Thermal Evaluation of Starline 9200 Series Window Wall System

Presented to:

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Contents

Introduction

Evoke Buildings Engineering Inc. (Evoke) was contracted by Starline Windows for the thermal evaluation of the Starline 9200 Series Window Wall system. Evoke evaluated various scenarios to determine the thermal transmittances and condensation risk for the climates of Vancouver, BC and Edmonton, AB. This report summarizes the thermal evaluation.

The evaluated Starline 9200 Window Wall System is comprised of the following features:

1. Window mullions and couplers have a 1 9/16" (39 mm) multi chamber thermal breaks.
2. 4 ½" (114 mm) deep frames.
3. Insulated aluminum deflection head with thermal break located at the edge of the concrete floor.
4. Spandrels are single glazed with 3 inches of mineral wool (R-12.6) insulation in the back pan.
5. The T-angle support at the edge of the concrete floor allows for extra insulation at the bypass.

The evaluated Starline 9200 Window Wall System with a raised metal panel has most of the same features as the evaluated baseline system, with the following differences:

- Spandrels are finished with a metal panel.
- 4.5 inches of mineral wool (R-18.9) insulation in the back pan
- More insulation at the slab bypass.

Scenarios with vision sections include a double glazed IGU, with Low-E coating on surface #2, a 1/2-inch argon filled cavity, and warm edge spacers.

See Figures 1 and 2 for details of the evaluated systems.

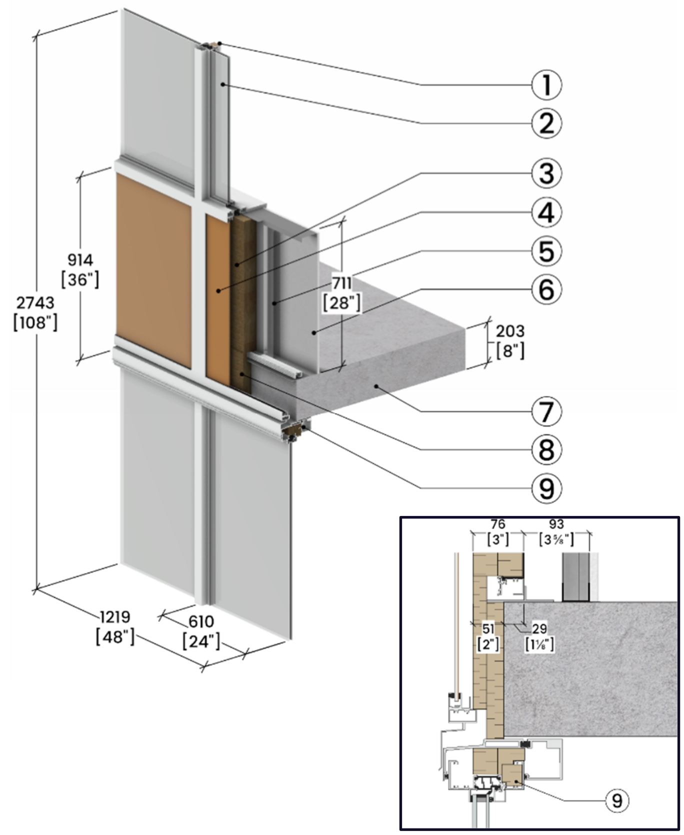
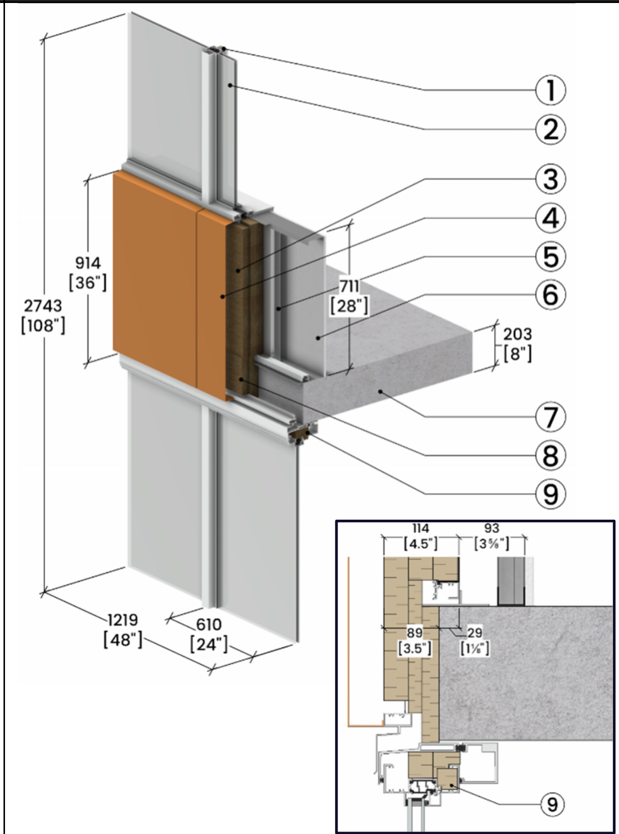
	Baseline System	Raised Panel System
		
Frame	1. Insulated aluminum frames, including couplers and deflection head	1. Insulated aluminum frames, including couplers and deflection head
Vision	2. Double glazed IGU (Low-E on #2, ½" argon space) and warm edge spacer.	2. Double glazed IGU (Low-E on #2, ½" argon space) and warm edge spacer.
Spandrel	3. 3" of mineral wool in pack pan 4. Single lite spandrel glass	3. 4.5" of mineral wool in pack pan 4. 2" raised metal panel
Back-up	5. Steel-framed wall with 1 5/8-inch steel studs inboard the back-pan 2 inches (3 5/8 inches total cavity), 6. Wood sill and 1/2 in drywall interior finishes.	5. Steel-framed wall with 1 5/8-inch steel studs inboard the back-pan 2 inches (3 5/8 inches total cavity), 6. Wood sill and 1/2 in drywall interior finishes.
Bypass	7. 8" concrete floor slab 8. 2" mineral wool outboard of concrete floor slab 9. Deflection head thermal break at concrete edge	7. 8" concrete floor slab 8. 3.5" mineral wool outboard of concrete floor slab 9. Deflection head thermal break at concrete edge

