DOW CORNING

High Performance Building Solutions

MORRISON HERSHFIELD

NORTHERN FACADES

The Reality of Quantifying Curtain Wall Spandrel Thermal Performance: 2D, 3D and Hotbox Testing

BEST 4

Kansas City MO April 14, 2015

Neil Norris

Larry Carbary

Stanley Yee

Patrick Roppel

Phillip Ciantar

Learning Objectives

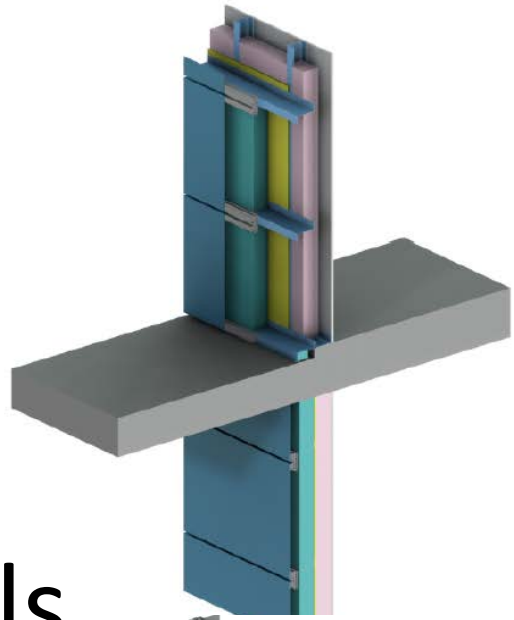
Participants will :

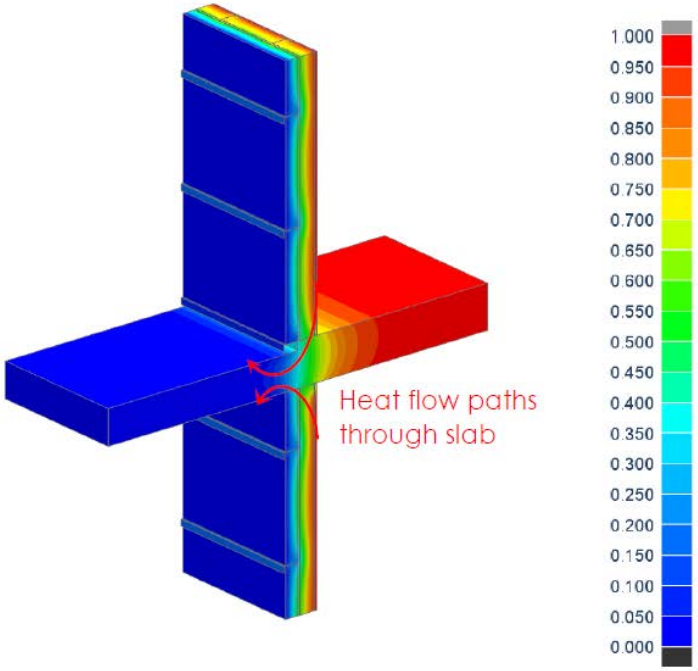
1. Learn about increasing the thermal performance of curtainwall systems
2. Learn about the performance of vacuum insulation panels incorporated into spandrels
3. See Therm 6.3 used in optimized fashion to better match testing
4. Learn about ASTM C1363 Guarded Hot Box Testing.
5. Be exposed to thermal modeling in 3D

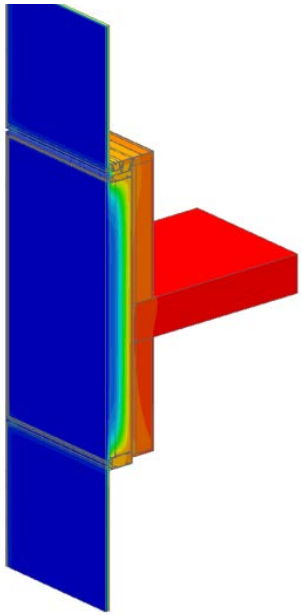
Agenda

- Introduction
- Exterior Insulation advantages ASHRAE 1365 RP
- AIM in Curtainwall
- Hot Box Testing ASTM C1363
- 2D Modeling with Therm 6.3
- 3D Modeling
- Learnings and interpretations
- Summary and Conclusions

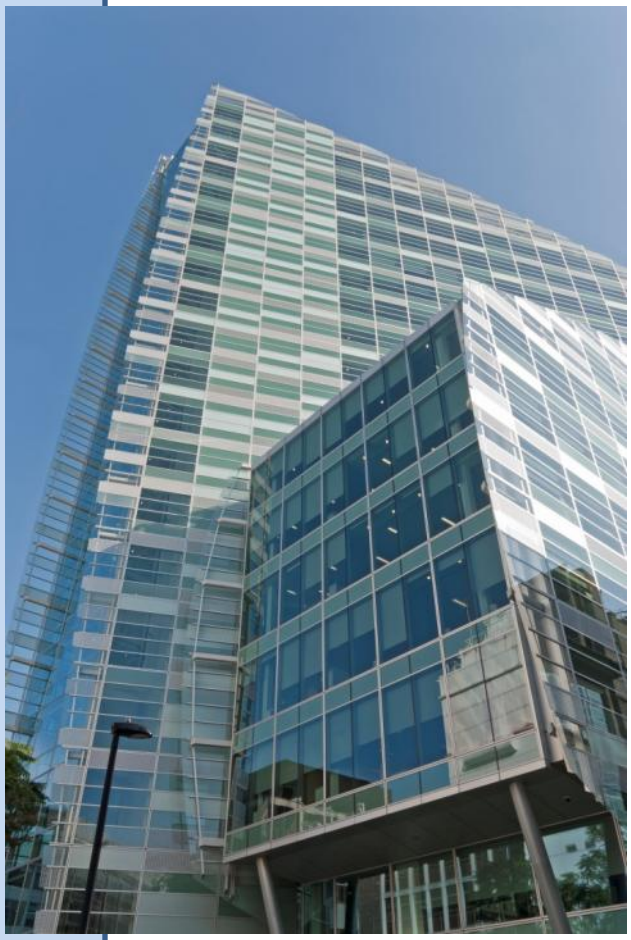
Curtainwalls do not expose slabs







VIP Enabled Spandrels Provide Superior Performance for Curtain Walls: Fact or Fiction



- Highest aesthetical and functional requirements
- Slim façade with high vision share requires lowest U-values for spandrels
- Spandrels with embedded VIP addresses need for easy installation and multiple design options

VIP integrated façade modules will enable high vision share while complying to thermal performance requirements

Typical Curtainwall

Just Add more insulation……

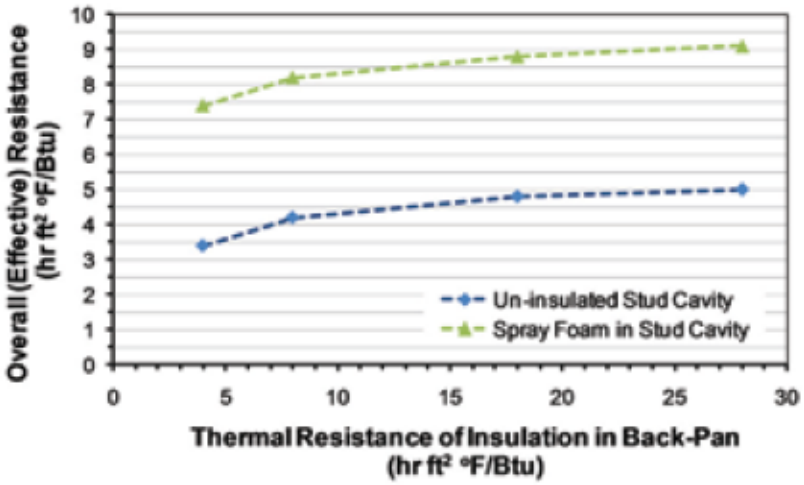


Figure 1: Diminishing Rate of Return of Spandrel Section Overall Thermal Reaction.

