Submittal Transmittal

Detailed, Grouped by Each Number

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200 Park Avenue, 9th Floor
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Project # 11668500
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Lend Lease (US) Construction LMB Inc.

Date: 8/21/2015 **Reference Number: 0566**

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Qty	Submittal Package No	Description	Due Date	Package Action
102	0007 - 08 44 13 - 2	PNA - Tower System Design - Thermal Calculations - Wall Types A,B,E	8/27/2015	

Transmitted For	Delivered Via	Tracking Number
Approval/Resubmission	Prolog Converge	

Items	Qty	Description	Notes	Item Action
0001	102	System Design - Thermal Calculations - Wall Types A,B,E		

Cc:	Company Name	Contact Name	Copies	Notes

Remarks

Signature **Signed Date**

PERMASTEELISA NORTH AMERICA

LEND LEASE
LEND LEASE (US) CONSTRUCTION LMB, INC.
RECEIVED
8/21/15
0007-08 4 13-2
SUBMITTAL NUMBER

217 WEST 57TH STREET

PROJECT 865

NEW YORK, NY

EXTERIOR WALL PACKAGE

SYSTEM DESIGN - THERMAL CALCULATIONS (WALL TYPE A)

DOC NAME: 90918 TC 001-02-150812 JH

EXTELL DEVELOPMENT COMPANY

ADRIAN SMITH & GORDON GILL

AJLP CONSULTING

LEND LEASE

Rev.	Date	Description	Prepared by	Checked by
02	08/12/2015	Third Submission	JH	JH
01	05/29/2015	Second Submission	JH	AF
00	03/09/2015	First Submission	JH	AF

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TABLE OF CONTENTS

1 SUMMARY

THERM 6.3 software was used to analyze the two-dimensional heat transfer through the frame and glazing edge areas. The frame U-values have been derived using THERM 6.3 according to NFRC standard.
Main results are reported in the following:

Wall Type		U - Factor BTU/(h·ft²·°F)	Overall U - Factor BTU/(h·ft²·°F)	SHGC (Dimensionless)	Condensation Resistance (%)
WT-A	WT-A Vision	0.38	0.32	0.28	35.0
	WT-A Opaque	0.09			

Table 1: Summary of Results

2 THERM KEY

Material	Thermal Conductivity (Btu/h.ft².F)	Model Color
* Fin Bracket Average Conductivity	9.63	
Aluminum Alloy (Painted)	92.45	
Butyl Rubber	0.14	
Ethylene Propylene Diene Monomer (EPDM)	0.14	
Frame Cavity NFRC	Calculated by THERM	
Frame Cavity Slightly Ventilated	Calculated by THERM	
Glass (Plate or Float)	0.58	
IGU Gap Cavity	0.02	
Insulation	0.02	
Neoprene (Polychloroprene)	0.13	
PVC	0.10	
Polyamide 6.6 with 25% Glass Fiber	0.17	
Polyurethane Foam	0.03	
Silica Gel (Desiccant)	0.08	
Silicone Gasket	0.20	
Silicone Sealant	0.20	
Steel – Galvanized Sheet (0.14%C)	35.82	
Steel – Stainless (Buffed)	9.82	

Table 2: THERM Material Color Key

* Given a thermal conductivity of 0.024 W/m.K for air and 160.00 W/m.K for aluminum, an average thermal conductivity can be calculated for the setting block based on an area weighted method. The calculation can be seen below.

$$\left(10.4\% * 160\frac{W}{m.K}\right) + \left(89.6\% * 0.024\frac{W}{m.K}\right) = 16.66\frac{W}{m.K}$$

3 BOUNDARY CONDITIONS

Calculation	Standard	Cold-Side Environmental Temperature	Warm-Side Environmental Temperature	External Wind Speed	External Heat Transfer Coefficient	Internal Relative Humidity	Internal Heat Transfer Coefficient
Thermal Transmittance	NFRC (100-2010)	-0.4°F	69.8°F	12.3mph	4.58 Btu/h-ft²-F	----	0.53 Btu/h-ft²-F
Condensation Assessment	Project Specification (06/02/14)	5.0°F	68.0°F	15.0mph	5.43 Btu/hft²-F	35%	0.53 Btu/h-ft²-F

Table 3: Boundary Conditions

4 GENERAL DESCRIPTION

This report must be read in conjunction with Permasteelisa's system drawings dated August 20th 2015. The thermal performance of the typical façade type is stated in the following report. The overall U-value, as well as Condensation Assessment of the curtain wall panels have been performed according to the (NFRC), (ASHRAE) and (ISO) Standards.

