



February 18, 2013

MH ref.: 5130005.00

Andy Hoffman
Market Support Manager – *Industrial Market*
Tnemec Company Inc.
123 West 23rd Avenue
North Kansas City, Missouri 64116

Dear Mr. Hoffman:

Re: Thermal Performance of Tnemec Fluid-applied Acrylic Insulation Coating (Aerolon Acrylic series 971)

Tnemec Company Inc. manufactures a proprietary acrylic coating with thermal insulating properties. There is interest from clients on the potential benefit of applying a coating on conductive elements (thermal bridges) that bypass the thermal insulation of building envelope assemblies. The benefits of minimizing thermal bridging are increased “effective” R-value (or lower heat flow, U-values) and improved condensation resistance.

Morrison Hershfield (MH) was contracted by Tnemec Company Inc. to conduct a thermal analysis of the impact of applying their insulating coating to standard construction details and target promising applications.

Thermal Analysis

MH evaluated the impact of applying the insulating coating to the following thermal bridging categories:

1. Structural steel beams that bypass the thermal insulation
2. Structural clips for cladding of exterior insulated assemblies
3. Steel stud assemblies
4. Concrete slabs

Two variations of details were evaluated for each category and several increments of coating thickness. The coating thickness was simulated for three thicknesses (60 mil, 120 mil, ½ inch) using a conductivity of 0.0356 W/m K (0.0202 BTU/hr ft °F). Table 1 summarizes the details scenarios evaluated for this study.

MH completed our thermal analysis using 3D heat transfer software from Siemens called Nx. The analysis utilized steady-state conditions, published thermal properties of materials, and information provided by Tnemec for their product. Graphics illustrating the detail scenarios and more detailed information on the modeling procedures and properties can be found in Appendix A.

Table 1: Construction Detail Scenarios

Detail	Category	Detail Scenarios
1	Structural steel beams that bypass the thermal insulation	<ul style="list-style-type: none"> • Split insulated steel stud assembly with horizontal z-girts supporting metal cladding • R12 in exterior cavity and R12 in stud cavity • Structural steel column and beam intersection • Coating applied to exterior beam
2		<ul style="list-style-type: none"> • Curtain wall spandrel panel • R20 in metal back-pan • Structural steel column and beam intersection • Coating applied to exterior beam
3	Structural sub-girts or clips for the attachment of cladding of exterior insulated steel stud assemblies	<ul style="list-style-type: none"> • Split insulated steel stud assembly with vertical z-girts supporting metal cladding • R12 in exterior cavity and R12 in stud cavity • Coating applied to exterior z-girts
4		<ul style="list-style-type: none"> • Split insulated steel stud assembly with intermittent clips supporting metal cladding • R12 in exterior cavity and R12 in stud cavity • Coating applied to exterior clips
5	Steel stud assemblies	<ul style="list-style-type: none"> • Interior insulated steel stud assembly • R12 insulation in stud cavity • Coating applied to exterior flange of steel studs
6		<ul style="list-style-type: none"> • Split insulated steel stud assembly with intermittent clips supporting metal cladding • R12 in exterior cavity and R12 in stud cavity • Coating applied to exterior flange of steel studs and clips
7	Thermal bridges at floor slabs; concrete balcony and shelf angle	<ul style="list-style-type: none"> • Split insulated steel stud assembly with shelf angle and brick ties supporting brick veneer • R12 in exterior cavity and R12 in stud cavity • Shelf angle and flashing attached directly to slab and bypasses exterior insulation • Coating applied to flashing and shelf angle
8		<ul style="list-style-type: none"> • Exterior insulated concrete block wall assembly with brick veneer • R12 insulation in cavity • Pre-cast concrete balcony slab supported by angle (on 3 sides) • Coating applied to stand-off angle

Results

The simulated effective R-Values and U-value (heat flow per area and degree) for each detail scenario is summarized in Tables 1 and 2.

Table 2: Summary of “Effective” R-values for the Detail Scenarios

Detail Scenario	Effective R-value (hr ft ² °F/BTU)				Percent Difference		
	No Coating	60 mil Coating	120 mil Coating	0.5 inch coating	60 mil Coating	120 mil Coating	0.5 inch coating
		(R-0.24)	(R-0.5)	(R-2.0)	(R-0.24)	(R-0.5)	(R-2.0)
1	13.9	14.1	14.3	14.7	1.8%	2.7%	5.4%
2	3.2	3.3	3.4	3.4	3.1%	3.8%	5.3%
3	14.1	15.2	16.0	18.7	7.2%	12.5%	28.2%
4	18.2	18.9	19.5	20.9	3.8%	6.4%	13.7%
5	9.0	9.3	9.6	10.4	3.5%	6.1%	14.4%
6	18.2	19.3	20.0	21.9	5.6%	9.2%	18.4%
7	9.6	10.8	11.7	13.9	12.5%	19.8%	37.0%
8	11.8	12.0	12.2	13.1	1.7%	3.2%	10.0%

Table 3: Summary of U-values for the Detail Scenarios

Detail Scenario	U-Value (BTU/hr ft ² °F)				Percent Difference		
	No Coating	60 mil Coating	120 mil Coating	0.5 inch coating	60 mil Coating	120 mil Coating	0.5 inch coating
		(R-0.24)	(R-0.5)	(R-2.0)	(R-0.24)	(R-0.5)	(R-2.0)
1	0.072	0.071	0.070	0.068	1.8%	2.7%	5.4%
2	0.310	0.300	0.298	0.294	3.1%	3.8%	5.3%
3	0.071	0.066	0.063	0.053	7.2%	12.5%	28.2%
4	0.055	0.053	0.051	0.048	3.8%	6.4%	13.7%
5	0.111	0.107	0.105	0.096	3.5%	6.1%	14.4%
6	0.055	0.052	0.050	0.046	5.6%	9.2%	18.4%
7	0.105	0.092	0.086	0.072	12.5%	19.8%	37.0%
8	0.085	0.083	0.082	0.076	1.7%	3.2%	10.0%

Temperature Indices at the coldest location on critical surfaces for evaluating condensation resistance is presented in Table 3. Temperature indices are non-dimensionalized ratios of the temperature difference across an assembly. A value of zero is the outdoor temperature and one is the indoor temperature. Non-dimensionalizing the critical surface temperatures allows the results to be extrapolated to any design condition for evaluating the potential of condensation in cold climates. More information on using temperature indices in practice and thermal images showing the temperature distribution of the assemblies can be found in Appendix B.