ASHRAE Research Project 1365 "Thermal Performance of Building Envelope Details for Mid- and High-rise Buildings"

Table 1: Overall Thermal Transmittance of Curtain Wall Spandrel Section [Btu/hr ft^2 °F (W/m^2 K)]

	Back-Pan Insulation R-Value (RSI)			
	R-4	R-8	R-18	R-28
Un-insulated Stud Cavity	0.29 (1.66)	0.24 (1.35)	0.21 (1.19)	0.20 (1.14)
Spray Foam in Stud Cavity	0.14 (0.77)	0.12 (0.69)	0.11 (0.64)	0.11 (0.63)

Product Concept: High Performance Insulation through Vacuum Insulation Panel inserts

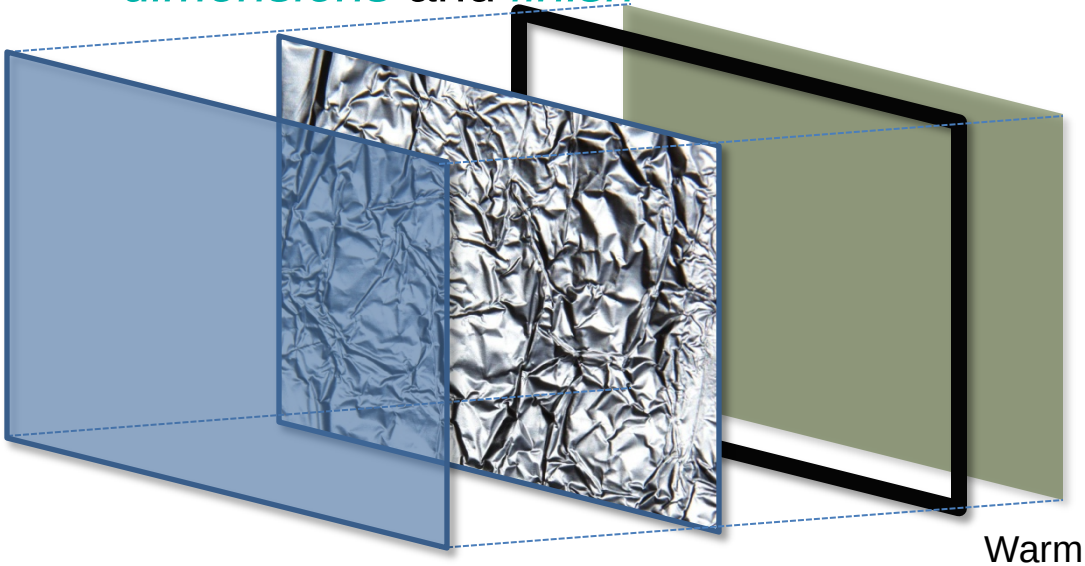
Comparative thickness for U value of ~ 0.3 W/m²K

R ~19 hr-F-ft2/BTU

*A*rchitectural *I*nsulation *M*odule

Flexible design to fit building uniqueness

Customized architectural unit: *performance*, *dimensions* and *finish*



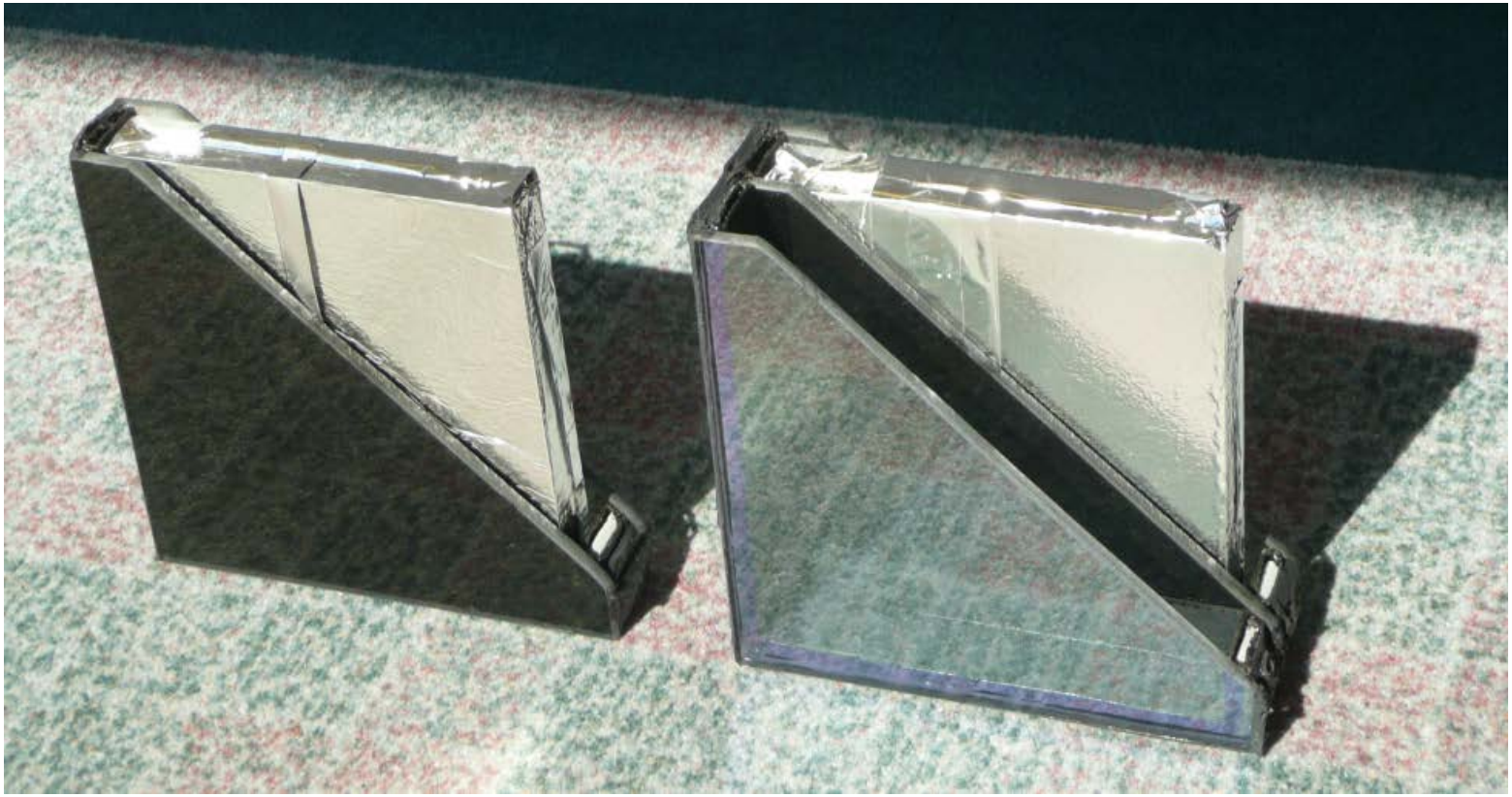
Warm edge spacer (commercial)

Architectural Finish (options)
- Glass (opaque)
- Aluminum
-Steel…

High Performance Insulation
- VIP

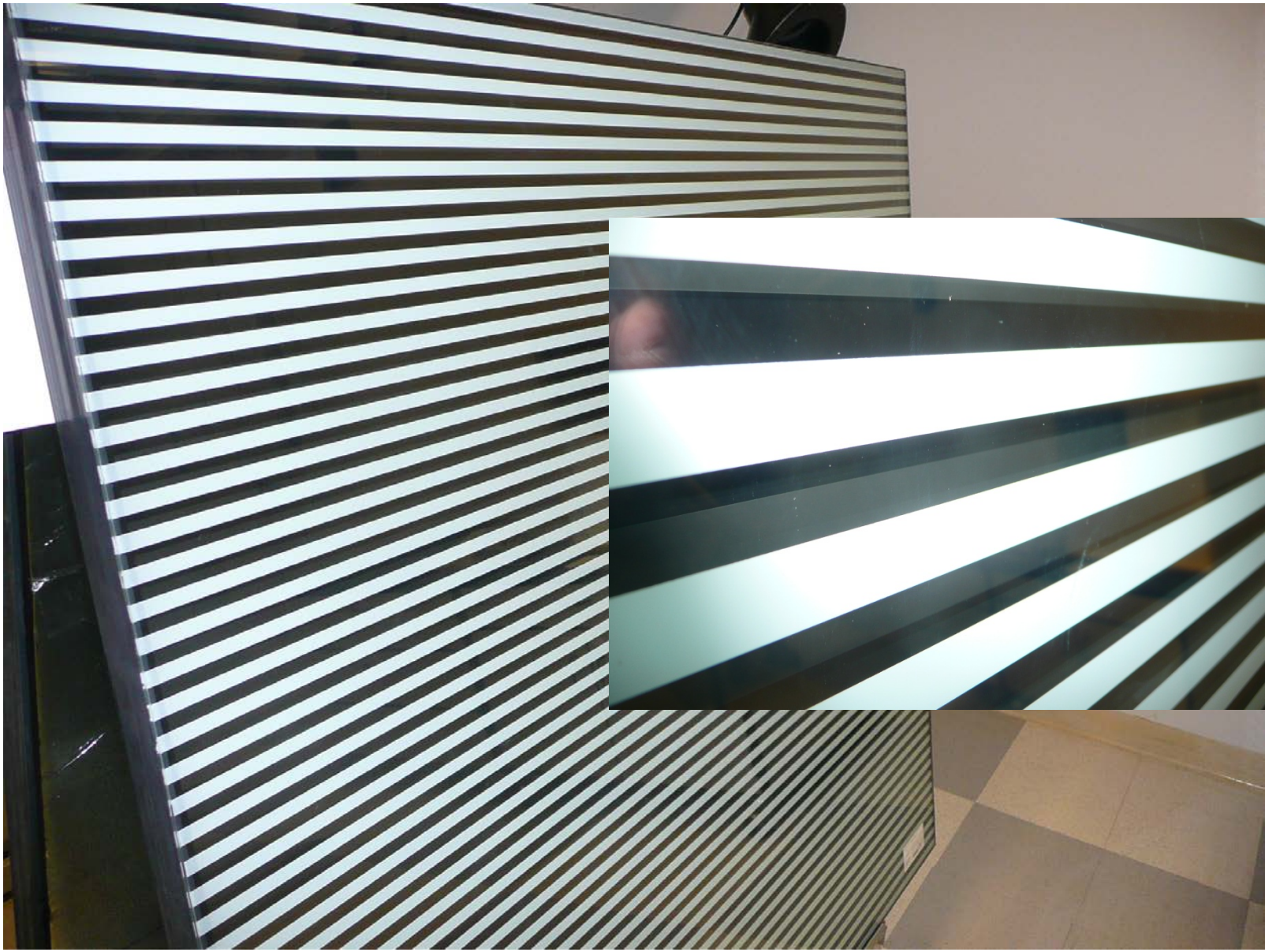
Back panel (options)
- Glass (opaque)
- Aluminum
-Steel