Typical elevation and sections are shown in the following figure.

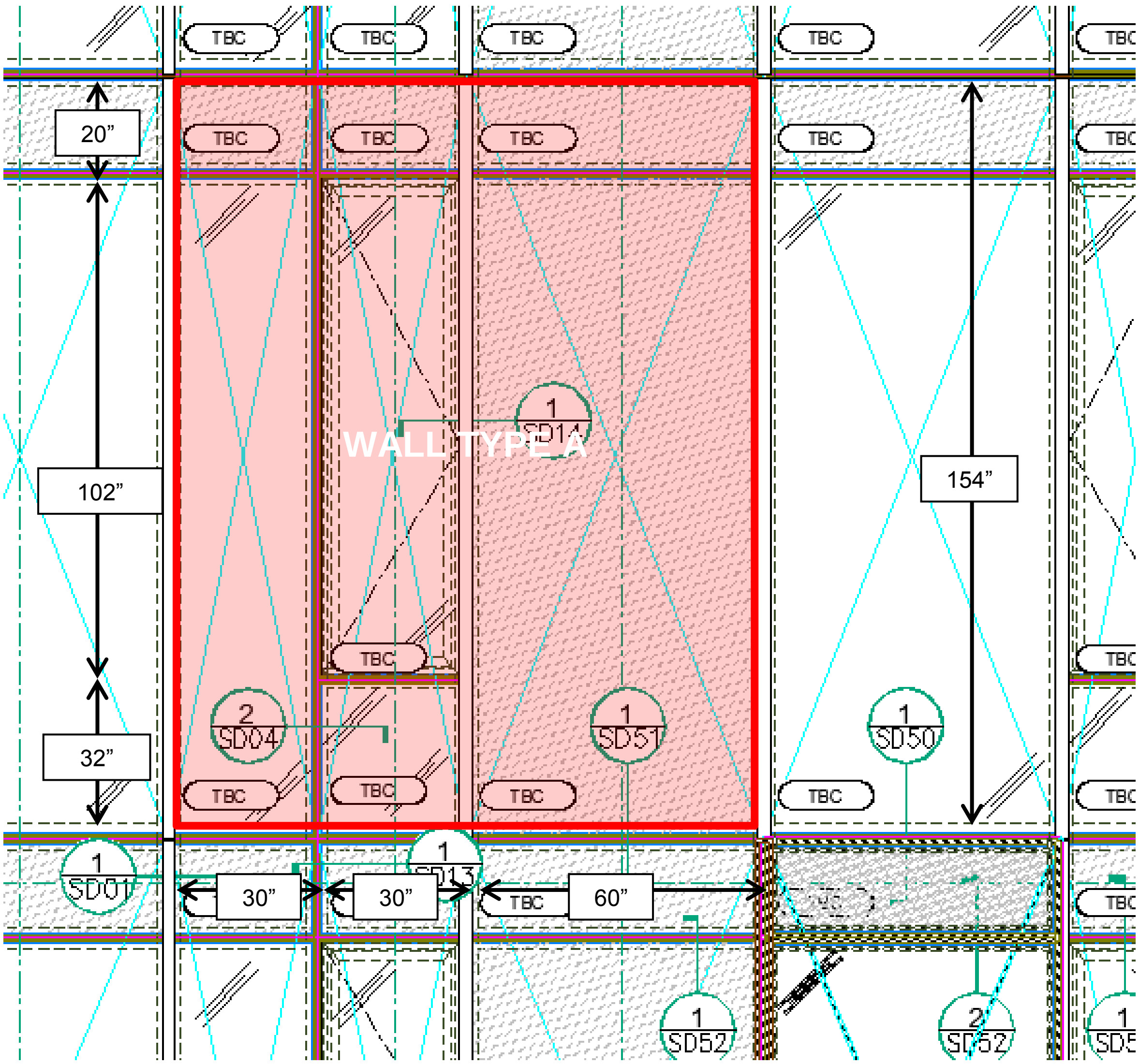

Figure 1: Wall Type A (SE01)

5 THERMAL TRANSMITTANCE

5.1 Thermal Transmittance Calculation Method

The heat transfer through the frame and glazing is assessed as described in the thermal guide (NFRC) and (ISO15099).