Figure 1. Geometry and Components for the Upstand Spandrel Scenarios

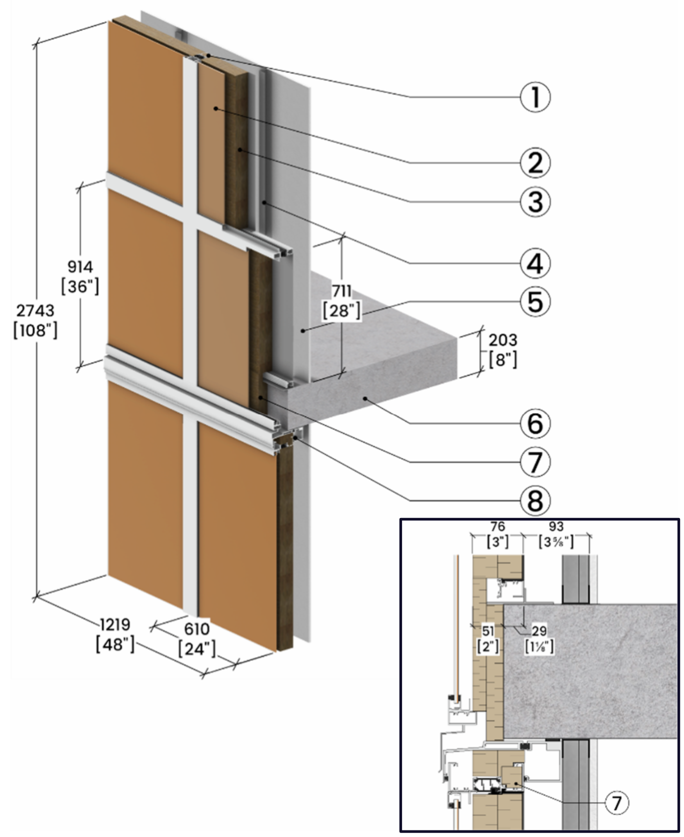
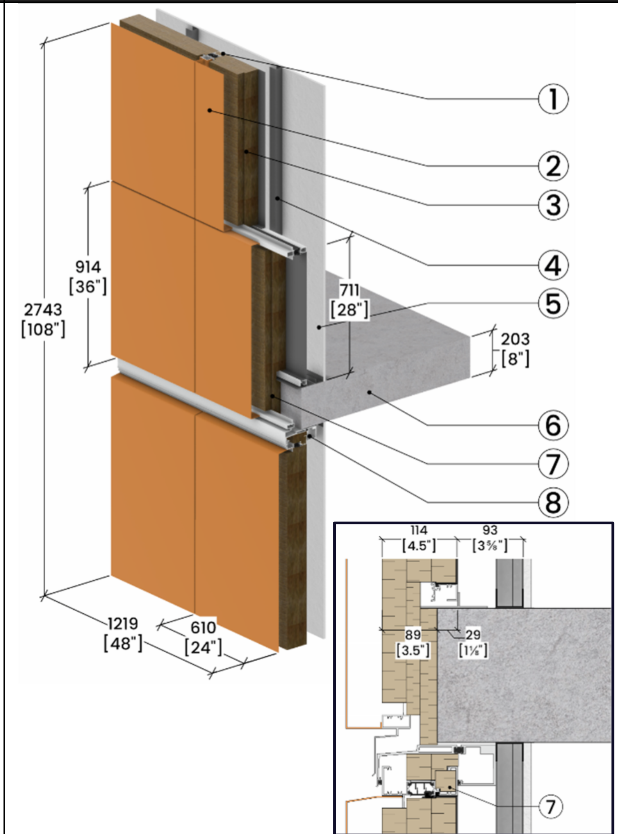
	Baseline System	Raised Panel System
		
Frame	1. Insulated aluminum frames, including couplers and deflection head	1. Insulated aluminum frames, including couplers and deflection head
Spandrel	2. 3” of mineral wool in pack pan 3. Single lite spandrel glass	2. 4.5” of mineral wool in pack pan 3. 2” raised metal panel
Back-up	4. Steel-framed wall with 1 5/8-inch steel studs inboard the back-pan 2 inches (3 5/8 inches total cavity), 5. Wood sill and 1/2 inch drywall interior finishes.	4. Steel-framed wall with 1 5/8-inch steel studs inboard the back-pan 2 inches (3 5/8 inches total cavity), 5. Wood sill and 1/2 inch drywall interior finishes.
Bypass	6. 8” concrete floor slab 7. 2” mineral wool outboard of concrete floor slab 8. Deflection head thermal break at concrete edge	6. 8” concrete floor slab 7. 3.5” mineral wool outboard of concrete floor slab 8. Deflection head thermal break at concrete edge

Figure 2. Geometry and Components for the Full height Spandrel Scenarios

The evaluation of the baseline and the raised panel 9200 series window wall systems included the following eight scenarios:

1. **Baseline - Upstand Spandrel Section:** As shown in Figure 1 above.
2. **Baseline - Upstand Spandrel Section with Inboard Insulation:** The same geometry as Scenario 1, with additional insulation within the backup wall on the interior side of the back pan. Two options were analyzed, the addition of 1-inch mineral wool (R-4.2) and 2" mineral wool (R-8.4).
3. **Baseline - Full Height Spandrel:** As shown in Figure 2 above.
4. **Baseline - Full Height Spandrel with Inboard Insulation:** The same geometry as Scenario 3, with additional insulation within the backup wall on the interior side of the back pan. Two options were analyzed, the addition of 1-inch mineral wool (R-4.2) and 2-inch mineral wool (R-8.4).
5. **Raised Panel - Upstand Spandrel Section:** As shown in Figure 1 above.
6. **Raised Panel - Upstand Spandrel Section with Inboard Insulation:** The same geometry as Scenario 5, with additional insulation within the backup wall on the interior side of the back pan. Two options were analyzed, the addition of 1-inch mineral wool (R-4.2) and 2" mineral wool (R-8.4).
7. **Raised Panel - Full Height Spandrel:** As shown in Figure 2 above.
8. **Raised Panel - Full Height Spandrel with Inboard Insulation:** The same geometry as Scenario 7, with additional insulation within the backup wall on the interior side of the back pan. Two options were analyzed, the addition of 1-inch mineral wool (R-4.2) and 2-inch mineral wool (R-8.4).

The geometry of the evaluated systems is based on drawings provided by Starline Windows and are presented in Appendix A.

Methodology

The thermal analysis was done using 3D thermal simulation using the Simcenter 3D software package from Siemens, which is a general-purpose computer aided design (CAD) and finite element analysis (FEA) package. The thermal solver and modeling procedures utilized for this evaluation were extensively calibrated and validated to within +/- 5% of hotbox testing[1,2,3]. The thermal analysis utilized steady-state conditions, published thermal data for materials, and information provided by Starline Windows.

Glazing air cavities and film coefficients are based on ISO 10077-2:2017 "Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames". Boundary conditions were modeled using heat transfer coefficients for convection (i.e. film

[1] ASHARE Research Project 1365-RP, Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction, 2011

[2] AISI Research Report RP18-1, Thermal Analysis of Cold-Formed Steel Wall Assemblies, 2018

[3] Building Envelope Thermal Bridging Guide, Version 1.6, 2021

coefficients). Radiation was directly simulated for the glass and framing exposed directly to the interior and exterior environment. Additional assumptions for the thermal analysis are provided in Appendix B.

For the condensation risk analysis, the temperature index (refer to Appendix B) was determined at the identified locations for the following interior and exterior winter design conditions.

- Interior temperature: 21°C
- Vancouver, BC design temperature: -7°C
- Edmonton, AB design temperature: -30°C

Surface temperatures due to average steady-state conductive heat flow in three-dimensions were utilized as a means of highlighting where the critical temperature locations are. Recognize that the objective of this analysis is not to predict in-service surface temperature subject to transient conditions, air leakage, variable heating systems, and/or limitations of this modeling approach.

Thermal Transmittance Results

The evaluated systems include thermal transmittances for the clear field assembly, spandrel with the slab, and the bypass linear transmittance. Figure 3 shows the model and components for each type of thermal transmittance and effective R-values for the upstand and full height spandrel systems.