Vacuum panels within the IG units

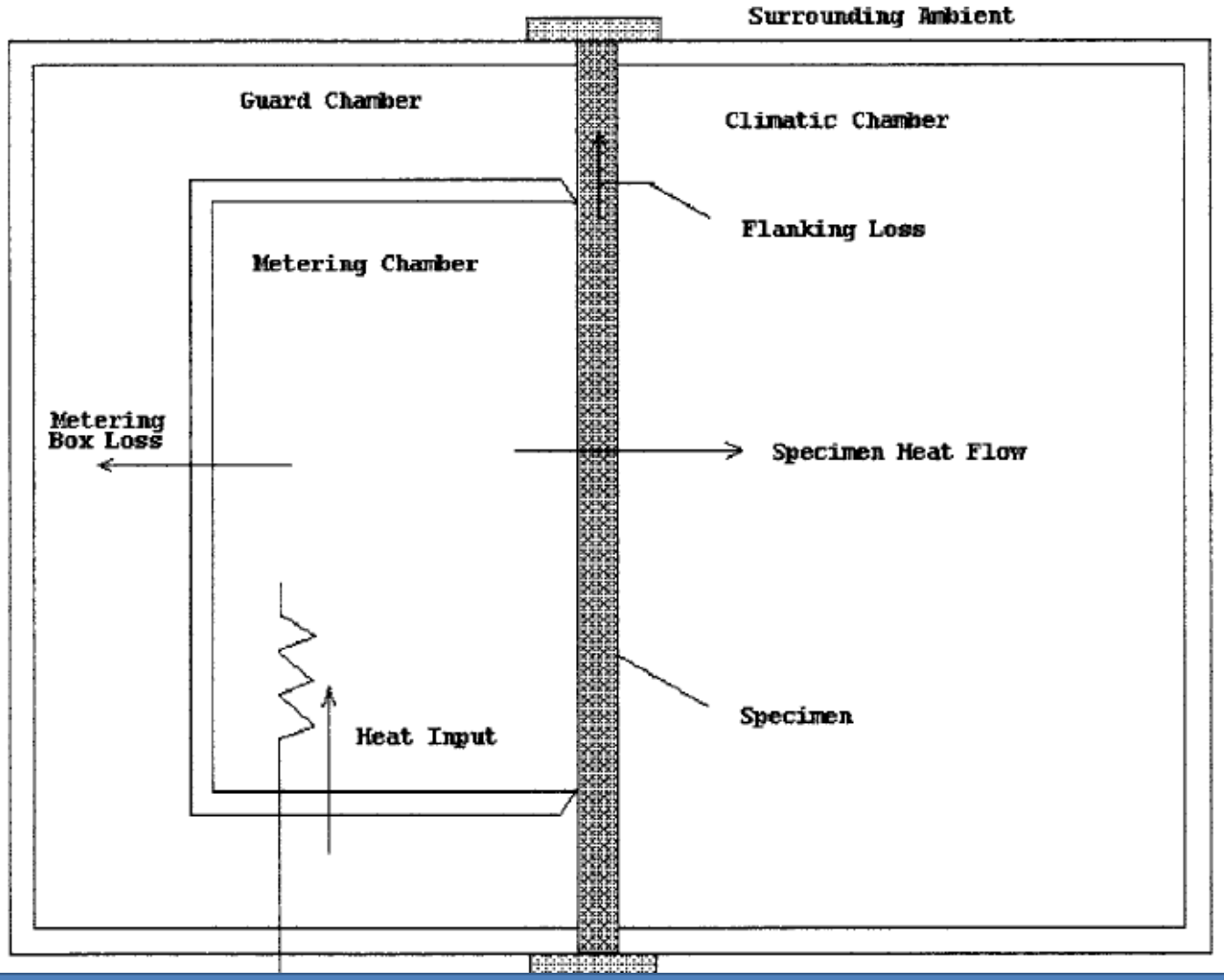


AIM Module in Shipping Crate

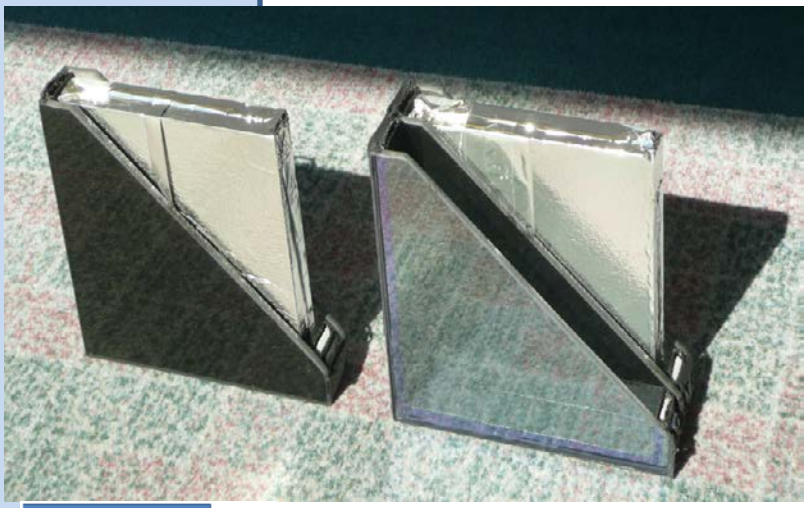
Shadow AIM Module

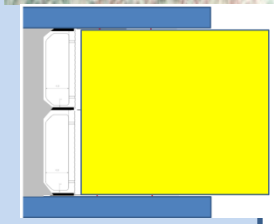


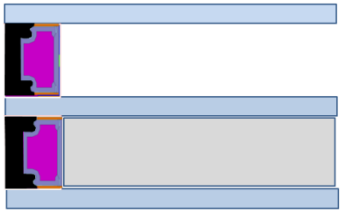
ASTM C1363 Guarded Hot Box

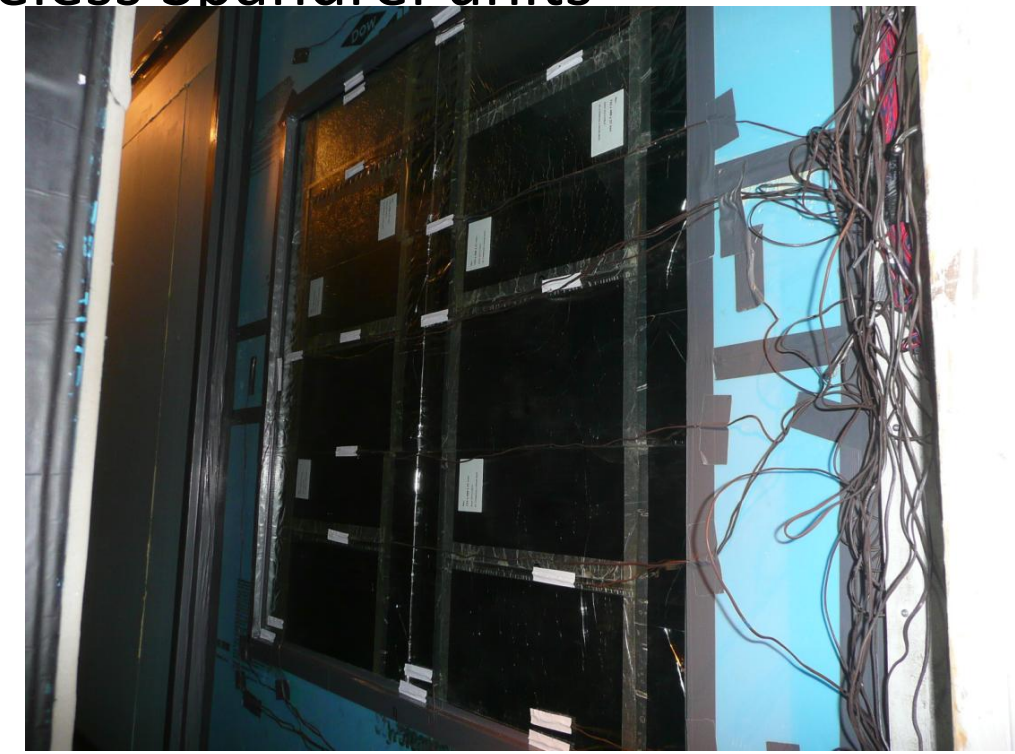


Test Results of Full 5’ x 5’ (1520mm x 1520mm) Frameless Spandrel units



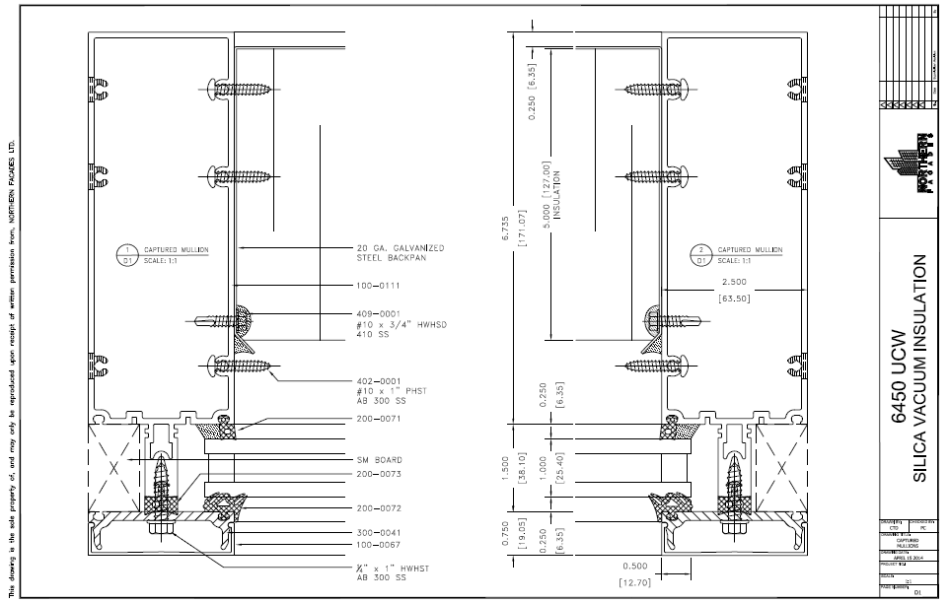


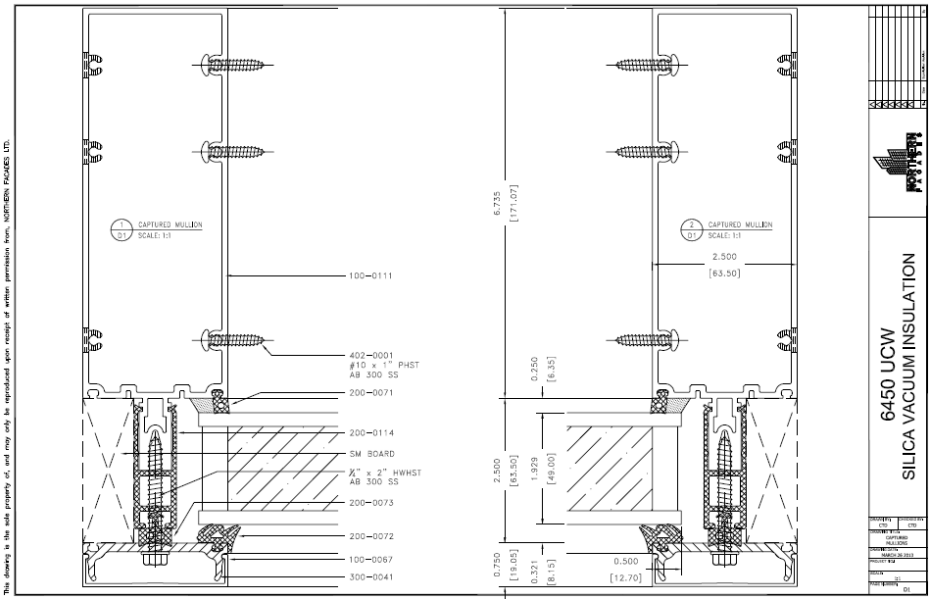




Assembly	U value BTU/(h °F ft^2)	R Value (h °F ft^2) /BTU	Assembly	U value W/m2K	R Value m2K/W
1” Double IG	0.33	3.06	**25mm Double IG**	1.87	0.53
1 ¾” Triple IG	0.18	5.48	**44mm Triple IG**	1.02	0.98
2” Triple Glaze AIM	**0.09**	**11.76**	50mm Triple Glaze AIM	**0.51**	**1.96**