Table 4: Summary of Critical Surface Temperature Index for Evaluating Condensation Resistance in Cold Climates

Detail Scenario	Effective R-value (hr ft ² °F/BTU)				Location
	No Coating	60 mil Coating	120 mil Coating	0.5 inch coating	
		(R-0.24)	(R-0.5)	(R-2.0)	
1	0.50	0.54	0.55	0.60	Steel Column in Wall Cavity
2	0.66	0.70	0.71	0.74	Steel Beam in Wall Cavity
3	0.46	0.49	0.51	0.54	Interior Surface of Exterior Sheathing between studs
4	0.51	0.52	0.53	0.54	Interior Surface of Exterior Sheathing between studs
5	0.08	0.08	0.08	0.08	Interior Surface of Exterior Sheathing between studs
6	0.51	0.52	0.52	0.53	Interior Surface of Exterior Sheathing between studs
7	0.78	0.82	0.84	0.89	Concrete floor slab at interior gypsum
8	0.88	0.89	0.89	0.91	Concrete floor slab at interior gypsum

Conclusions

The most promising application with regards to minimizing heat flow through assemblies is coating brick masonry shelf angles and metal flashings. Thermal bridging at floor slabs due to shelf angles and metal flashings are a challenge. The impact of thermal bridging at floor slabs is often not fully recognized in practice but there is growing recognition that this is a problem area. We have some questions whether flashing or an angle coated with the insulating coating will be effective with the dead weight of brick. One way of answering this question is to evaluate the impact of only counting on the insulating properties of the coating that is not below the brick. Similar applications that could be explored are metal flashing in rain-screen assemblies and flashing around window perimeters of exterior insulated assemblies.

Coating steel stud flanges and sub-girt framing for steel stud assemblies also appears like a viable target market; you can target cladding manufacturers that are developing clip systems to



help them be competitive by utilizing your coating to offset the insulation and wall thickness required to meet energy efficiency standards.

Coating the steel beams bypassing the thermal insulation, as per details 1 and 2, doesn't reduce the heat loss through an assembly a lot if the beams bypass the insulation infrequently. However, the potential to improve the condensation resistance of this type of detail is significant. A surface with a temperature index of 0.5 or less represents a value that typically warrants closer attention when designing buildings with elevated moisture levels (i.e. residential buildings) in cold climates. In contrast, surfaces with a temperature index greater than 0.7 has little risk of condensation for outdoor design temperatures down to -30°F.

Applying coatings to steel beams that bypass the thermal insulation is worth exploring in more detail for different insulation ratios (i.e. less exterior insulation) and different configurations to fully explore the potential benefit.

Yours truly,
Morrison Hershfield Limited



Ivan Lee, M.A.Sc.
Building Science Consultant



Patrick Roppel, P.Eng.
Principal, Building Science Specialist

Appendix A: Modeling Assumptions and Procedures

Modeling Procedures

Modeling procedures follow the procedures outlined in ASHRAE 1365-RP “Thermal Performance of Building Envelope Details for Mid- and High-rise Buildings. These procedures using Nx were extensively calibrated and validated as part of 1365-RP. Our approach has been to yield results that are agreeable with widely accepted testing standards (ASTM C 236, ASTM C976, or ASTM C1363).

General Modeling Principles

Contact Resistance

Contact resistance between materials was incorporated into the model. Bolts bypassing the thermal insulation connecting steel supports were included in the models; individual screws to attach sheathings and bolts into concrete were not directly modeled.

Table A.1: Summary of Contact Resistances

Location	Contact Resistance hr·ft ² ·°F /Btu (m ² °C/W)
Steel flanges at sheathing interfaces	0.17 (0.030)
Insulation interfaces	0.057 (0.010)
Steel to concrete interfaces	0.057 (0.010)
Steel to steel interfaces	0.011 (0.0020)

Material Properties

Constant thermal conductivities were selected using standard tabulated values (typically measured at 24°C or 75°F). The thermal conductivity, density, and specific heat are based on values provided in the 2009 ASHRAE Handbook – Fundamentals.

Air Cavities

Unventilated air cavities are dependent on the cavity surface temperatures, surface emittances, and geometry. Table 3, chapter 26, of the 2009 ASHRAE Handbook – Fundamentals provides the thermal resistances of plane air spaces, including the effects of radiation, conduction, and convection.

A thermal resistance of 0.91 Btu/ hr·ft²·°F (0.16 W/m² K) was selected for stud air cavities. A thermal resistance of 0.91 Btu/ hr·ft²·°F (0.16 W/m² K) was selected for voids in masonry. Air cavities in the glazing assemblies were modeled using the procedures in ISO 10077-2:2003 (E) using the assumption $\Delta T = 10^{\circ}\text{C}$ (18°F) and $T_m = 10^{\circ}\text{C}$ (50°F).

Boundary Conditions

The values selected for this project are based on values presented in Table 1, chapter 26, of the 2009 ASHRAE Handbook – Fundamentals and were applied consistently between details. Table A.2 summarizes the heat transfer coefficients applied to all the details for this project.



Table A.2: Heat Transfer Coefficients at Interior and Exterior Air for Opaque Building Envelope Components¹

Location	Description of Condition	Heat Transfer Coefficient Btu/h·ft ² ·°F (W/m ² K)
Exterior wall surface with generic cladding	Heat transfer coefficient to account for vented air space and cladding; surface is not directly exposed to wind	1.5 (8.3)
Exterior brick veneer	Surface exposed to 15 mph (24 km/h) wind	6.0 (34)
Interior wall surface	Vertical surface exposed to indoor air and surfaces	1.5 (8.3)
Interior ceiling surface	Horizontal surface exposed to indoor air and surfaces with upward heat flow	1.6 (9.3)
Interior floor surface	Horizontal surface exposed to indoor air and surface with downward heat flow	1.1 (6.1)

The heat transfer coefficients specific to glazing systems for interior surfaces were incorporated into the modeling as summarized in Table A.3. These coefficients are based on values suggested by Annex B of ISO 10077-2.