There are then the following thermal transmittances (U-values):

- Centre-glazing U-value U_g, which is assumed to apply to the whole of the glazing (defined in section 5.2.1);
- Centre-panel U-value U_{sp}, which is assumed to apply to the whole of the spandrel panel (defined in section 5.2.2);
- Frame U-value U_f (defined in section 5.3);
- Edge U-value U_{edge1}, U_{edge2}, to take into account the heat transfer due to the interaction (edge effect) between the framing and glazing/spandrel panel (defined in section 5.3).

The overall U-value of the curtain wall is then calculated by using the principle of the area weighting of U-values of the frames and glass (as explained in section 5.4).

5.2 Center U-Value

One-dimensional center U-value calculation has been performed for glass and spandrel.

5.2.1 Glazing

The calculations have been performed with the following glass for the typical elevation. (Calculated with Window 6.3 Software according to NFRC):

Glass Makeup:

Outer-lite:	5/16" IPASOL PLATIN 46/31 on Surface # 2 (Interpane)
Cavity:	½" Air with Stainless Steel Spacers
Inner-lite:	¼" – 0.060" – ¼" Laminate

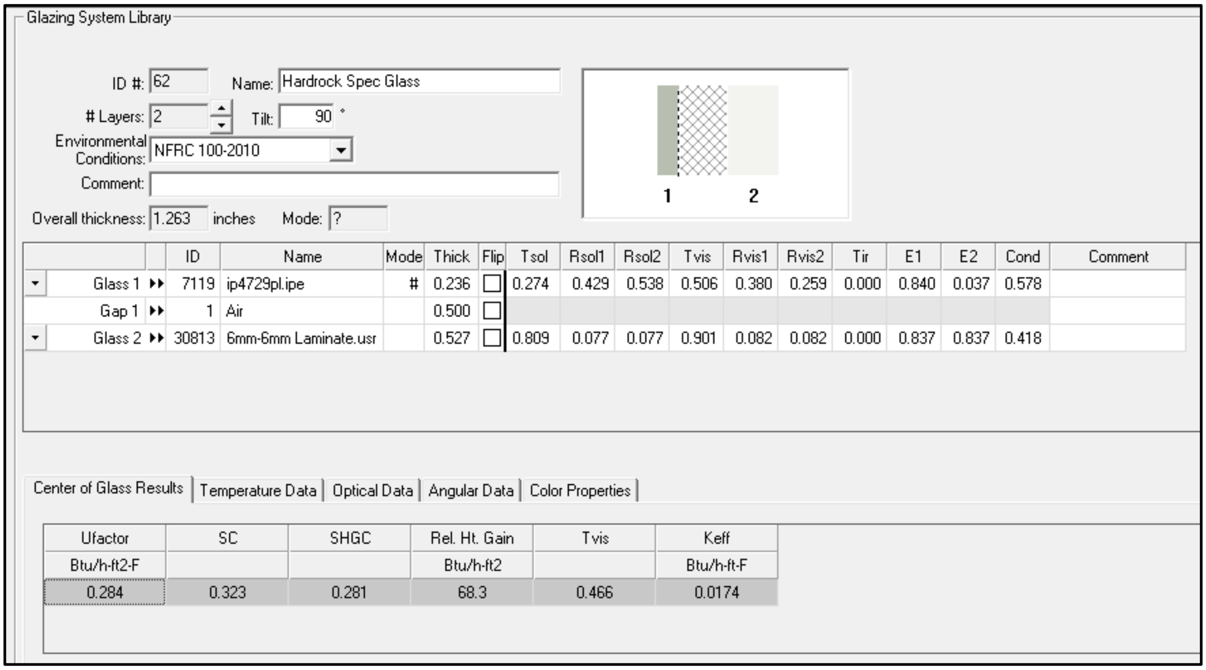

Figure 2: WINDOW 6 Model

Standard	Glass Characteristics	Value
NFRC 100 -2010	Thermal Transmittance (Btu/h.ft².F)	0.28
NFRC 200 – 2010	Solar Heat Gain Coefficient	0.28