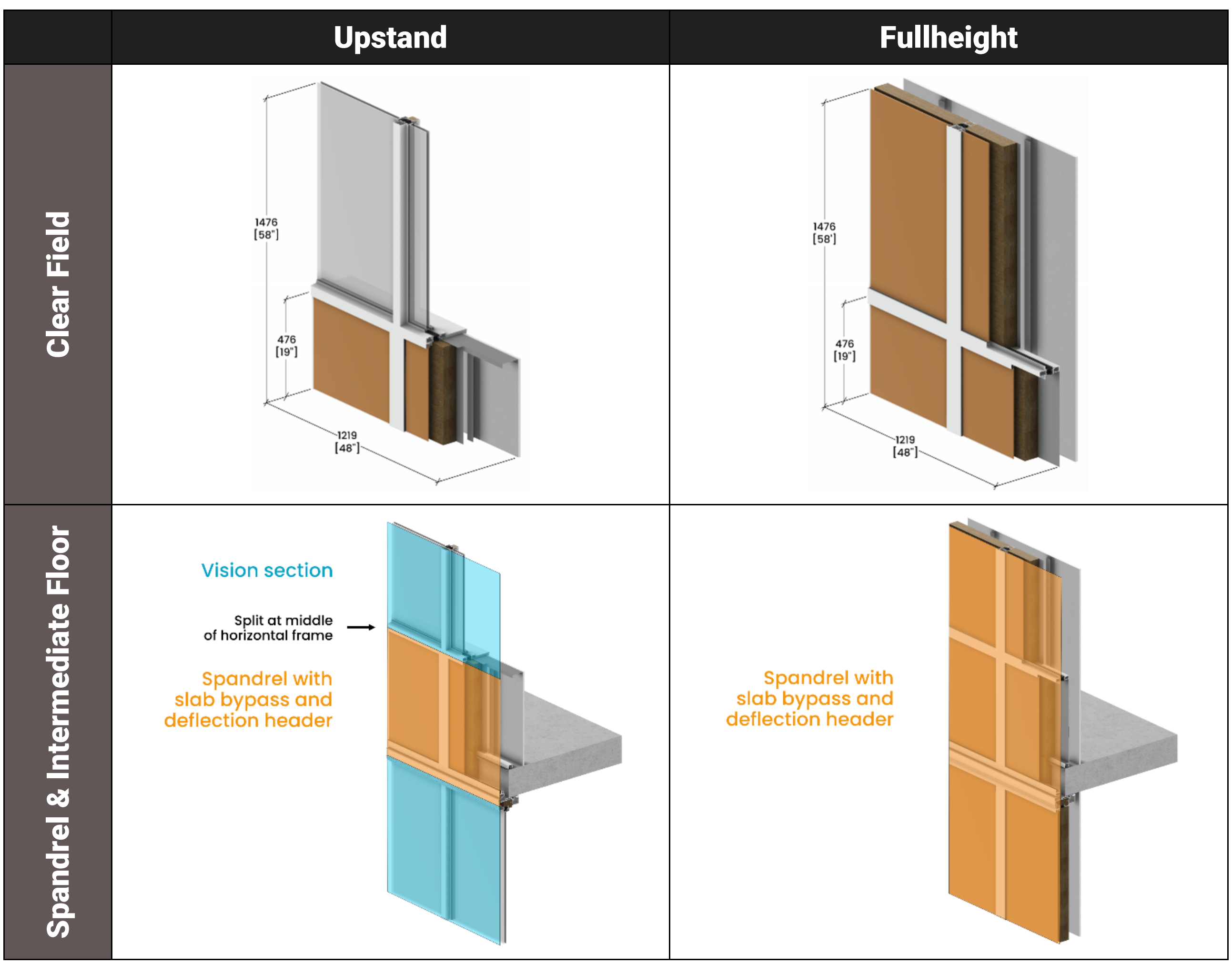


Figure 3. Model and Components Included Thermal Transmittances

The thermal transmittance for the vision section without the impact of the deflection header is shown in Table 1. The same vision performance is assumed for both the baseline and raised panel systems.

Table 1. Thermal Transmittances of Vision Section for Upstand Scenarios

Component	U-Value Btu/h ft² °F (W/m² °K)	Effective R-Value h ft² °F / Btu (m² °K/ W)
Vision section without deflection header	0.283 (1.61)	3.5 (0.621)

Baseline Starline 9200 System

The assembly thermal transmittances bypass linear transmittances and effective R-values for the Baseline Starline 9200 Window Wall System are presented in Tables 2 and 3. Additional assembly details and material properties are provided in Appendix A and B.

Example temperature profiles for each scenario and linear transmittances for the window sill-to-spandrel interface can be found in Appendix C. The window sill-to-spandrel linear transmittances can be utilized to estimate the clear field spandrel for other upstand spandrel heights.

Table 2. Thermal Transmittances for Baseline Starline 9200 System: Upstand Spandrel

Scenario	Inboard Insulation Nominal R-Value	Clear Field Spandrel		Spandrel with Slab		Bypass Linear Transmittance
		U_o	R_o	U_s	R_s	Ψ_{bypass}
	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	Btu/h ft °F (W/m °K)
Baseline	R-0.0 (0.00)	0.086 (0.487)	R-11.6 (2.05)	0.192 (1.09)	R-5.2 (0.92)	0.314 (0.543)
1" Inboard Insulation	R-4.2 (0.74)	0.074 (0.420)	R-13.5 (2.38)	0.184 (1.05)	R-5.4 (0.96)	0.324 (0.561)
2" Inboard Insulation	R-8.4 (1.48)	0.069 (0.394)	R-14.4 (2.54)	0.180 (1.03)	R-5.5 (0.98)	0.326 (0.565)

Table 3. Thermal Transmittances for Baseline Starline 9200 System: Full Height Spandrel

Scenario	Inboard Insulation Nominal R-Value	Clear Field Spandrel		Spandrel with Slab		Bypass Linear Transmittance
		U_o	R_o	U_s	R_s	Ψ_{bypass}
	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	Btu/h ft °F (W/m °K)
Baseline	R-0.0 (0.00)	0.083 (0.474)	R-12.0 (2.11)	0.111 (0.629)	R-9.0 (1.59)	0.246 (0.427)
1" Inboard Insulation	R-4.2 (0.74)	0.061 (0.347)	R-16.3 (2.88)	0.092 (0.521)	R-10.9 (1.92)	0.275 (0.476)
2" Inboard Insulation	R-8.4 (1.48)	0.049 (0.276)	R-20.6 (3.62)	0.081 (0.458)	R-12.4 (2.18)	0.289 (0.500)

Raised Panel Starline 9200 System

The assembly thermal transmittances bypass linear transmittances and effective R-values for the Raised Panel Starline 9200 Window Wall System are presented in Tables 4 and 5. Additional assembly details and material properties are provided in Appendix A and B.

Example temperature profiles for each scenario and linear transmittances for the window sill-to-spandrel interface can be found in Appendix C.

Table 4. Thermal Transmittances for Raised Panel Starline 9200 System: Upstand Spandrel

Scenario	Inboard Insulation Nominal R-Value	Clear Field Spandrel		Spandrel with Slab		Bypass Linear Transmittance
		U_o	R_o	U_s	R_s	Ψ_{bypass}
	ft2 hr °F/Btu (m2 K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	ft2 hr °F/Btu (m2 K/W)
Baseline	R-0.0 (0.00)	0.071 (0.401)	R-14.1 (2.49)	0.176 (1.002)	R-5.7 (1.00)	0.309 (0.535)
1" Inboard Insulation	R-4.2 (0.74)	0.062 (0.355)	R-16.0 (2.82)	0.171 (0.970)	R-5.9 (1.03)	0.316 (0.547)
2" Inboard Insulation	R-8.4 (1.48)	0.059 (0.334)	R-17.0 (2.99)	0.168 (0.956)	R-5.9 (1.05)	0.319 (0.552)

Table 5. Thermal Transmittances for Raised Panel Starline 9200 System: Full Height Spandrel

Scenario	Inboard Insulation Nominal R-Value	Clear Field Spandrel		Spandrel with Slab		Bypass Linear Transmittance
		U_o	R_o	U_s	R_s	Ψ_{bypass}
	ft2 hr °F/Btu (m2 K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	ft² hr °F/Btu (m² K/W)	ft2 hr °F/Btu (m2 K/W)
Baseline	R-0.0 (0.00)	0.073 (0.414)	R-13.7 (2.41)	0.109 (0.619)	R-9.2 (1.61)	0.325 (0.562)
1" Inboard Insulation	R-4.2 (0.74)	0.055 (0.312)	R-18.2 (3.20)	0.091 (0.519)	R-10.9 (1.93)	0.327 (0.566)
2" Inboard Insulation	R-8.4 (1.48)	0.045 (0.253)	R-22.5 (3.95)	0.082 (0.464)	R-12.2 (2.16)	0.334 (0.578)

Condensation Risk

The condensation risk was evaluated for the climates of Vancouver, BC and Edmonton, AB based on the 2.5% January Design Temperatures from NECB 2020. Table 6 illustrates the minimum allowable temperature indices per various indoor humidity for surfaces exposed to interior air and the following conditions:

- Exterior Temperature Vancouver, BC: -7°C
- Exterior Temperature Edmonton, AB: -30°C
- Interior Temperature: 21°C

Table 6. Temperature Indices to Meet Condensation Risk Criteria

Indoor Relative Humidity	Interior Temperature, °C	Indoor Air Dewpoint, °C	Minimum Allowable Temperature Index for Vancouver, BC	Minimum Allowable Temperature Index for Edmonton, AB
25%	21.0	0.21	0.26	0.59
30%	21.0	2.78	0.35	0.64
35%	21.0	4.99	0.43	0.69
50%	21.0	10.22	0.62	0.79
60%	21.0	12.98	0.71	0.84

Baseline Starline 9200 System

Table 7 provides the temperature index (T_i) at various locations for the upstand spandrel section shown in Figure 4. Tables 8 and 9 outline the surface temperature and maximum interior RH levels at various locations for Vancouver, BC and Edmonton, AB.