Table A.3: Heat Transfer Coefficients for Glazing Components

Location	Description of Condition	Heat Transfer Coefficient Btu/h·ft ² ·°F (W/m ² K)
Exterior surfaces	Surface exposed to 15 mph (24 km/h) wind	6.0 (34)
Interior centre of glass	Based on surface temperature of glass in view with surfaces at 70°F (21°C) and Δ70°F (Δ39°C) across the assembly	1.3 (7.5)
Interior edge of glass	Reduced radiation and convection in edges or junction between two surfaces, applied to a distance of 30 mm from sight line	0.9 (5.0)
Horizontal frame surface	Reduced radiation and convection in edges or junction between two surfaces	0.9 (5.0)
Vertical frame surface	Aluminum frame exposed to indoor air and surfaces	1.3 (7.5)

Boundary temperatures were applied to create a unit temperature difference across the assembly. The generic simulated results are not dependent on the absolute air temperatures because the selected materials are defined as constant values, independent of temperature.

¹ Including the effects of radiation and convection as outlined in Table 1, chapter 26, of the 2009 ASHRAE Handbook – Fundamentals and the assumptions in Table 5.2



Detail 1

Exterior and Interior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Horizontal Z-Girts (24" o.c.) Supporting Metal Cladding – Structural Steel Column & Cantilever Beam Intersection (Canopy Support) – Coating Applied to Steel Beam



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	13.9	0.072	-	0.50
60 mil Coating (R-0.24)	14.1	0.071	1.8%	0.54
120 mil Coating (R-0.5)	14.3	0.070	2.7%	0.55
0.5 inch Coating (R-2.0)	14.7	0.068	5.4%	0.60

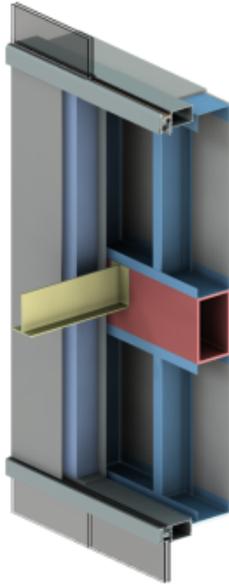
*Critical Surface Temperature Index at Steel Column in Wall Cavity

ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fiberglass Batt Insulation in Stud Cavity	3 5/8" (92)	0.29 (0.042)	R-12 (2.1 RSI)	0.9 (14)	0.17 (710)
4	3 5/8" x 1 5/8" Steel Studs	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Exterior Insulation	3" (76)	0.33 (0.036)	R-12 (2.11 RSI)	1.8 (28)	0.29 (1220)
7	Horizontal Z-girts w/ 1 1/2" Flange	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
8	Steel Post (HSS 76x76x3.2)	1/8" (3.2)	347 (50)	-	489 (7830)	0.12 (500)
9	Steel Beam (HSS 76x76x3.2)	1/8" (3.2)	347 (50)	-	489 (7830)	0.12 (500)
10	Metal cladding with 1/2" (13mm) vented air space is incorporated into exterior heat transfer coefficient					
11	Exterior Film (left side) ¹	-	-	R-0.2 (0.03 RSI) to R-0.7 (0.12 RSI)	-	-

¹Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

Detail 2

Conventional Curtain Wall w/ Insulated Spandrel Panel & 3 5/8" x 1 5/8" Steel Stud (16" o.c.)- Beam Intersection Connected to Steel Beam – Coating Applied to Exterior Beam



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	3.2	0.310	-	0.66
60 mil Coating (R-0.24)	3.3	0.300	3.1%	0.70
120 mil Coating (R-0.5)	3.4	0.298	3.8%	0.71
0.5 inch Coating (R-2.0)	3.4	0.294	5.3%	0.74

*Critical Surface Temperature Index at Steel Beam in Wall Cavity

ID	Component	Thickness Inches (mm)	Conductivity Btu·in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.7 (0.12 RSI)	-	-
2	Structural Steel Beam (10" x 6" x 3/8" HSS)	-	347 (50)	-	489 (7830)	0.12 (500)
3	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
4	Air Cavity	4 5/8" (117)	-	R-0.9 (0.16 RSI)	0.075 (1.2)	0.24 (1000)
5	3 5/8" x 1 5/8" Steel Studs (16" o.c.) w/ Top & Bottom Tracks	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
6	Curtain wall system: double glazed & thermal broken, U = 0.35 BTU/hr.ft ² .°F (2.0 W/m ² K) ²					
7	Back Pan Insulation	Varies	-	R-5 to R-25 (0.88 to 4.4 RSI)	4 (64)	0.20 (850)
8	Steel Beam (W6x12)	-	347 (50)	-	489 (7830)	0.12 (500)
9	Composite Metal Panel	3/16" (4)	347 (50)	-	489 (7830)	0.12 (500)
10	Exterior Film (left side) ¹	-	-	R-0.2 (0.03 RSI)	-	-

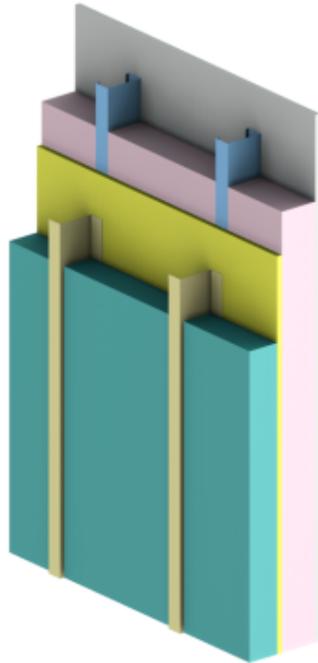
¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

² The thermal conductivity of air spaces within framing was found using ISO 100077-2



Detail 3

Exterior Insulated 3 5/8" Steel Stud (16" o.c.) Wall Assembly with Vertical Z-Girts (16" o.c.) Supporting Metal Cladding – Coating Applied to Exterior Z-girts



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	14.1	0.071	-	0.46
60 mil Coating (R-0.24)	15.2	0.066	7.2%	0.49
120 mil Coating (R-0.5)	16.0	0.063	12.5%	0.51
0.5 inch Coating (R-2.0)	18.7	0.053	28.2%	0.54

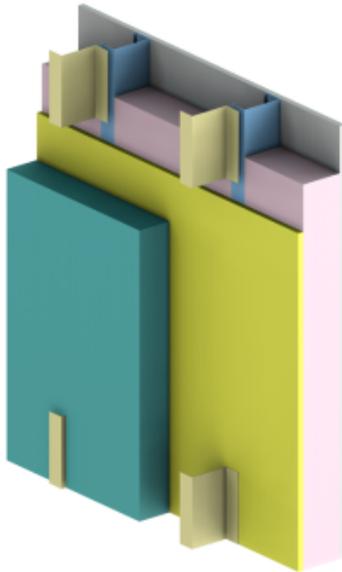
*Critical Surface Temperature Index at Interior Surface of Exterior Sheathing between Studs

ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fiberglass Batt Insulation in Stud Cavity	3 5/8" (92)	0.29 (0.042)	R-12 (2.1 RSI)	0.075 (1.2)	0.24 (1000)
4	3 5/8" x 1 5/8" Steel Studs	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Exterior Insulation	3" (76)	0.33 (0.036)	R-12 (2.11 RSI)	1.8 (28)	0.29 (1220)
7	Vertical Z-Girts w/ 1 1/2" Flange	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
8	Metal cladding with 1/2" (13mm) vented air space is incorporated into exterior heat transfer coefficient					
9	Exterior Film (left side) ¹	-	-	R-0.7 (0.12 RSI)	-	-

¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

Detail 4

Exterior Insulated 3 5/8" Steel Stud (16" o.c.) Wall Assembly with Vertical Z-Girts (16" o.c.) Supporting Metal Cladding – Coating Applied to Exterior Z-girts



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	18.2	0.055	-	0.51
60 mil Coating (R-0.24)	18.9	0.053	3.8%	0.52
120 mil Coating (R-0.5)	19.5	0.051	6.4%	0.53
0.5 inch Coating (R-2.0)	20.9	0.048	13.7%	0.54

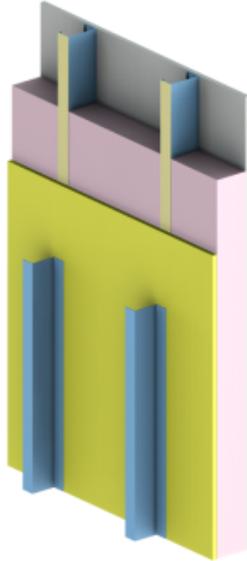
*Critical Surface Temperature Index at Interior Surface of Exterior Sheathing between studs

ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fiberglass Batt Insulation in Stud Cavity	3 5/8" (92)	0.29 (0.042)	R-12 (2.1 RSI)	0.075 (1.2)	0.24 (1000)
4	3 5/8" x 1 5/8" Steel Studs	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Exterior Insulation	3" (76)	0.33 (0.036)	R-12 (2.11 RSI)	1.8 (28)	0.29 (1220)
7	Intermittent vertical Z-Girts w/ 1 1/2" Flange	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
8	Metal cladding with 1/2" (13mm) vented air space is incorporated into exterior heat transfer coefficient					
9	Exterior Film (left side) ¹	-	-	R-0.7 (0.12 RSI)	-	-

¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

Detail 5

Interior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Vertical Z-Girts (16" o.c.) Supporting Metal Cladding – Coating Applied to Exterior Flange of Steel Stud



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	9.0	0.111	-	0.08
60 mil Coating (R-0.24)	9.3	0.107	3.5%	0.08
120 mil Coating (R-0.5)	9.6	0.105	6.1%	0.08
0.5 inch Coating (R-2.0)	10.4	0.096	14.4%	0.08

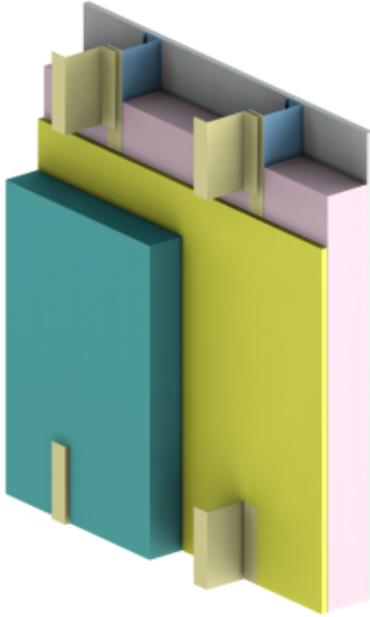
*Critical Surface Temperature Index at Interior Surface of Exterior Sheathing between Studs

ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fiberglass Batt Insulation in Stud Cavity	3 5/8" (92)	0.29 (0.042)	R-12 (2.1 RSI)	0.075 (1.2)	0.24 (1000)
4	3 5/8" x 1 5/8" Steel Studs	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Vertical Z-Girts w/ 1 1/2" Flange	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
7	Metal cladding with 1/2" (13mm) vented air space is incorporated into exterior heat transfer coefficient					
8	Exterior Film (left side) ¹	-	-	R-0.7 (0.12 RSI)	-	-

¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

Detail 6

Exterior Insulated 3 5/8" x 1 5/8" Steel Stud (16" o.c.) Wall Assembly with Intermittent Vertical Z-Girts (16" o.c.) Supporting Metal Cladding – Coating Applied to Exterior Flange of Steel Studs and Exterior Clips



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	14.1	0.071	-	0.46
60 mil Coating (R-0.24)	15.2	0.066	7.2%	0.49
120 mil Coating (R-0.5)	16.0	0.063	12.5%	0.51
0.5 inch Coating (R-2.0)	18.7	0.053	28.2%	0.54

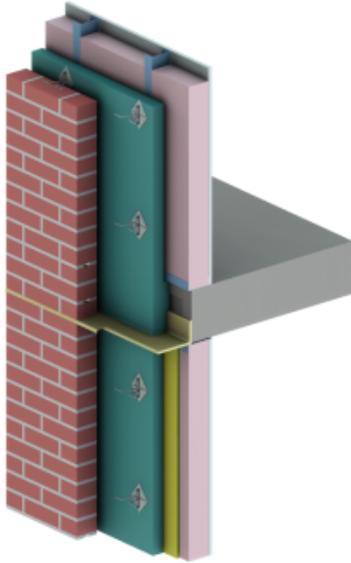
*Critical Surface Temperature Index at Interior Surface of Exterior Sheathing between Studs

ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fiberglass Batt Insulation in Stud Cavity	3 5/8" (92)	0.29 (0.042)	R-12 (2.1 RSI)	0.075 (1.2)	0.24 (1000)
4	3 5/8" x 1 5/8" Steel Studs	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Exterior Insulation	3" (76)	0.33 (0.036)	R-12 (2.11 RSI)	1.8 (28)	0.29 (1220)
7	Intermittent vertical Z-Girts w/ 1 1/2" Flange	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
8	Metal cladding with 1/2" (13mm) vented air space is incorporated into exterior heat transfer coefficient					
9	Exterior Film (left side) ¹	-	-	R-0.7 (0.12 RSI)	-	-

¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation

Detail 7

Exterior and Interior Insulated Wall Assembly with Shelf Angle & Brick Ties Supporting Brick Veneer – Coating Applied to Steel Shelf Angle and Flashing



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	9.6	0.105	-	0.78
60 mil Coating (R-0.24)	10.8	0.092	12.5%	0.82
120 mil Coating (R-0.5)	11.7	0.086	19.8%	0.84
0.5 inch Coating (R-2.0)	13.9	0.072	37.0%	0.89

*Critical Surface Temperature Index at Concrete Floor Slab at Interior Gypsum

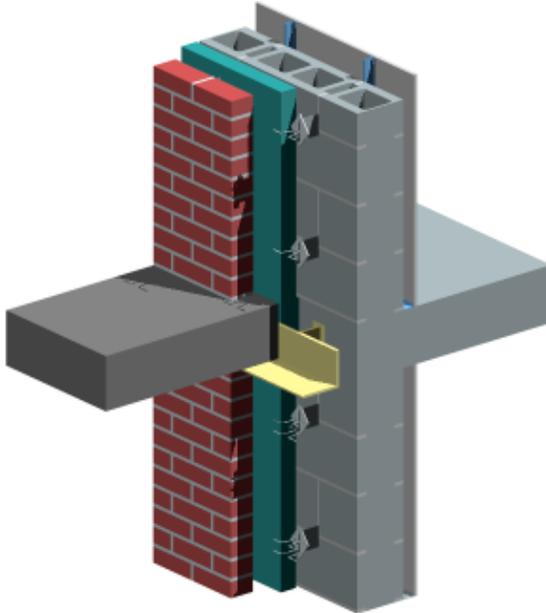
ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.6 (0.11 RSI) to R-0.9 (0.16 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fiberglass Batt Insulation in Stud Cavity	3 5/8" (92)	0.29 (0.042)	R-12 (2.1 RSI)	0.9 (14)	0.17 (710)
4	3 5/8" x 1 5/8" Steel Studs with Top and Bottom Tracks	18 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Exterior Sheathing	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
6	Exterior Insulation	3" (76)	0.33 (0.036)	R-12 (2.11 RSI)	1.8 (28)	0.29 (1220)
7	Brick Ties	14 gauge	347 (50)	-	489 (7830)	0.12 (500)
8	Shelf Angle	3/8" (10)	347 (50)	-	489 (7830)	0.12 (500)
9	Flashing	20 gauge	347 (50)	-	489 (7830)	0.12 (500)
10	Brick Veneer	3 5/8" (92)	5.4 (0.78)	-	120 (1920)	0.19 (720)
11	Concrete Slab	8" (203)	12.5 (1.8)	-	140 (2250)	0.20 (850)
12	Air Gap	1" (25)	-	R-0.9 (0.16 RSI)	0.075 (1.2)	0.24 (1000)
13	Exterior Film (left side) ¹	-	-	R-0.2 (0.03 RSI)	-	-

¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation



Detail 8

Exterior Insulated Concrete Block Wall Assembly with Masonry Ties Supporting Brick Veneer – Angle Supported Slab & Slab Intersection – Coating Applied to Angle Support



	Effective R-Value (hr ft ² °F/BTU)	U-Value (BTU/hr ft ² °F)	Percent Difference	Surface Temperature Index*
No Coating	11.8	0.085	-	0.88
60 mil Coating (R-0.24)	12.0	0.083	1.7%	0.89
120 mil Coating (R-0.5)	12.2	0.082	3.2%	0.89
0.5 inch Coating (R-2.0)	13.1	0.076	10.0%	0.91

*Critical Surface Temperature Index at Concrete Floor Slab at Interior Gypsum

ID	Component	Thickness Inches (mm)	Conductivity Btu-in / ft ² ·hr·°F (W/m K)	Nominal Resistance hr·ft ² ·°F/Btu (m ² K/W)	Density lb/ft ³ (kg/m ³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film (right side) ¹	-	-	R-0.6 (0.11 RSI) to R-0.9 (0.16 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Air in Stud Cavity	1 5/8" (41)	-	R-0.9 (0.16 RSI)	0.075 (1.2)	0.24 (1000)
4	1 5/8" Steel Studs with Metal Tracks	20 gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Standard Concrete Block	7 5/8" (190)	3.5 (0.5)	-	119 (1900)	0.19 (800)
6	Insulation	3" (76)	0.33 (0.036)	R-12 (2.11 RSI)	1.8 (28)	0.29 (1220)
7	Masonry Ties @ 16" (406) o.c.	14 gauge	347 (50)	-	489 (7830)	0.12 (500)
8	Brick Veneer	3 5/8" (92)	5.4 (0.78)	-	120 (1920)	0.19 (720)
9	Concrete Slab	8" (203)	12.5 (1.8)	-	140 (2250)	0.20 (850)
10	Slab & Brick (Anchored to Slab at 16" o.c.) Support Angle	-	347 (50)	-	489 (7830)	0.12 (500)
11	Air Gap	1" (25)	-	R-0.9 (0.16 RSI)	0.075 (1.2)	0.24 (1000)
12	Exterior Film (left side) ¹	-	-	R-0.2 (0.03 RSI)	-	-

¹ Value selected from table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation



Appendix B: Using Temperature Indices and Thermal Images

Indexed Surface Temperatures

A temperature index is a way to represent a surface temperature of interest (or concern) relative to a temperature difference. It allows a surface temperature to be extrapolated to any set of indoor and outdoor temperatures. Essentially, it is the temperature drop between the inside air and a surface, divided by the total temperature difference.

Indexed surfaces temperatures are calculated as follows:

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

Where

- T_i is the temperature index (-)
- $T_{surface}$ is the coldest temperature of the surface
- $T_{outside}$ is the outdoor temperature
- T_{inside} is the indoor temperature

Surface temperatures presented using temperature indices allow the surface temperatures to be applicable to any set of indoor and outdoor conditions. A temperature index of zero is the outdoor air temperature and a temperature index of one is the indoor air temperature.

Evaluating the condensation resistance using dew-point methods and surface temperatures limited to steady-state conductive heat flow requires a full awareness of the limitations and should not be the sole basis for hygrothermal design of opaque building envelope assemblies. More discussion on how to efficiently approximate condensation of wall assemblies using a temperature index is available upon request.