2” Double Glaze AIM	**0.05**	**19.05**	50mm Double Glaze AIM	**0.3**	**3.33**

Details for 5’ x 5’ system





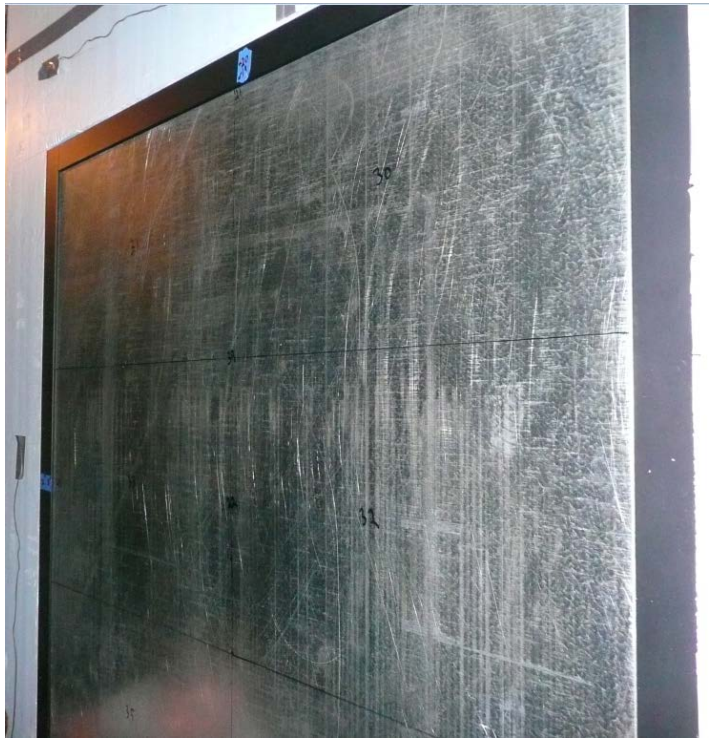
5 Systems built and tested

1. Air IGU over MW and Backpan
2. AR IGU over MW and Backpan
3. Shadow AIM over MW and Backpan
4. AIM over MW and Backpan
5. AIM only

Building of the Frames

Test Results

Spandrel Assembly	**U-value** W/m^{2}K (BTU/hrft^2^{o}F)	**R-value** m^{2}K/W (hrft^2^{o}F/BTU)
IGU Air	USI-0.89 (**U-0.156**)	RSI-1.13 (**R-6.40**)
IGU Argon	USI-0.87 (**U-0.153**)	RSI-1.15 (**R-6.52**)
Shadow AIM	USI-0.56 (**U-0.097**)	RSI-1.80 (**R-10.23**)
AIM	USI-0.50 (**U-0.088**)	RSI-2.00 (**R-11.36**)
AIM w/out Backpan Insulation	USI-0.60 (**U-0.105**)	RSI-1.68 (**R-9.52**)



