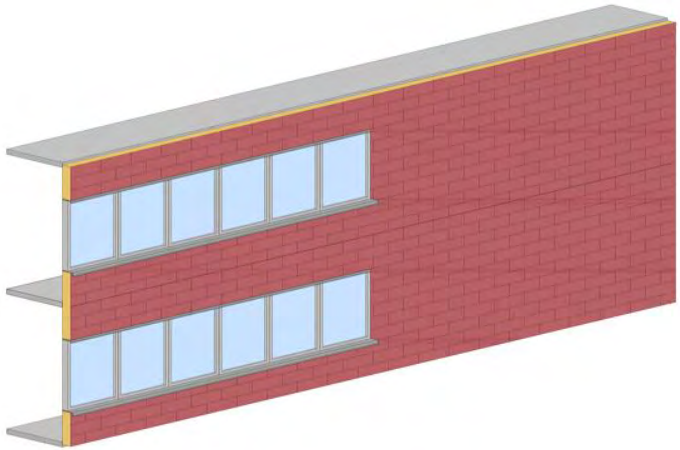
Contemplated Revisions

Window:	R2	Window:	R4
Wall:	R40	Wall:	R20
R_{eff}:	R3.8	R_{eff}:	R6.7



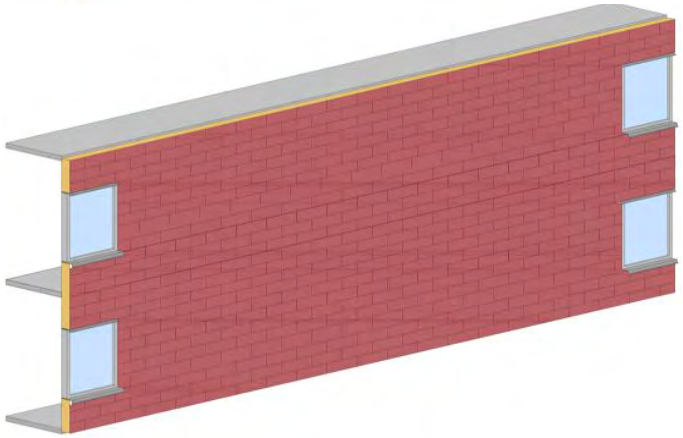
50% Fenestration
50% Wall

Window R2, Wall R20; R3.6
Window R2, Wall R40; R3.8
Window R4, Wall R20; R6.7



25% Fenestration
75% Wall

Window R2, Wall R20; R6.2
Window R2, Wall R40; R7.0
Window R4, Wall R20; R10



10% Fenestration
90% Wall

Window R2, Wall R20; R10.5
Window R2, Wall R40; R13.8
Window R4, Wall R20; R14.3

So, what would be the overall thermal performance for this stock of buildings?

THANK YOU!

rjutras@cleb.com