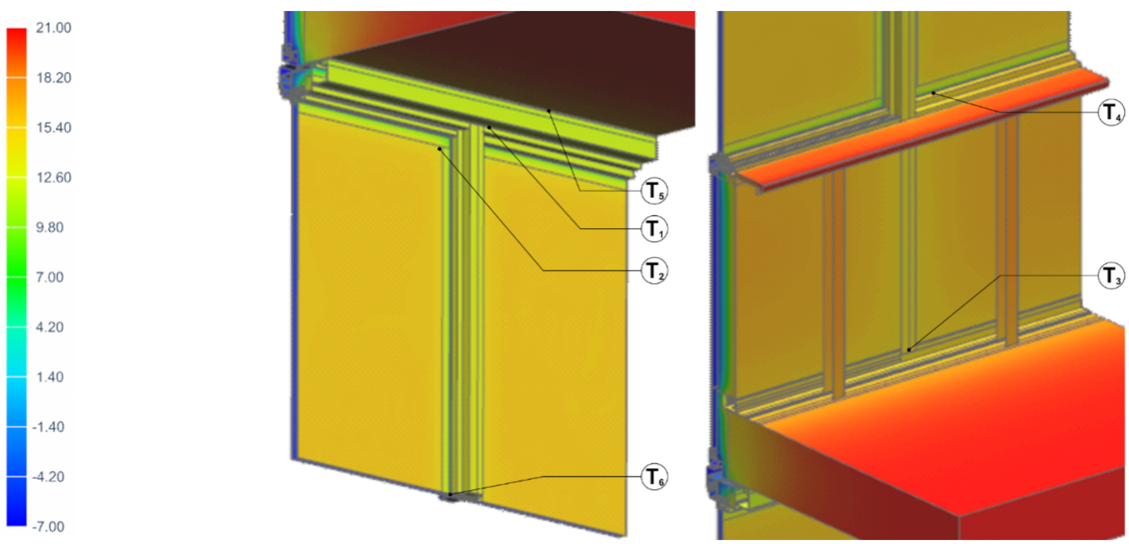


Figure 4. Location of the Minimum Temperatures for Scenarios 1 and 2. Illustrated on the Baseline System for Vancouver, BC

Table 7. Temperature Indices for Baseline Starline 9200 System: Upstand Spandrel

Scenario	Inboard Insulation Nominal R-Value ft² hr °F/Btu (m2 °K/W)	Temperature Location T_1	T_2	T_3	T_4	T_5	T_6
Baseline	R-0.0 (0.00)	0.66	0.71	0.77	0.77	0.79	0.73
1" Inboard Insulation	R-4.2 (0.74)	0.67	0.71	0.69	0.74	0.78	0.73
2" Inboard Insulation	R-8.4 (1.48)	0.66	0.71	0.65	0.72	0.77	0.73

Table 8. Condensation Risk Analysis for Baseline Starline 9200 System: Upstand Spandrel for Vancouver

Scenario	Inboard Insulation Nominal R-Value	Temperature Location											
		T_1		T_2		T_3		T_4		T_5		T_6	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	11.6	55%	12.8	59%	14.7	67%	14.5	67%	15.1	69%	13.5	62%
1" Inboard Insulation	R-4.2 (0.74)	11.9	56%	12.8	59%	12.2	57%	13.8	63%	14.9	68%	13.3	61%
2" Inboard Insulation	R-8.4 (1.48)	11.4	54%	12.7	59%	11.2	53%	13.2	61%	14.7	67%	13.5	62%

Table 9. Condensation Risk Analysis for Baseline Starline 9200 System: Upstand Spandrel for Edmonton

Scenario	Inboard Insulation Nominal R-Value	Temperature Location											
		T_1		T_2		T_3		T_4		T_5		T_6	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	3.8	32%	6.0	38%	9.5	48%	9.2	47%	10.2	50%	7.4	41%
1" Inboard Insulation	R-4.2 (0.74)	4.4	34%	6.1	38%	4.9	35%	7.8	43%	10.0	49%	7.0	40%
2" Inboard Insulation	R-8.4 (1.48)	3.5	31%	6.0	37%	3.1	31%	6.8	40%	9.5	48%	7.4	41%

Table 10 provides the temperature index (T_i) at various locations for the full height spandrel section shown in Figure 5. Tables 11 and 12 outline the surface temperature and maximum interior RH levels at various locations for Vancouver, BC and Edmonton, AB.

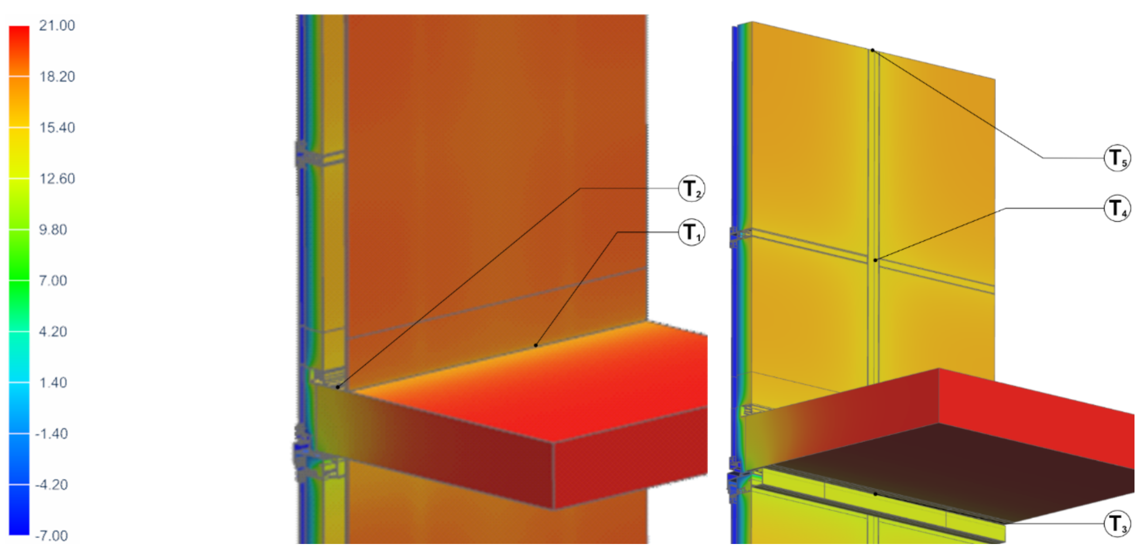


Figure 5. Location of the Minimum Temperatures for Scenarios 3 and 4. Illustrated on the Baseline Full Height Spandrel Section for Vancouver, BC

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Table 10. Temperature Indices for Baseline Starline 9200 System: Full Height Spandrel

Scenario	Inboard Insulation Nominal R-Value	Temperature Location				
	ft² hr °F/Btu (m² °K/W)	T_1	T_2	T_3	T_4	T_5
Baseline	R-0.0 (0.00)	0.86	0.78	0.70	0.76	0.77
1" Inboard Insulation	R-4.2 (0.74)	0.83	0.73	0.66	0.55	0.55
2" Inboard Insulation	R-8.4 (1.48)	0.82	0.68	0.60	0.45	0.45

Table 11. Condensation Risk Analysis for Baseline Starline 9200 System: Full Height Spandrel for Vancouver