Minimum indexed surface temperatures are provided at concealed cavity surfaces, as well as at other points of interest (e.g. lowest temperature on window framing or floor surface) depending on the detail. Colour isothermal plots are provided to illustrate the temperature indices variations viewed from the interior and exterior.

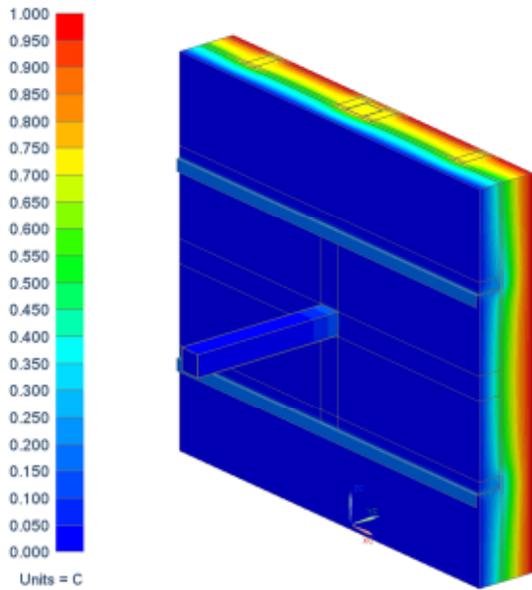


Fig B.1. Thermal profile from exterior for Detail 1

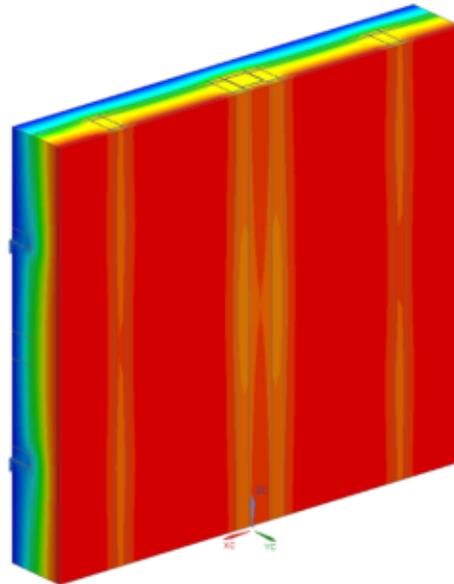


Fig B.2. Thermal profile from Interior for Detail 1

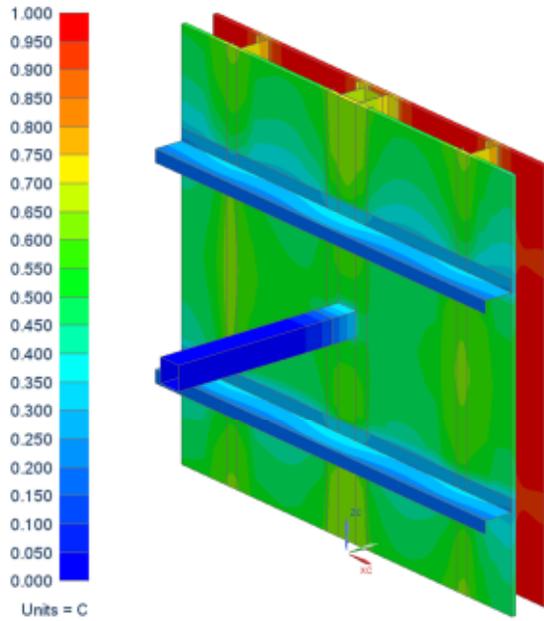


Fig B.3. Thermal profile with insulation removed for Detail 1

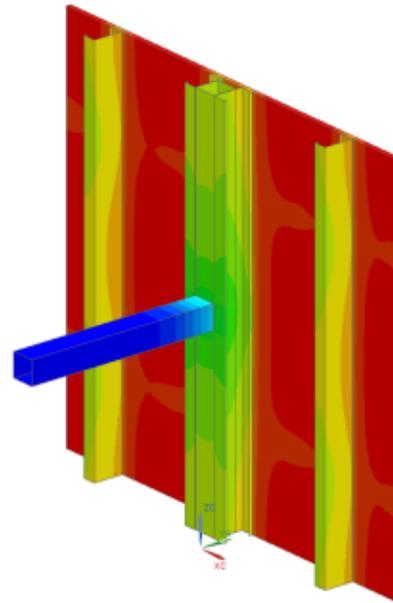


Fig B.4. Thermal profile of steel beam and post for Detail 1