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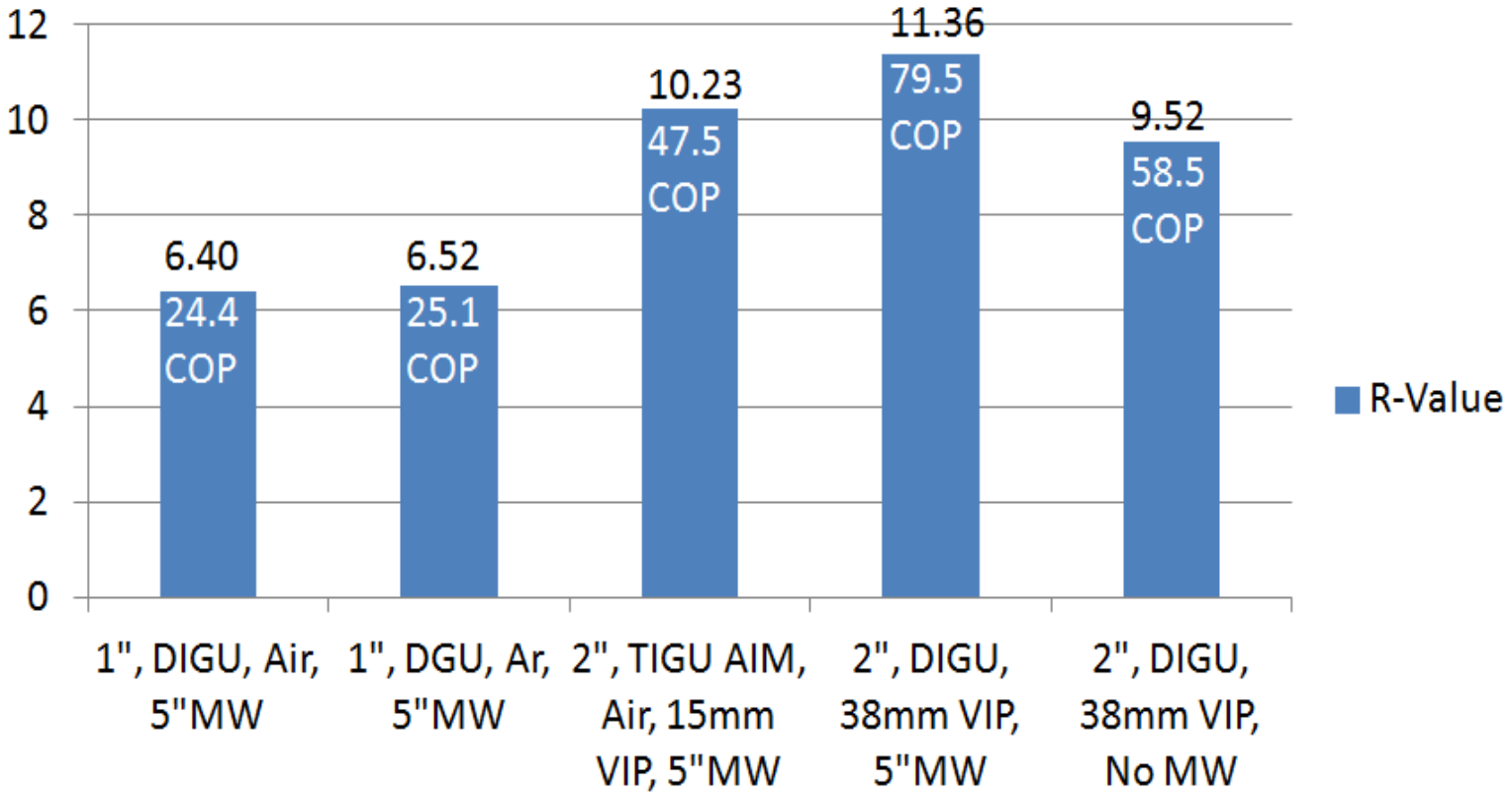
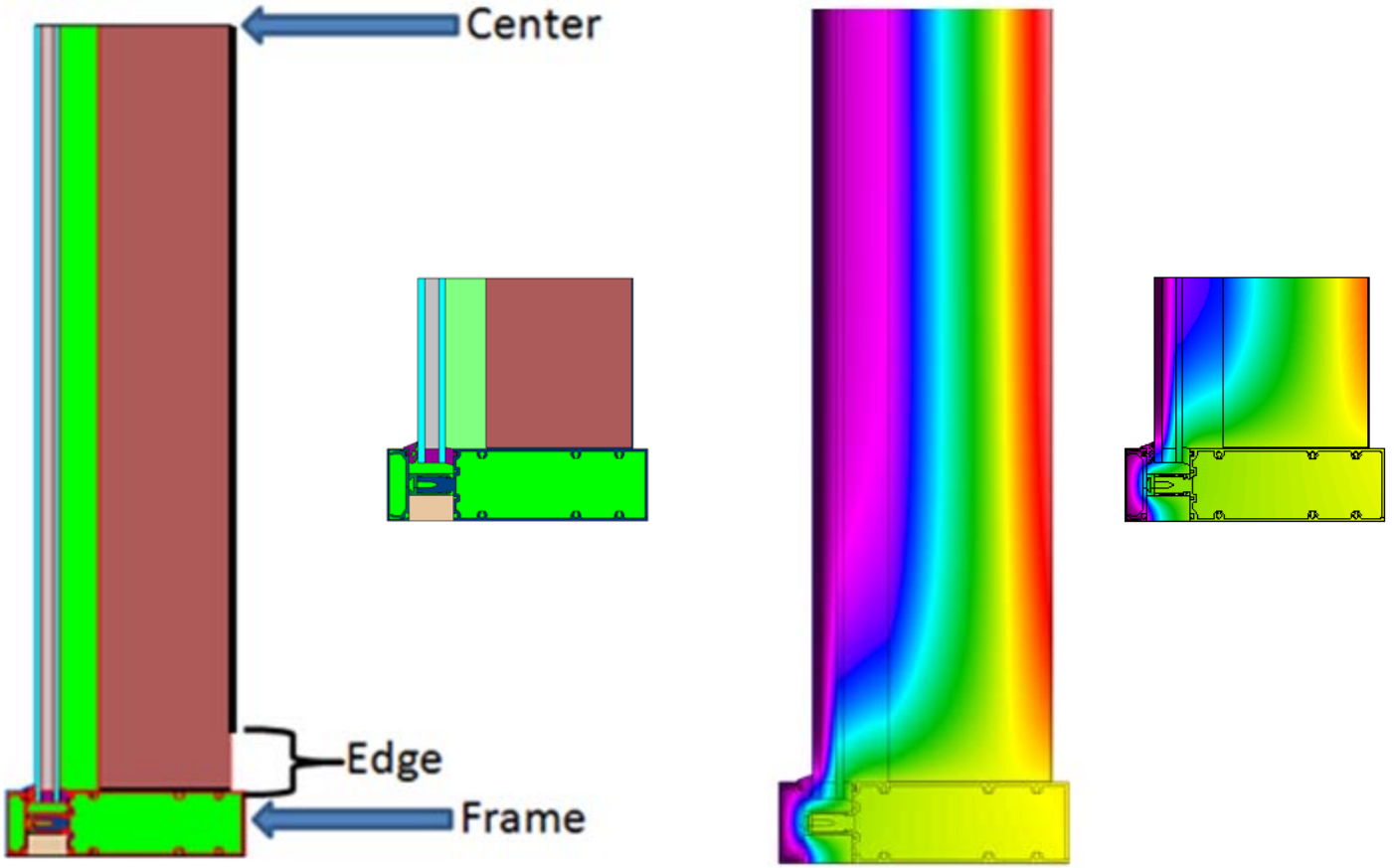


Therm trials



Therm Model Comparisons

Spandrel Assembly	162mm (6.4”) Model		748mm (29.4”) Model	
	U-value W/m²K (BTU/hrft²°F)	**R-value** m²K/W (hrft²°F/BTU)	**U-value** W/m²K (BTU/hrft²°F)	**R-value** m²K/W (hrft²°F/BTU)
IGU Air	USI-0.65 (**U-0.114**)	RSI-1.54 (**R-8.74**)	USI-0.69 (**U-0.122**)	RSI-1.44 (**R-8.20**)
IGU Argon	USI-0.63 (**U-0.111**)	RSI-1.58 (**R-8.98**)	USI-0.68 (**U-0.12**)	RSI-1.47 (**R-8.34**)
Shadow AIM	USI-0.43 (**U-0.076**)	RSI-2.30 (**R-13.08**)	USI-0.46 (**U-0.082**)	RSI-2.16 (**R-12.27**)
AIM	USI-0.34 (**U-0.059**)	RSI-2.99 (**R-16.96**)	USI-0.38 (**U-0.067**)	RSI-2.64 (**R-14.96**)
AIM w/out Backpan Insulation	USI-0.47 (**U-0.082**)	RSI-2.14 (**R-12.14**)	USI-0.52 (**U-0.091**)	RSI-1.93 (**R-10.94**)

Therm NFRC 100 compared to Hot Box

		AIM in Frame	AIM in Frame plus MW	Shadow AIM in Frame plus MW	Air IGU in Frame plus MW	AR IGU in Frame plus MW
Modeled values	Total U W/m2K	0.468	0.335	0.434	0.649	0.633
	Total U Btu/hr ft2 F	0.082	0.059	0.076	0.114	0.111
	Total R hr ft2 F/Btu	12.137	16.964	13.081	8.744	8.976
Tested Value	Total R hr ft2 F/Btu	9.160	11.360	10.230	6.440	6.580
	Delta R	-2.977	-5.604	-2.851	-2.304	-2.396
	Delta R %	-24.53	-33.03	-21.79	-26.35	-26.70