Scenario	Inboard Insulation Nominal R-Value	Temperature Location									
		T_1		T_2		T_3		T_4		T_5	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	17.0	78%	15.0	68%	12.7	59%	14.4	66%	14.6	67%
1" Inboard Insulation	R-4.2 (0.74)	16.3	75%	13.4	62%	11.5	54%	8.5	45%	8.5	44%
2" Inboard Insulation	R-8.4 (1.48)	15.9	73%	12.1	57%	9.9	49%	5.5	36%	5.5	36%

Table 12. Condensation Risk Analysis for Baseline Starline 9200 System: Full Height Spandrel for Edmonton

Scenario	Inboard Insulation Nominal R-Value	Temperature Location									
		T_1		T_2		T_3		T_4		T_5	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	13.7	63%	10.0	49%	5.9	37%	9.0	46%	9.3	47%
1" Inboard Insulation	R-4.2 (0.74)	12.5	58%	7.1	41%	3.6	32%	-1.7	21%	-1.9	21%
2" Inboard Insulation	R-8.4 (1.48)	11.7	55%	4.8	35%	0.8	26%	-7.3	13%	-7.3	13%

Raised Panel Starline 9200 System

Table 13 provides the temperature index (T_i) at various locations for the raised panel upstand spandrel section shown in Figure 6. Tables 14 and 15 outline the surface temperature and maximum interior RH levels at various locations for Vancouver, BC and Edmonton, AB.

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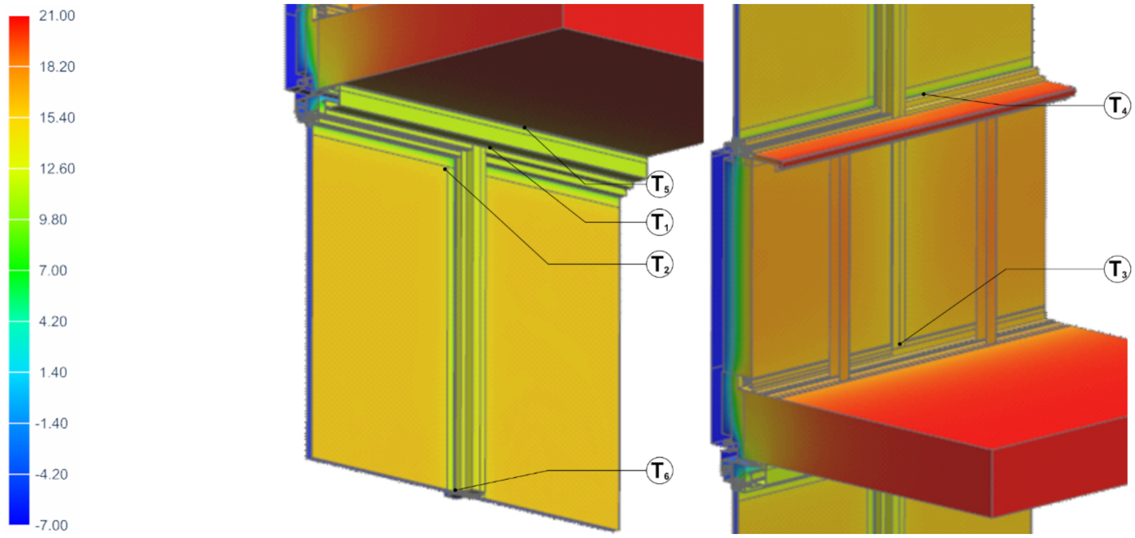


Figure 6. Location of the Minimum Temperatures for Scenario 5 and 6. Illustrated on the Raised Panel Upstand Spandrel Section for Vancouver, BC

Table 13. Temperature Indices for Raised Panel Starline 9200 System: Upstand Spandrel

Scenario	Inboard Insulation Nominal R-Value	Temperature Location					
	ft² hr °F/Btu (m2 °K/W)	T_1	T_2	T_3	T_4	T_5	T_6
Baseline	R-0.0 (0.00)	0.67	0.71	0.81	0.78	0.80	0.72
1" Inboard Insulation	R-4.2 (0.74)	0.66	0.71	0.71	0.75	0.79	0.72
2" Inboard Insulation	R-8.4 (1.48)	0.66	0.71	0.68	0.73	0.78	0.72

Table 14. Condensation Risk Analysis for Raised Panel Starline 9200 System: Upstand Spandrel for Vancouver

Scenario	Inboard Insulation Nominal R-Value	Temperature Location											
		T_1		T_2		T_3		T_4		T_5		T_6	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	11.7	55%	12.8	59%	15.6	71%	14.8	68%	15.3	70%	13.3	61%
1" Inboard Insulation	R-4.2 (0.74)	11.6	55%	12.8	59%	12.9	60%	13.9	64%	15.1	69%	13.3	61%
2" Inboard Insulation	R-8.4 (1.48)	11.5	55%	12.8	59%	12.1	57%	13.6	62%	14.9	68%	13.3	61%

Table 15. Condensation Risk Analysis for Raised Panel Starline 9200 System: Upstand Spandrel for Edmonton

Scenario	Inboard Insulation Nominal R-Value	Temperature Location											
		T_1		T_2		T_3		T_4		T_5		T_6	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	4.06	33%	6.01	38%	11.2	53%	9.69	48%	10.6	51%	6.92	40%
1" Inboard Insulation	R-4.2 (0.74)	3.88	32%	6.01	38%	6.26	38%	8.14	44%	10.2	50%	6.92	40%
2" Inboard Insulation	R-8.4 (1.48)	3.75	32%	5.99	38%	4.73	34%	7.47	42%	9.93	49%	6.92	40%

Table 16 provides the temperature index (T_i) at various locations for the full height spandrel section shown in Figure 7. Tables 17 and 17 outline the surface temperature and maximum interior RH levels at various locations for Vancouver, BC and Edmonton, AB.

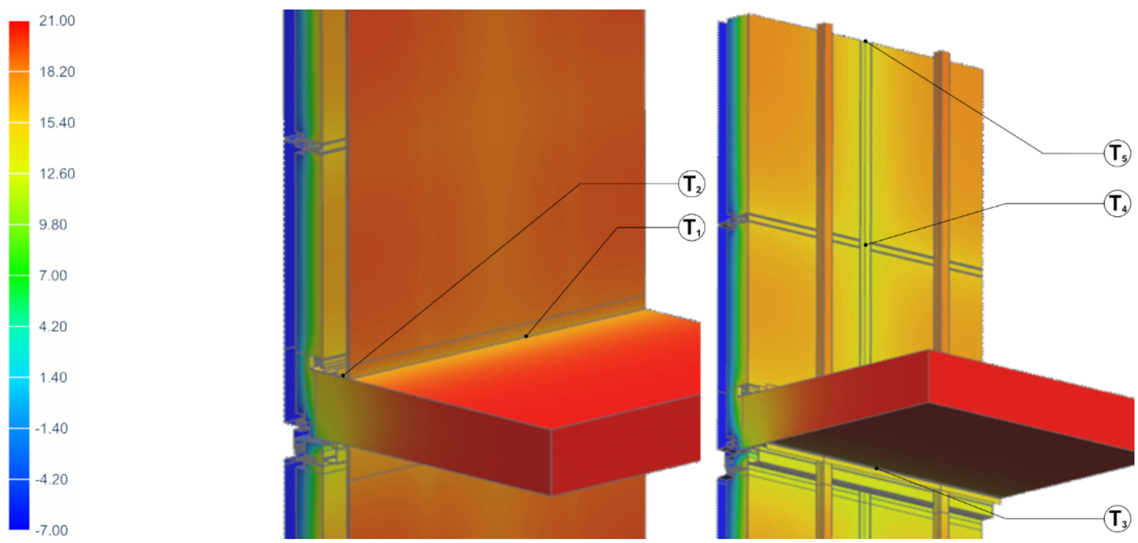


Figure 7. Location of the Minimum Temperatures for Scenario 5 and 6. Illustrated on the Raised Panel Upstand Spandrel Section for Vancouver, BC

Table 16. Temperature Indices for Raised Panel Starline 9200 System: Full Height Spandrel