Table 4: 1 Dimensional Analysis Summary

5.2.2 Spandrel Panel (Wall Type A)

In the following, the THERM model is presented graphically

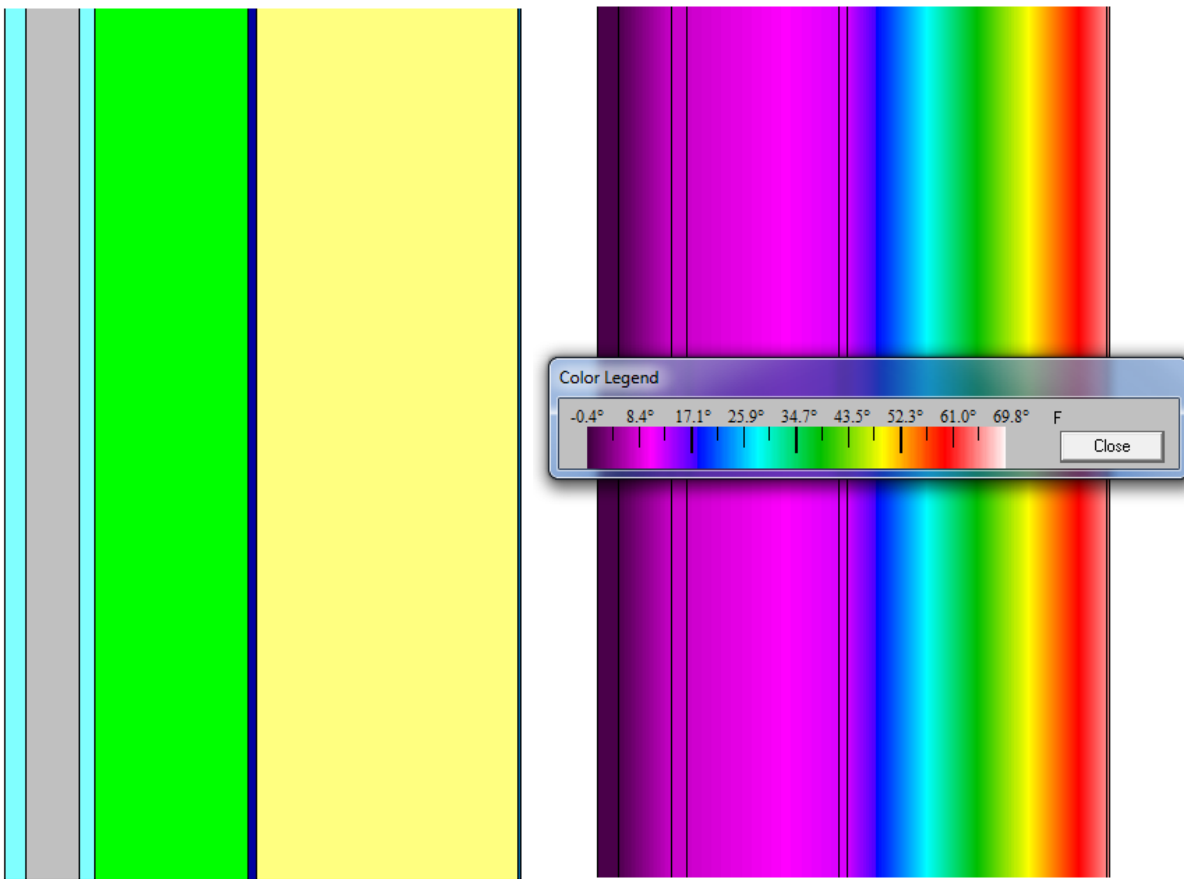

Figure 3: Spandrel Panel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Thermal Transmittance	U_{sp} = 0.05 Btu/h.ft².F

5.3 Wall Type A Frame U-Value

The frames have been modeled by means of 2-dimensional FEM analysis, using the THERM program (version 6.3) by the Lawrence Berkeley National Laboratory. Material properties have been assigned as per THERM internal library.