Therm NFRC 100 Adjusted compared to Hot Box

		AIM in Frame	AIM in Frame plus MW	Shadow AIM in Frame plus MW	Air IGU in Frame plus MW	AR IGU in Frame plus MW
Modeled values	Total U W/m2K	0.519	0.379	0.463	0.692	0.681
	Total U Btu/hr ft2 F	0.091	0.067	0.082	0.122	0.120
	Total R hr ft2 F/Btu	10.944	14.964	12.268	8.199	8.336
Tested Values	Total R hr ft2 F/Btu	9.160	11.360	10.230	6.440	6.580
	Delta R	-1.784	-3.604	-2.038	-1.759	-1.756
	Delta R %	-16.30	-24.09	-16.61	-21.46	-21.07

Adding the bolts 6” OC to the Higher insulation frames

		AIM in Frame plus MW	Shadow AIM in Frame plus MW
Modeled values	Total U W/m2K	0.421	0.502
	Total U Btu/hr ft2 F	0.074	0.088
	Total R hr ft2 F/Btu	13.479	11.320
Tested Values	Total R hr ft2 F/Btu	11.360	10.230
	Delta R	-2.119	-1.090
	Delta R %	-15.72	-9.63

NFRC 100 Uncertainty

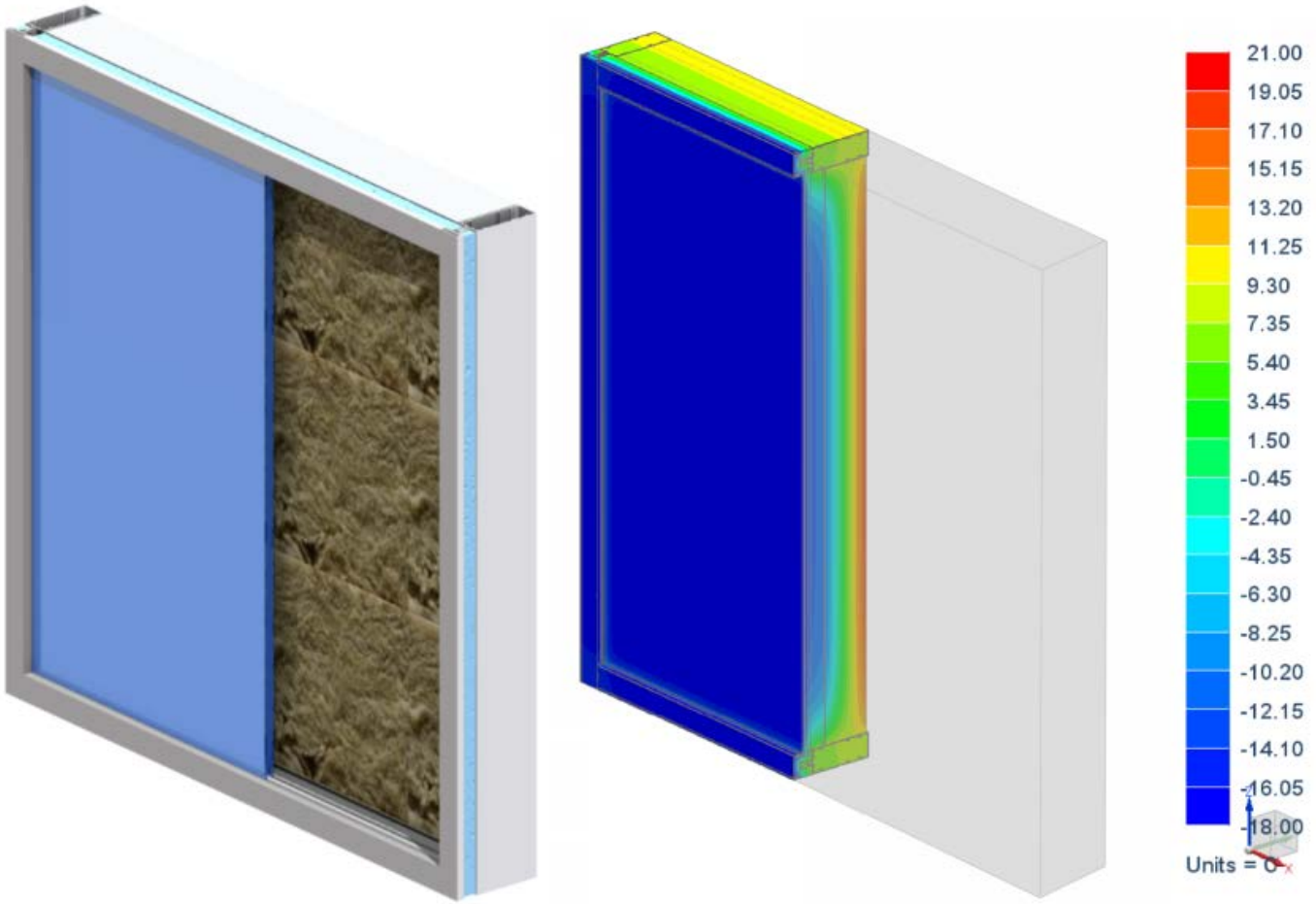
- For 2D simulations of assemblies with U-values less than 1.7 W/m^{2}K (0.30 Btu/hft^2^{o}F) NFRC 100 section 4.7.1 defines accepted equivalence for fenestration as within 0.17 W/m^{2}K (0.030 Btu/hft^2^{o}F) between testing and simulation values.

Equivalence Table

Simulated U-Factor	Accepted Difference Between Tested and Simulated U-Factor
1.7 W/m^{2}K (0.3 Btu/h·ft^2·°F) or less	0.17 W/m^{2}K (0.03 Btu/h·ft^2·°F) or less
Greater than 1.7 W/m^{2}K (0.3 Btu/h·ft^2·°F)	10% of Simulated U-Factor

- All Therm models are Equivalent!
- This is not right.

3D models


21.00
19.05
17.10
15.15
13.20
11.25
9.30
7.35
5.40
3.45
1.50
-0.45
-2.40
-4.35
-6.30
-8.25
-10.20
-12.15
-14.10
-16.05
-18.00
Units = C

3D Model Results

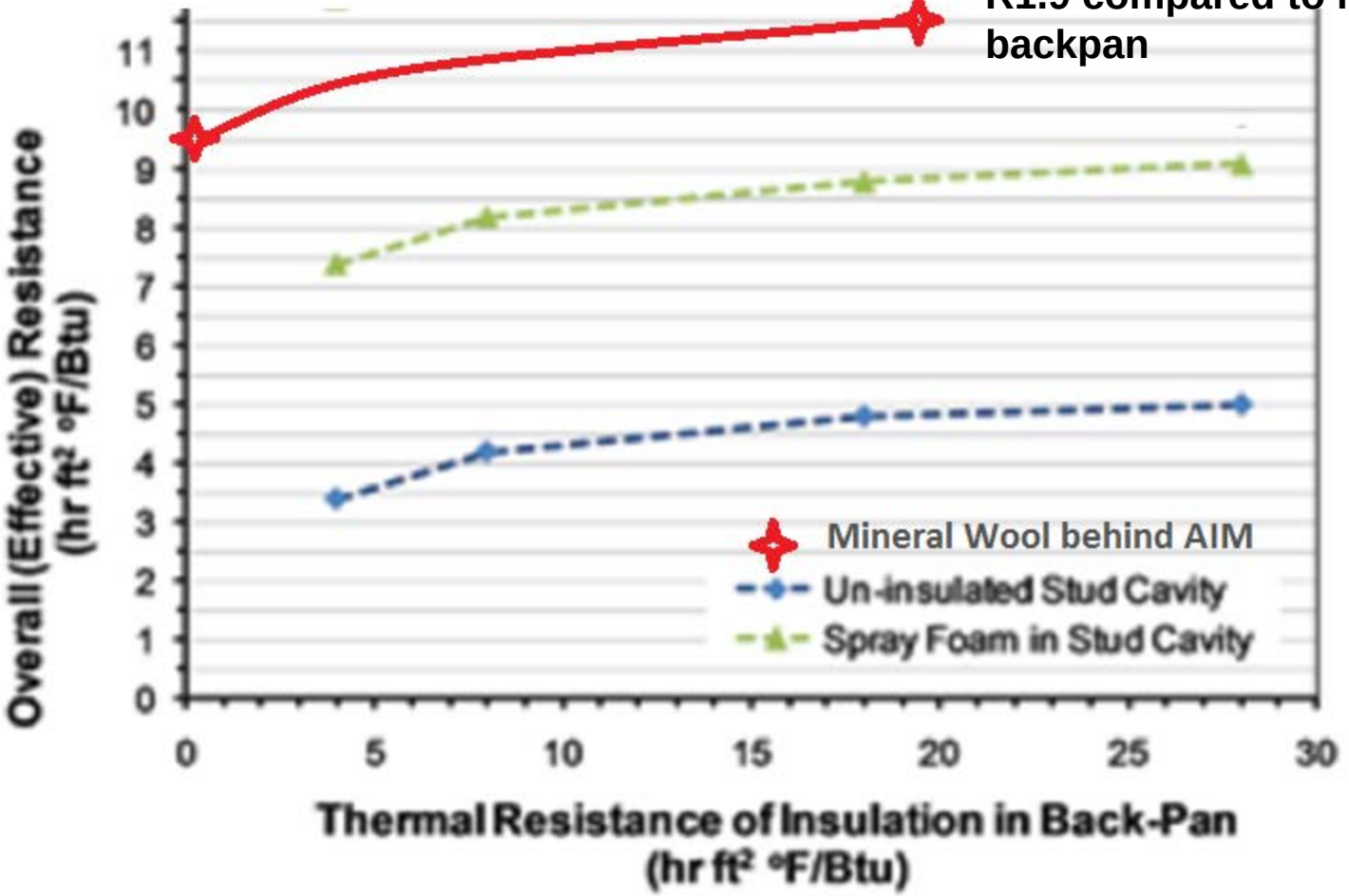
Spandrel Assembly	U-value W/m²K (BTU/hrft²°F)	R-value m²K/W (hrft²°F/BTU)
IGU Air	USI-0.90 (**U-0.158**)	RSI-1.13 (**R-6.40**)
IGU Argon	USI-0.87 (**U-0.153**)	RSI-1.15 (**R-6.54**)
Shadow AIM	USI-0.57 (**U-0.101**)	RSI-1.75 (**R-9.94**)
AIM	USI-0.51 (**U-0.089**)	RSI-1.97 (**R-11.20**)
AIM w/out Backpan Insulation	USI-0.59 (**U-0.103**)	RSI-1.70 (**R-9.68**)