Scenario	Inboard Insulation Nominal R-Value	Temperature Location				
	ft² hr °F/Btu (m² °K/W)	T_1	T_2	T_3	T_4	T_5
Baseline	R-0.0 (0.00)	0.85	0.78	0.71	0.68	0.74
1" Inboard Insulation	R-4.2 (0.74)	0.83	0.72	0.67	0.52	0.52
2" Inboard Insulation	R-8.4 (1.48)	0.81	0.68	0.63	0.42	0.42

Table 17. Condensation Risk Analysis for Raised Panel Starline 9200 System: Full Height Spandrel for Vancouver

Scenario	Inboard Insulation Nominal R-Value	Temperature Location									
		T_1		T_2		T_3		T_4		T_5	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	16.7	77%	14.7	67%	12.8	60%	12.1	57%	13.6	63%
1" Inboard Insulation	R-4.2 (0.74)	16.1	74%	13.2	61%	11.7	55%	7.6	42%	7.6	42%
2" Inboard Insulation	R-8.4 (1.48)	15.7	72%	12.0	56%	10.6	51%	4.8	35%	4.8	35%

Table 18. Condensation Risk Analysis for Baseline Starline 9200 System: Full Height Spandrel for Edmonton

Scenario	Inboard Insulation Nominal R-Value	Temperature Location									
		T_1		T_2		T_3		T_4		T_5	
		Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH	Surface Temperature	Maximum RH
	ft² hr °F/Btu (m2 °K/W)	°C	%	°C	%	°C	%	°C	%	°C	%
Baseline	R-0.0 (0.00)	13.2	61%	9.58	48%	6.14	38%	4.7	34%	7.49	42%
1" Inboard Insulation	R-4.2 (0.74)	12.1	57%	6.74	40%	3.97	33%	-3.4	19%	-3.3	19%
2" Inboard Insulation	R-8.4 (1.48)	11.4	54%	4.63	34%	2.02	28%	-8.5	12%	-8.5	12%

Closing

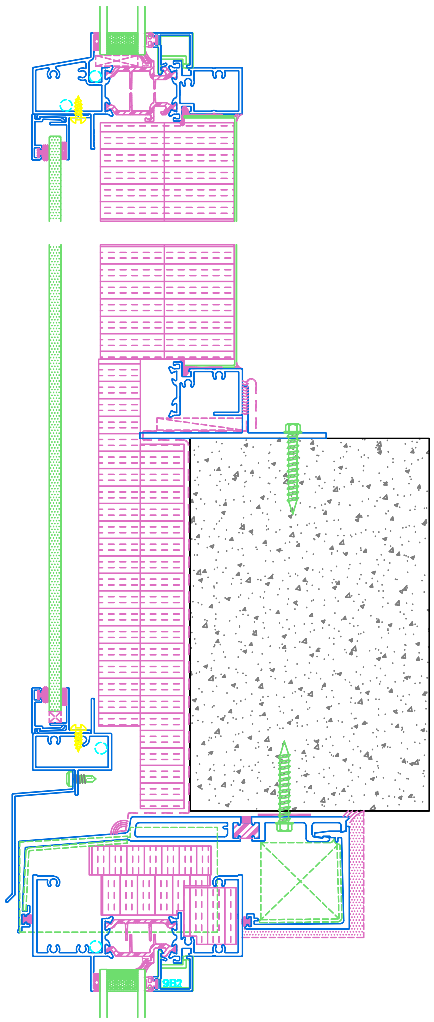
We believe that this report meets your objectives for the thermal evaluation of the Starline 9200 series window wall system. Please do not hesitate to contact us with any questions regarding this evaluation.

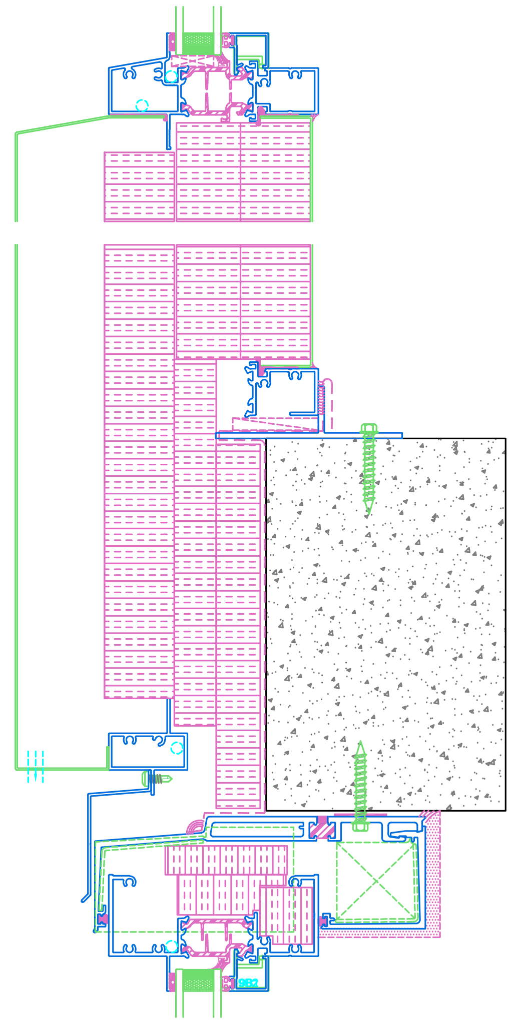
Evoke Buildings Engineering Inc.

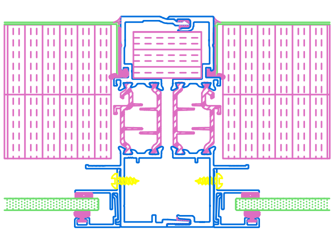
Susannah Coons
Building Science Consultant

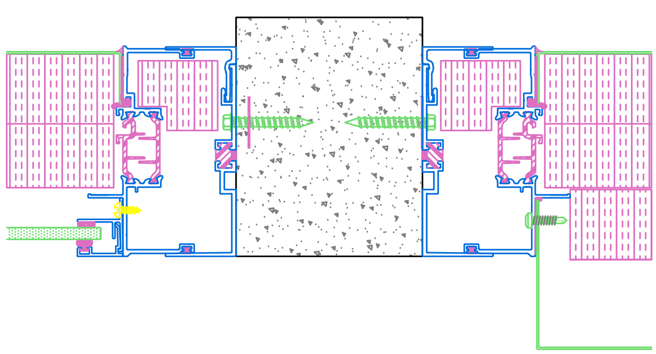
Patrick Roppel, P.Eng.
Building Science Specialist

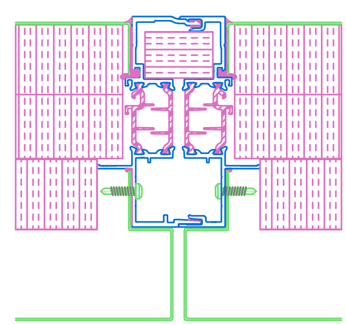
Appendix A: Detail Drawings and Datasheets











Appendix B: Simulation Assumptions and Material Properties

General Assumptions

Steady-state simulations were utilized for the thermal evaluation outlined in this report with the following assumptions:

1. Material properties were taken from the 2017 ASHARE Handbook – Fundamentals for common materials and information provided by Starline Windows.
2. Enclosed air spaces were modelled with an equivalent thermal conductivity of the air that includes the impacts of convection and radiation within the enclosure. Calculations for this equivalent conductivity are based on ISO 10077.
3. Interior/exterior air films were taken from Table 10, p. 26.21 of 2017 ASHRAE Handbook – Fundamentals depending on surface orientation. The exterior air films were based on an exterior windspeed of 6.7 m/s.
4. Interior glazing surface air films were modelled with separate radiation and convection coefficients to the interior with a view factor of 1.
5. Insulation and other components were considered tight to adjacent interfaces.
6. For the condensation risk evaluation, the exterior temperature was taken from 2020 NECB 2.5% January Design Condition.