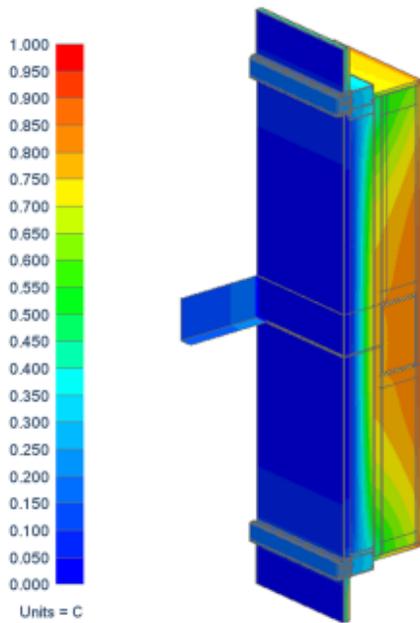


Fig B.5. Thermal profile from exterior for Detail 2

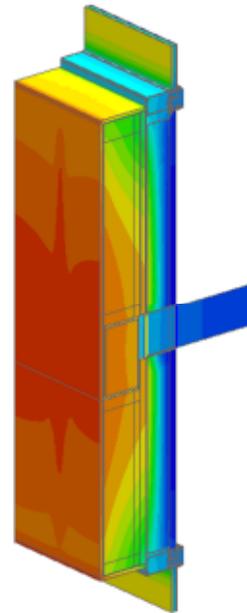


Fig B.6. Thermal profile from Interior for Detail 2

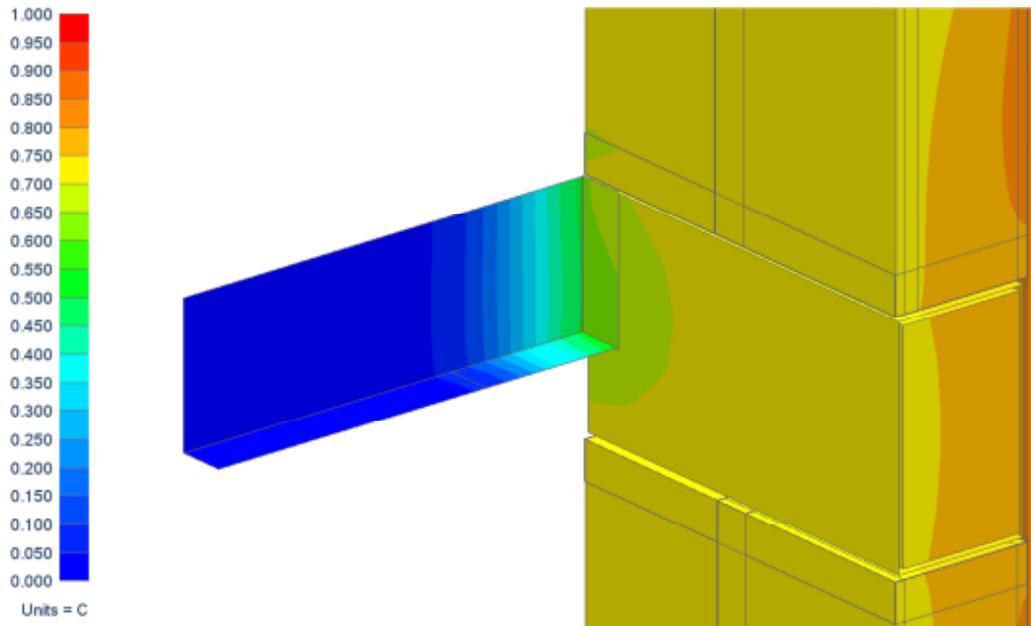


Fig B.7. Thermal profile of steel beam for Detail 2

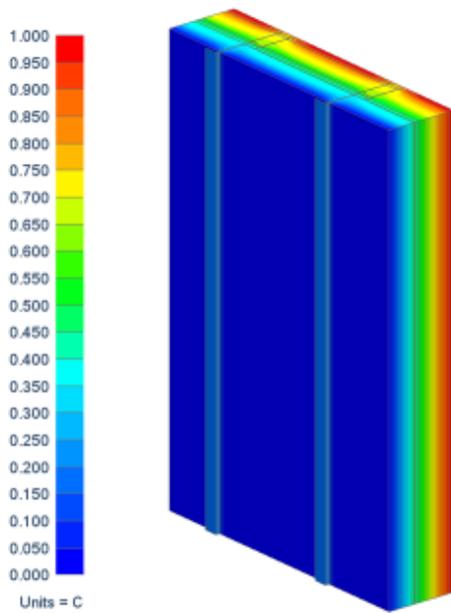


Fig B.8. Thermal profile from exterior for Detail 3 and 5



Fig B.9. Thermal profile from Interior for Detail 3 and 5

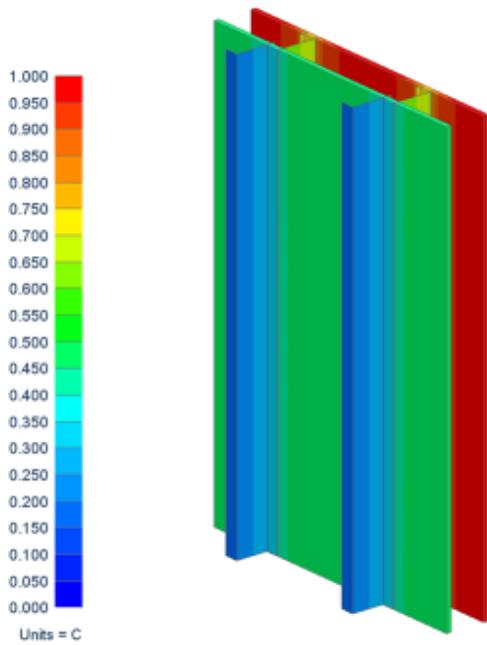


Fig B.10. Thermal profile with insulation removed for Detail 3 and 5

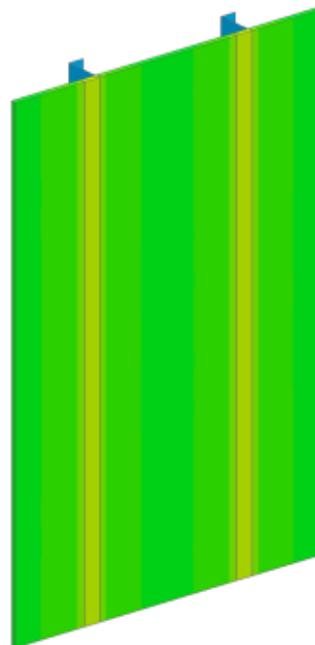


Fig B.11. Thermal profile of exterior sheathing for Detail 3 and 5

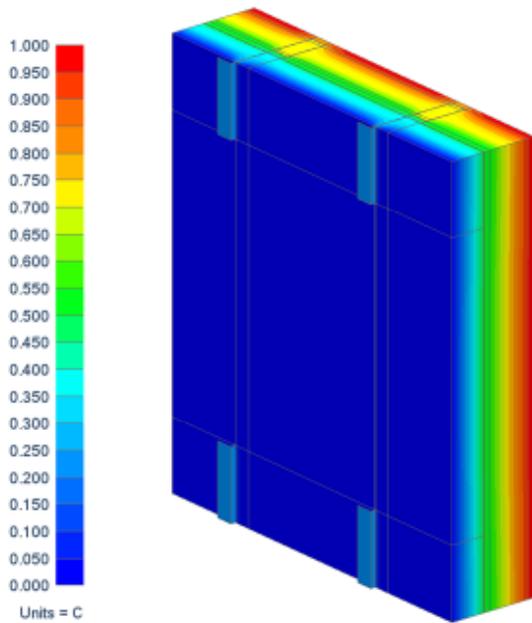


Fig B.12. Thermal profile from exterior for Detail 4 and 6