U values (W/m2K) for Northern Facades 6450 UCW System Based on 3D Modeling

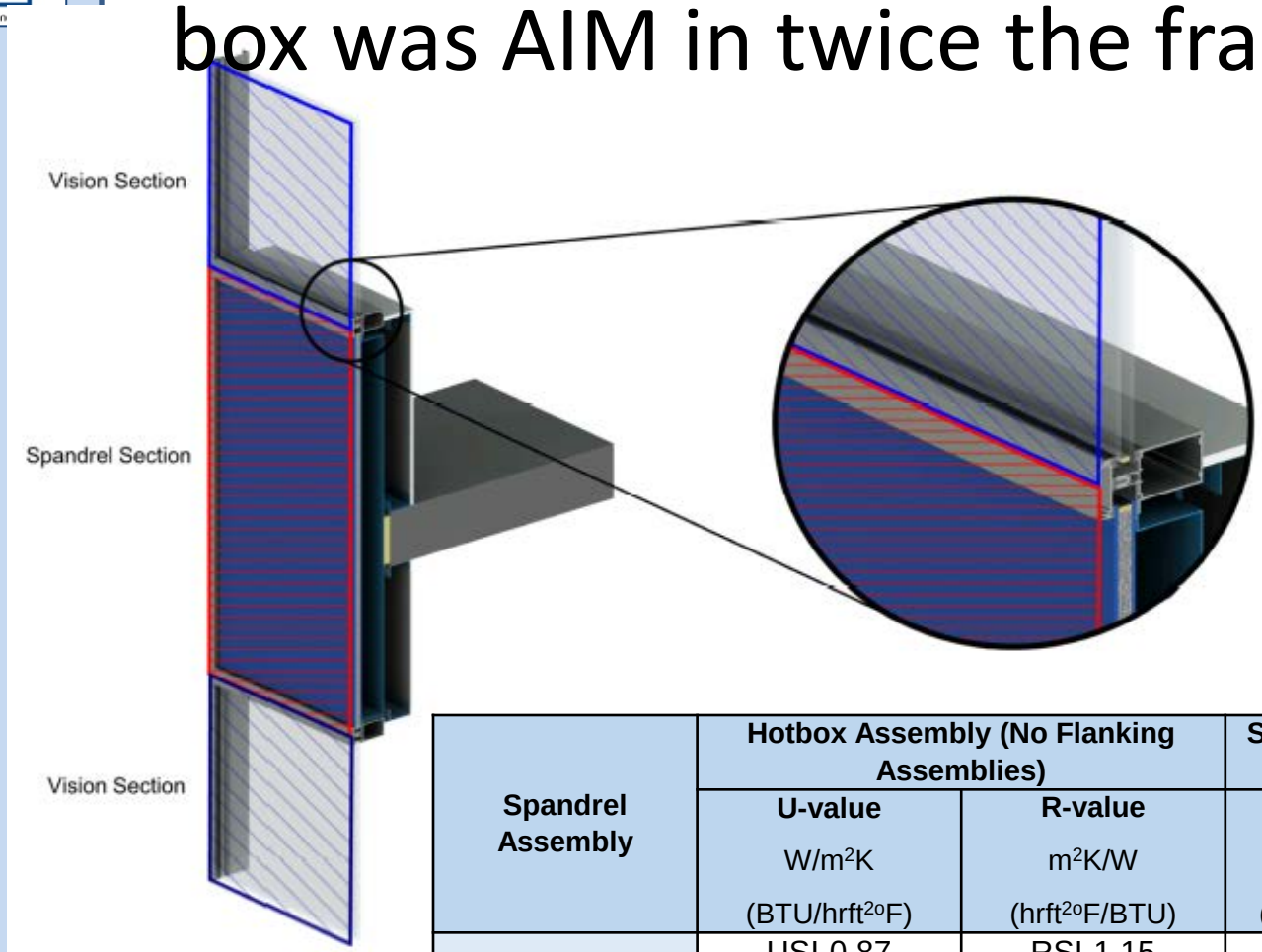
		AIM in Frame	AIM in Frame plus MW	Shadow AIM in Frame plus MW	Air IGU in Frame plus MW	AR IGU in Frame plus MW
Modeled values	Total U W/m2K	0.590	0.510	0.570	0.900	0.870
	Total U Btu/hr ft2 F	0.103	0.089	0.101	0.158	0.153
	Total R hr ft2 F/Btu	9.680	11.200	9.940	6.400	6.540
Tested Value	Total R hr ft2 F/Btu	9.160	11.360	10.230	6.440	6.580
	Delta R	-0.520	0.160	0.290	0.040	0.040
	Delta R %	-5.37	1.43	2.92	0.63	0.61