Temperature Index

The temperature index is the ratio of the surface temperature relative to the interior and exterior temperatures. The temperature index has a value between 0 and 1, where 0 is the exterior temperature and 1 is the interior temperature per the following equation:

$$T_i = \frac{T_{suface} - T_{outside}}{T_{inside} - T_{outside}}$$

This formula can be rearranged for $T_{surface}$ to determine the surface temperatures for any climate once the temperature index is known for a critical location to evaluate the condensation risk. The temperature indices shown in the temperature profiles in Appendix C are for general information and not intended to predict in-service temperatures subject to transient conditions, variable heating systems, and/or obstructions that restrict heat getting to the wall system. Refer to ASHRAE 1365-RP for a full discussion on the limitations of using steady-state temperature indices for evaluating condensation risk.

Boundary Conditions

Table B-1. Boundary Conditions

Boundary Condition	Heat Transfer Coefficient Btu/ft²·hr·°F (W/m² K)
Radiation Directly Simulated	
Exterior center of glass	4.6 (26)
Interior glass	0.38 (2.2)
Frame exposed to interior air	0.53 (3)
Combined Convective and Radiative Coefficient	
Exterior spandrel and metal panel	6 (34)
Interior floor	1.1 (6.1)
Interior ceiling	1.6 (9.3)
Interior vertical surface	1.5 (8.3)

Material Properties

Table B-2. Material Properties

Component	Material	Thermal Conductivity Btu · in/ft² · hr·°F (W/m K)
IGU		
Glass	Clear glass	6.9 (1.0)
Spacer box	Warm edge spacer	2.1 (0.31)
Spacer primary seal	Silicone	2.4 (0.35)
Gaskets	Santoprene	1.0 (0.14)
Polyshim II tape	Butyl	1.7 (0.24)
Window Wall		
Frame	Aluminum	1110 (160)
Thermal break	Polyamide (Nylon)	1.7 (0.25)
Sealant	Silicone	2.4 (0.35)
Frame, bypass, and back pan insulation	Mineral wool (R-4.2/in)	0.24 (0.034)
Back pan	Galvanized steel	430 (62)
Back-up Wall and Floor		
Drywall	Gypsum	1.1 (0.16)
Air cavities	Air	Varies per ISO 10077-2
Steel-framing	Galvanized steel	430 (62)
Sill	Wood	0.69 (0.10)
Floor	Concrete	12.5 (1.8)
Inboard insulation	Mineral wool (R-4.2/in)	0.24 (0.034)

Appendix C: Temperature Profiles and Window sill-to-Spandrel Transmittances

Linear transmittances for the window sill-to-spandrel interface are presented in tables C1 and C2. The window sill-to-spandrel linear transmittances can be utilized to estimate the clear field spandrel for other upstand spandrel heights. The spandrel clear field for determining the window sill-to-spandrel is the horizontal 2D section through the spandrel section.

Table C1. Window Sill-to-Spandrel Linear Transmittances for Baseline Starline 9200 System

Scenario	Inboard Insulation Nominal R-Value	Spandrel Clear Field		Sill Linear Transmittance
		U_{sill}	R_{sill}	Ψ_{sill}
	ft² hr °F/Btu (m² °K/W)	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	Btu/h ft °F (W/m °K)
Baseline	R-0 (0.00)	0.078 (0.441)	R-12.9 (2.27)	0.013 (0.022)
1" Inboard Insulation	R-4.2 (0.74)	0.058 (0.329)	R-17.2 (3.04)	0.026 (0.045)
2" Inboard Insulation	R-8.4 (1.48)	0.047 (0.264)	R-21.5 (3.78)	0.038 (0.065)

Table C2. Window Sill-to-Spandrel Linear Transmittances for Raised Panel Starline 9200 System

Scenario	Inboard Insulation Nominal R-Value	Spandrel Clear Field		Sill Linear Transmittance
		U_{sill}	R_{sill}	Ψ_{sill}
	ft² hr °F/Btu (m² °K/W)	ft² hr °F/Btu (m² K/W)	Btu/ft² hr °F (W/m² K)	Btu/h ft °F (W/m °K)
Baseline	R-0.0 (0.00)	0.061 (0.345)	R-16.4 (2.90)	0.015 (0.027)
1" Inboard Insulation	R-4.2 (0.74)	0.048 (0.271)	R-21.0 (3.69)	0.023 (0.040)
2" Inboard Insulation	R-8.4 (1.48)	0.040 (0.226)	R-25.1 (4.42)	0.030 (0.051)

The following figures illustrate the temperature distribution for the evaluated wall assembly. The profiles are presented as a temperature index (between 0 and 1). See Appendix B for more discussion on Temperature Index.

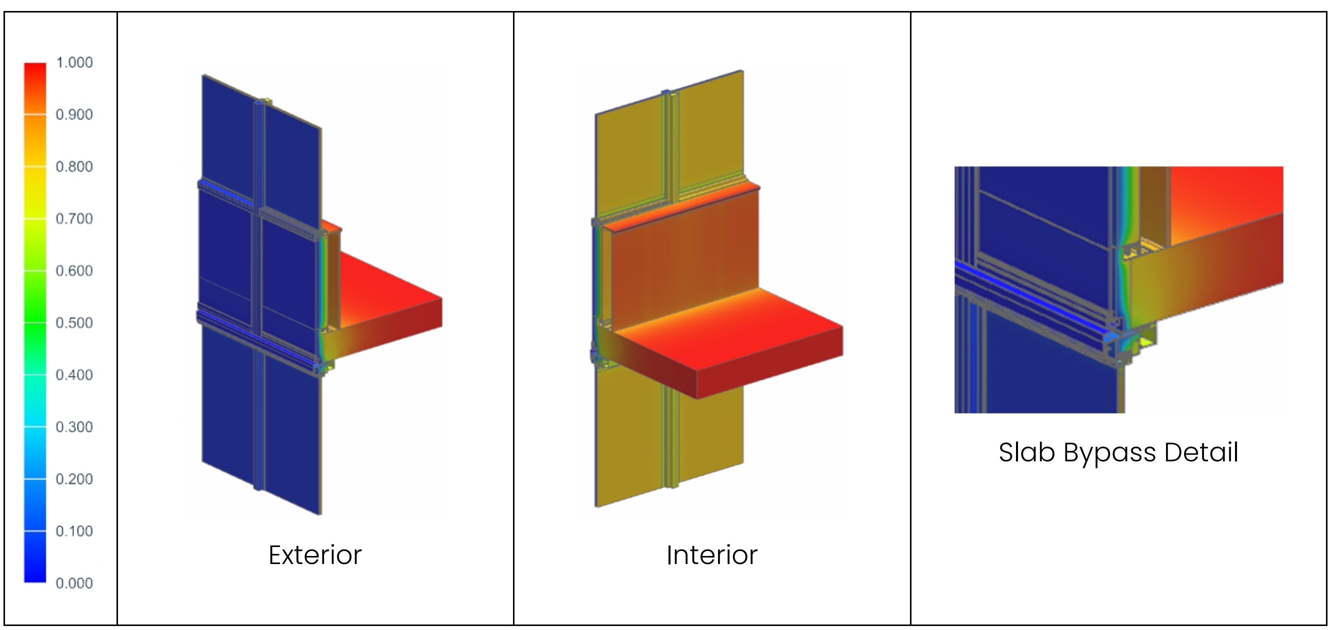


Table C1. Temperature Profile of Starline 9200 System: Baseline Upstand Spandrel Section