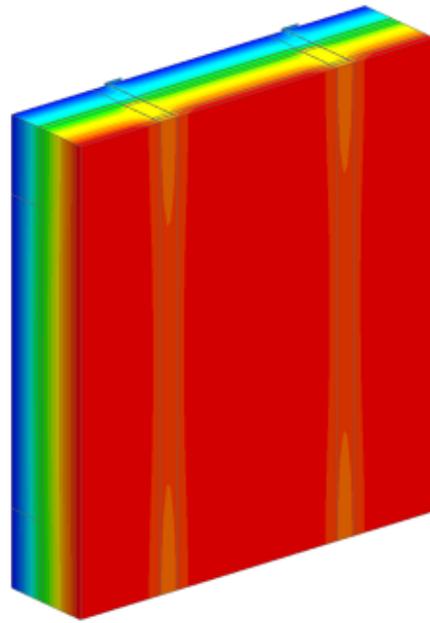


Fig B.13. Thermal profile from Interior for Detail 4 and 6

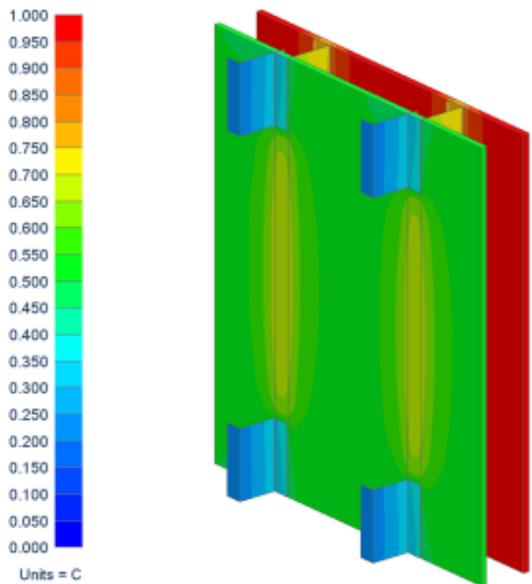


Fig B.14. Thermal profile with insulation removed for Detail 3 and 5

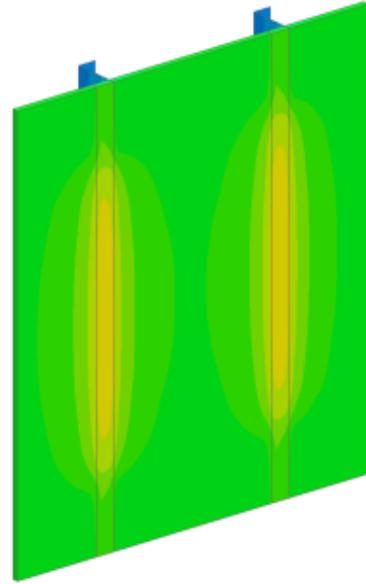


Fig B.15. Thermal profile of exterior sheathing for Detail 3 and 5

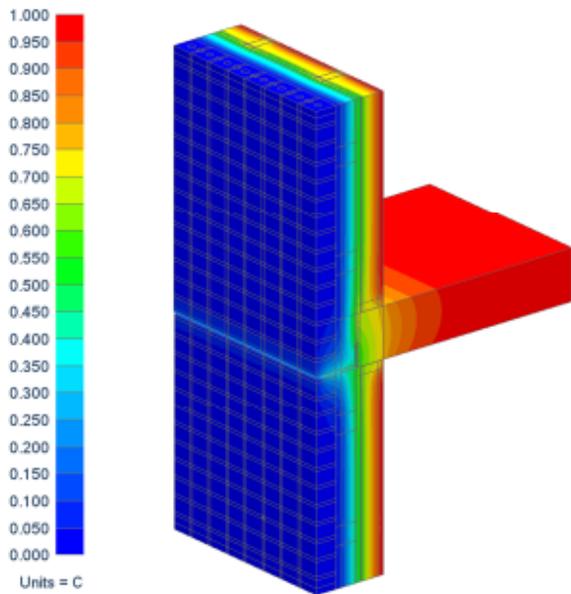


Fig B.16. Thermal profile from exterior for Detail 7

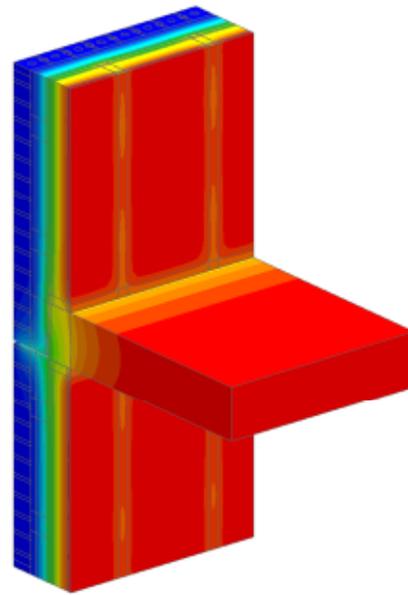


Fig B.17. Thermal profile from Interior for Detail 7

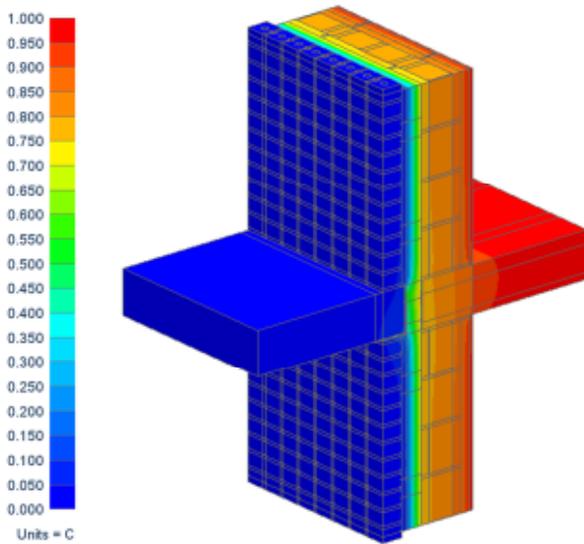


Fig B.18. Thermal profile from exterior for Detail 8

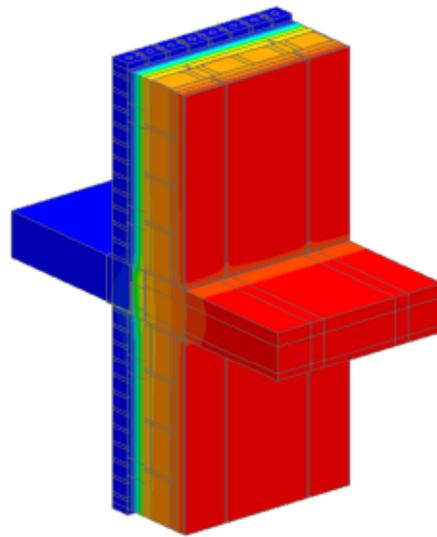


Fig B.19. Thermal profile from Interior for Detail 8