Hot Box testing confirmed ASHRAE Research Project 1365

5” Mineral Wool added R1.9 compared to no backpan

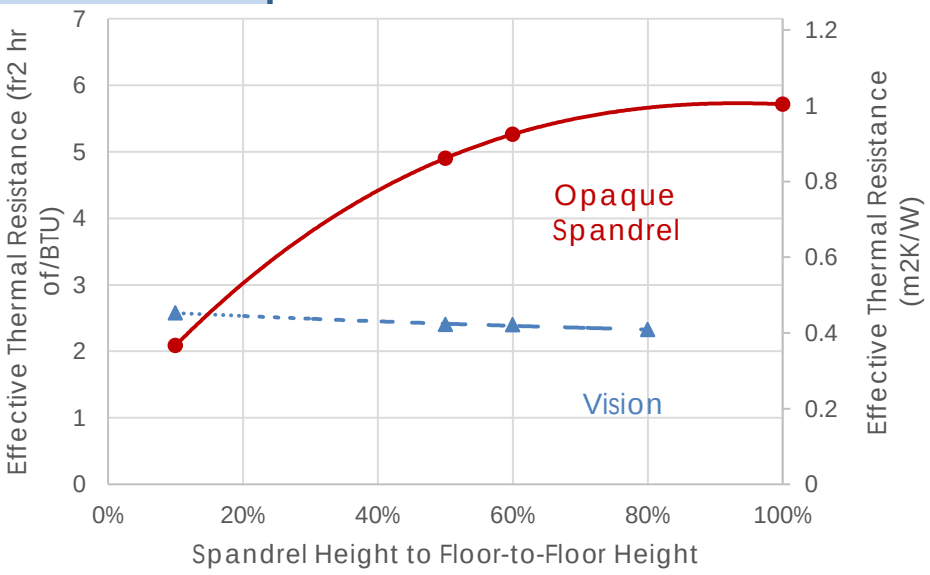


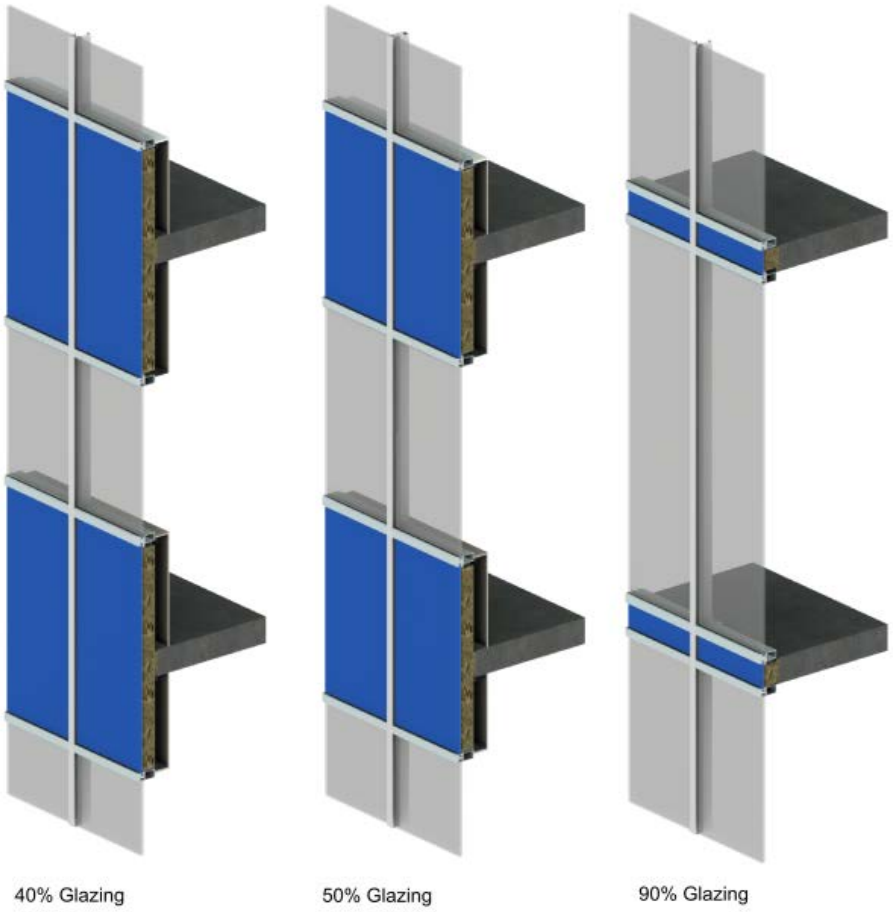
3D modeling AIM in the Frame. Hot box was AIM in twice the frame.



Spandrel Assembly	Hotbox Assembly (No Flanking Assemblies)		Spandrel System with Flanking Assemblies	
	U-value W/m^2K $(BTU/hrft^{2o}F)$	**R-value** m^2K/W $(hrft^{2o}F/BTU)$	**U-value** W/m^2K $(BTU/hrft^{2o}F)$	**R-value** m^2K/W $(hrft^{2o}F/BTU)$
IGU Argon	USI-0.87 (**U-0.153**)	RSI-1.15 (**R-6.54**)	USI-1.15 (**U-0.203**)	RSI-0.87 (**R-4.92**)
AIM	USI-0.51 (**U-0.089**)	RSI-1.97 (**R-11.20**)	USI-0.58 (**U-0.102**)	RSI-1.73 (**R-9.84**)

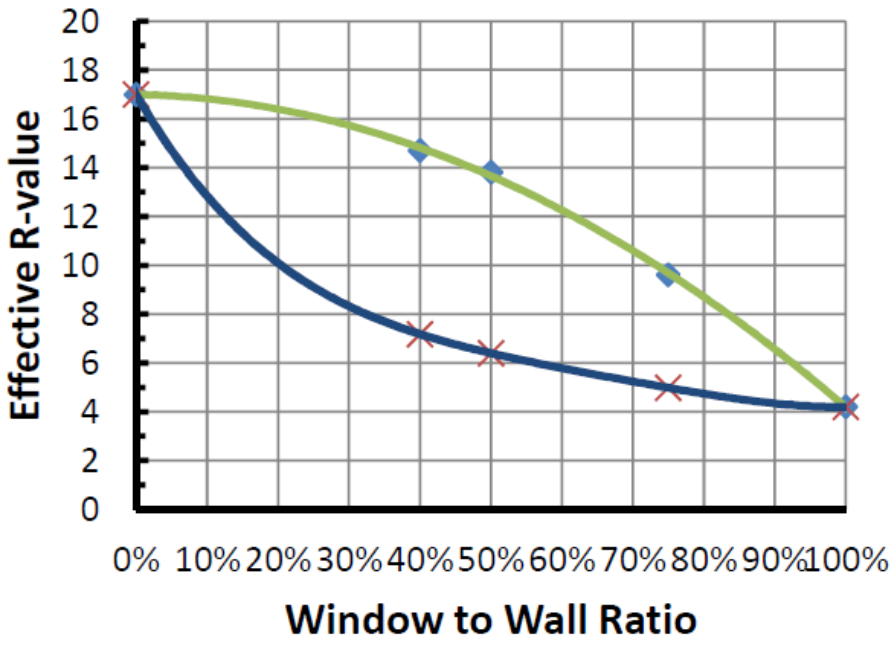
Standard Curtainwall



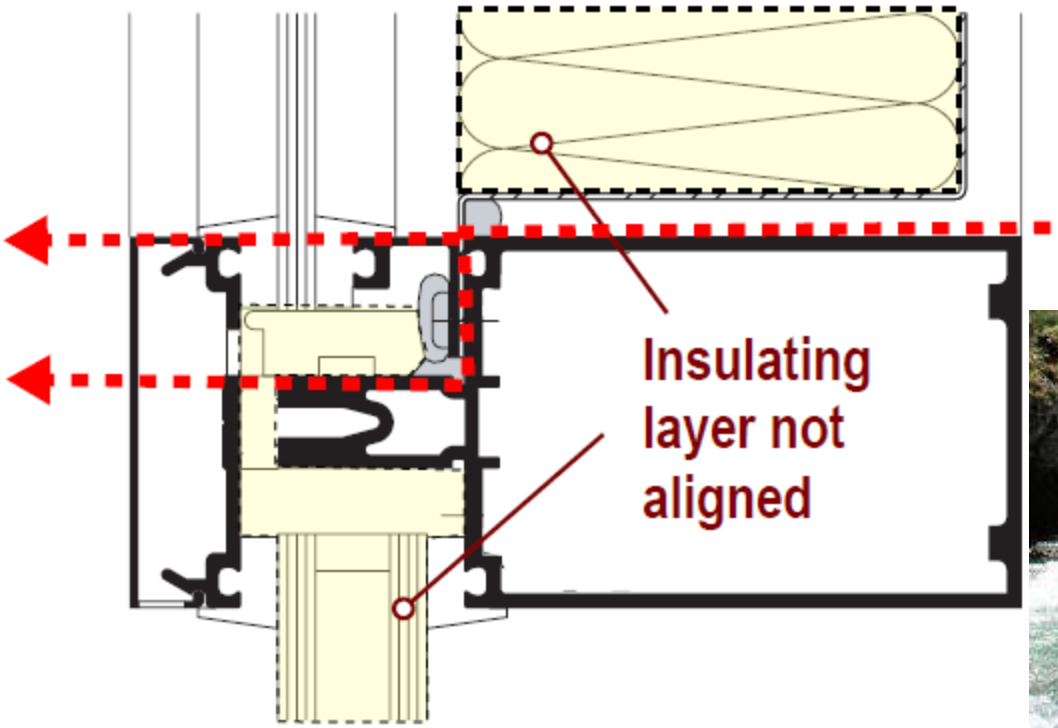


High Performance Modeling

WWR	Spandrel Height	Spandrel Section U-Value BTU/hr·ft²·°F (W/m²K)	Spandrel Section R-Value hr·ft²·°F/BTU (m²K/W)	Glazing Section U-Value BTU/hr·ft²·°F (W/m²K)	Glazing Section R-Value hr·ft²·°F/BTU (m²K/W)	Total Assembly U-Value BTU/hr·ft²·°F (W/m²K)	Total Assembly R-Value hr·ft²·°F/BTU (m²K/W)
75%	6 ft (1.8 m)	0.104 (0.59)	9.6 (1.70)	0.233 (1.32)	4.3 (0.76)	0.200 (1.14)	5.0 (0.88)
50%	5 ft (1.5 m)	0.072 (0.41)	13.8 (2.43)	0.240 (1.36)	4.2 (0.73)	0.156 (0.89)	6.4 (1.13)
40%	2.5 ft (0.8 m)	0.068 (0.39)	14.7 (2.59)	0.246 (1.40)	4.1 (0.72)	0.139 (0.79)	7.2 (1.27)



A Boulder in the Stream



Conclusions

- Hot box tests show trends reported in ASHRAE Research Project 1365:
- Variation in thermal results for the analyzed spandrels between the three methods detailed in this paper. Which method recommended to be used will depend on the level of accuracy required.
- 2D modelling of the hotbox spandrel assembly using NFRC-100 can approach within 10-15% of the hot box test values as long as there are some adjustments to the approach. Further alterations, such as changing the edge distance, will likely provide even better agreement.
- The AIM unit assemblies show significant improvement in thermal resistance over the typical spandrel systems. This offers great potential towards creating improved curtain wall systems
- Additional insulation in front of backpan adds limited thermal performance: Keep the insulation in front of the mullions.

Thank You

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