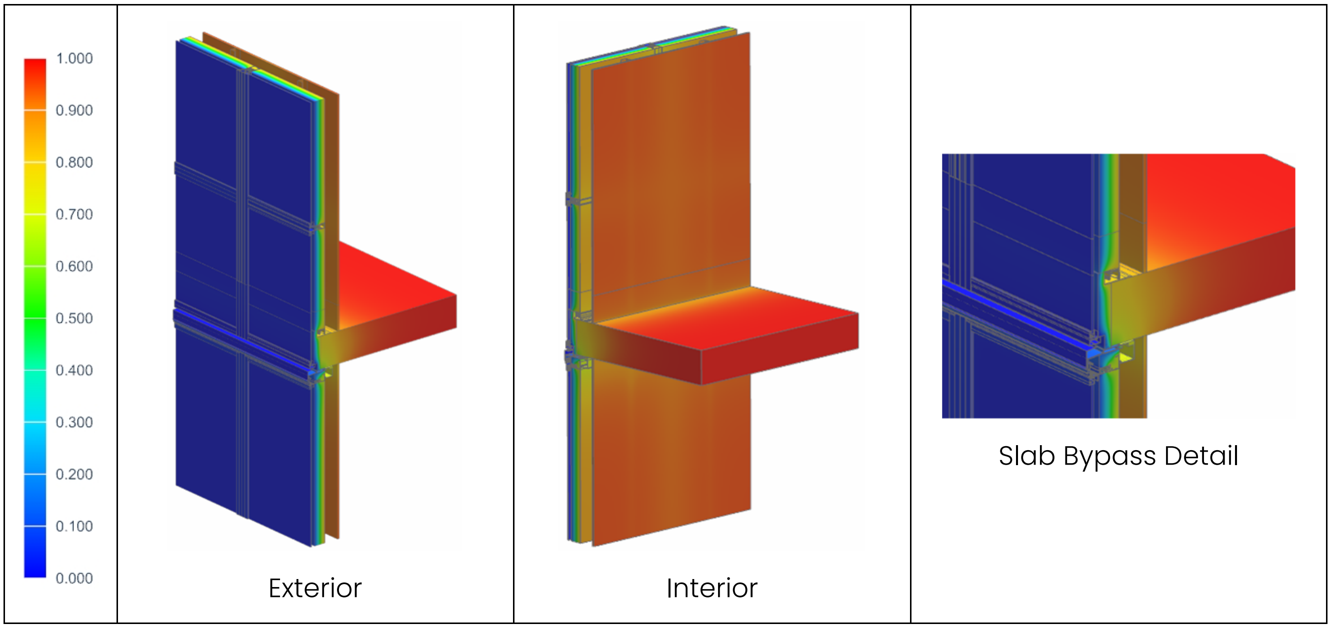


Table C2. Temperature Profile of Starline 9200 System: Baseline Full Height Spandrel Section

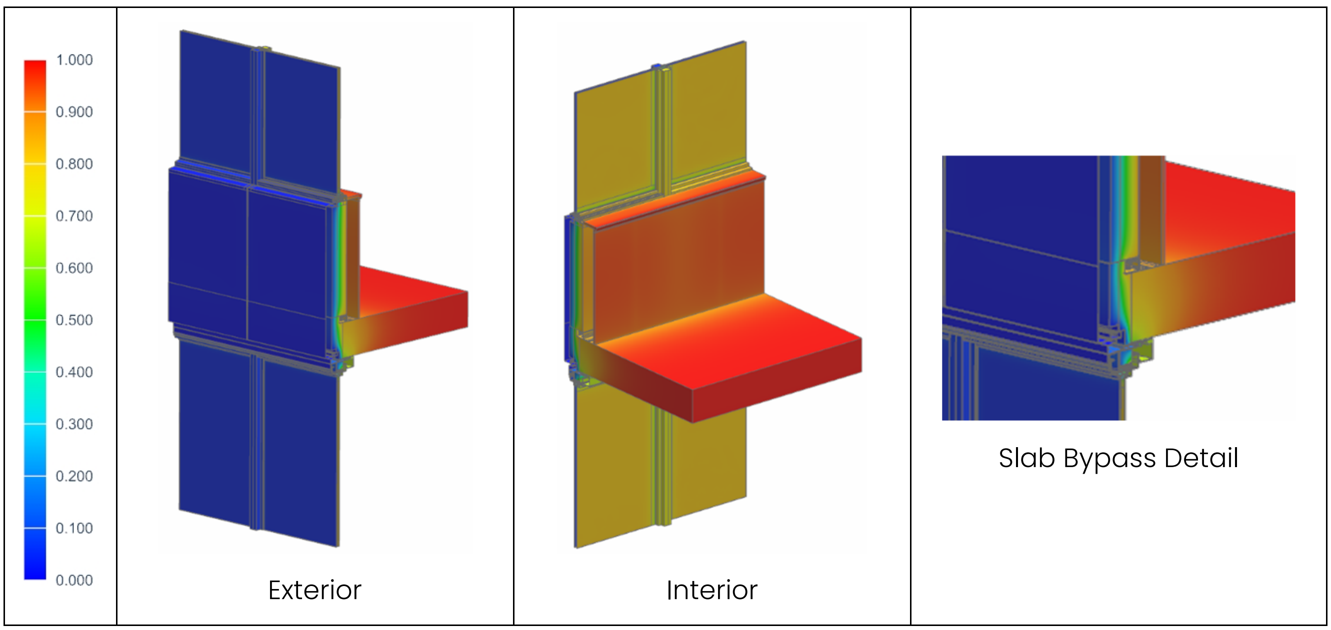


Table C3. Temperature Profile of Starline 9200 System: Raised Panel Upstand Spandrel Section

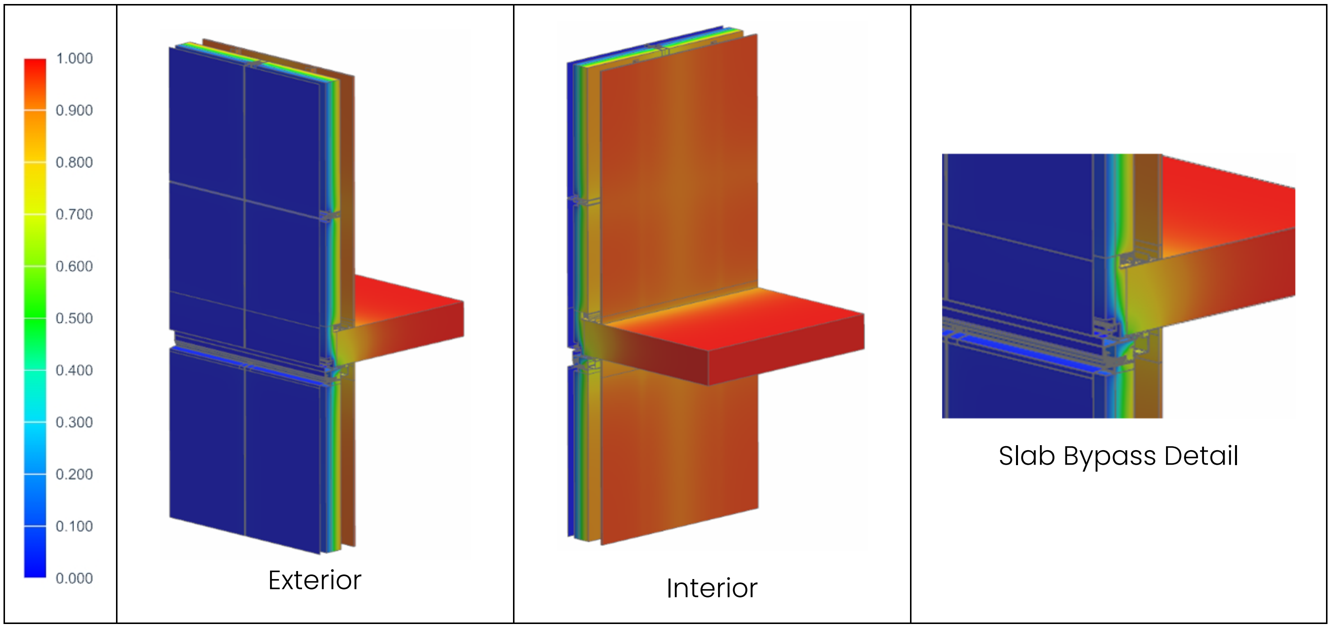


Table C4. Temperature Profile of Starline 9200 System: Raised Panel Full Height Spandrel Section