The frame has been modeled including stainless steel glazing spacers.

The projected width of the solid part of the framing (excluding the glazing gaskets) is measured from the inside. For each of the models, the projected width of the frames is stated along with the frame U-value.

5.3.1 Dart Mullion - Spandrel / Spandrel

In the following, the THERM model is presented graphically

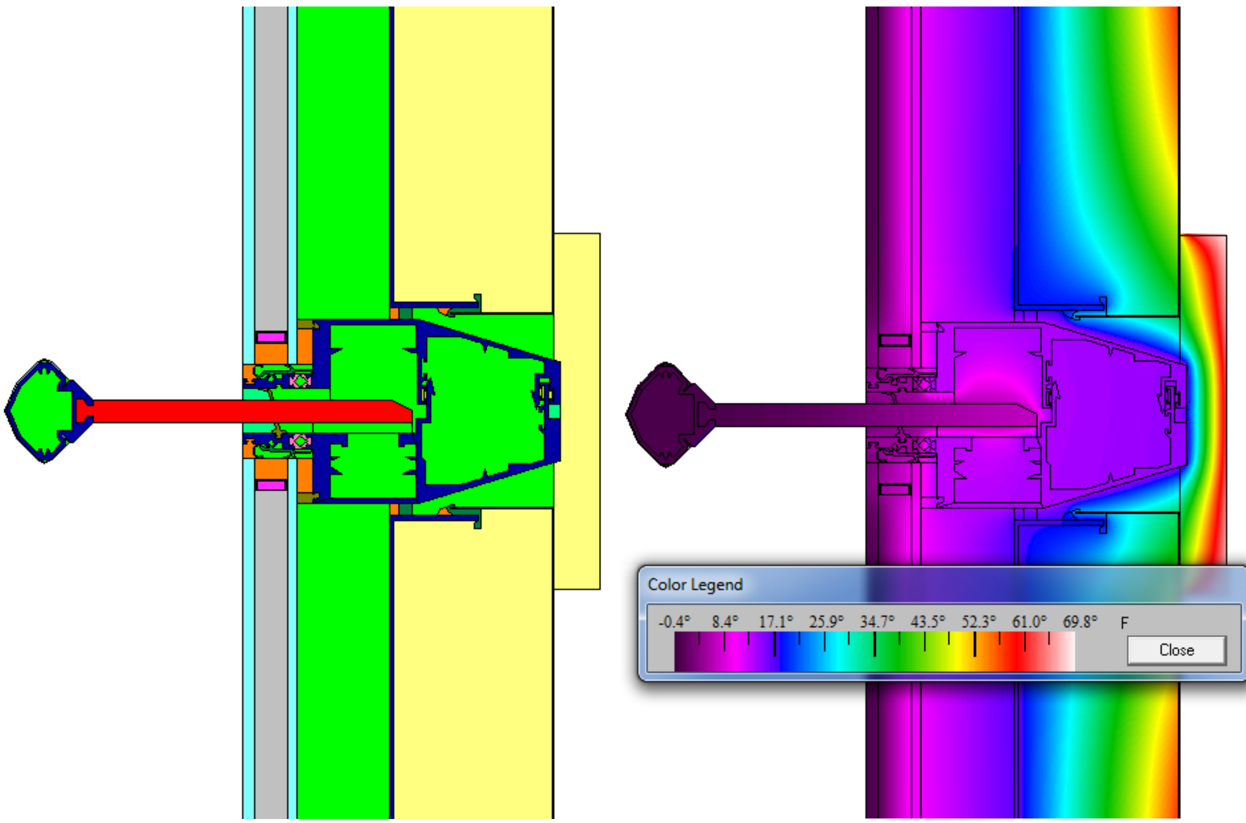

Figure 4: Dart Mullion – Spandrel/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.14 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.14 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.14 Btu/h.ft².F

5.3.2 Dart Mullion – Vision / Vision

In the following, the THERM model is presented graphically

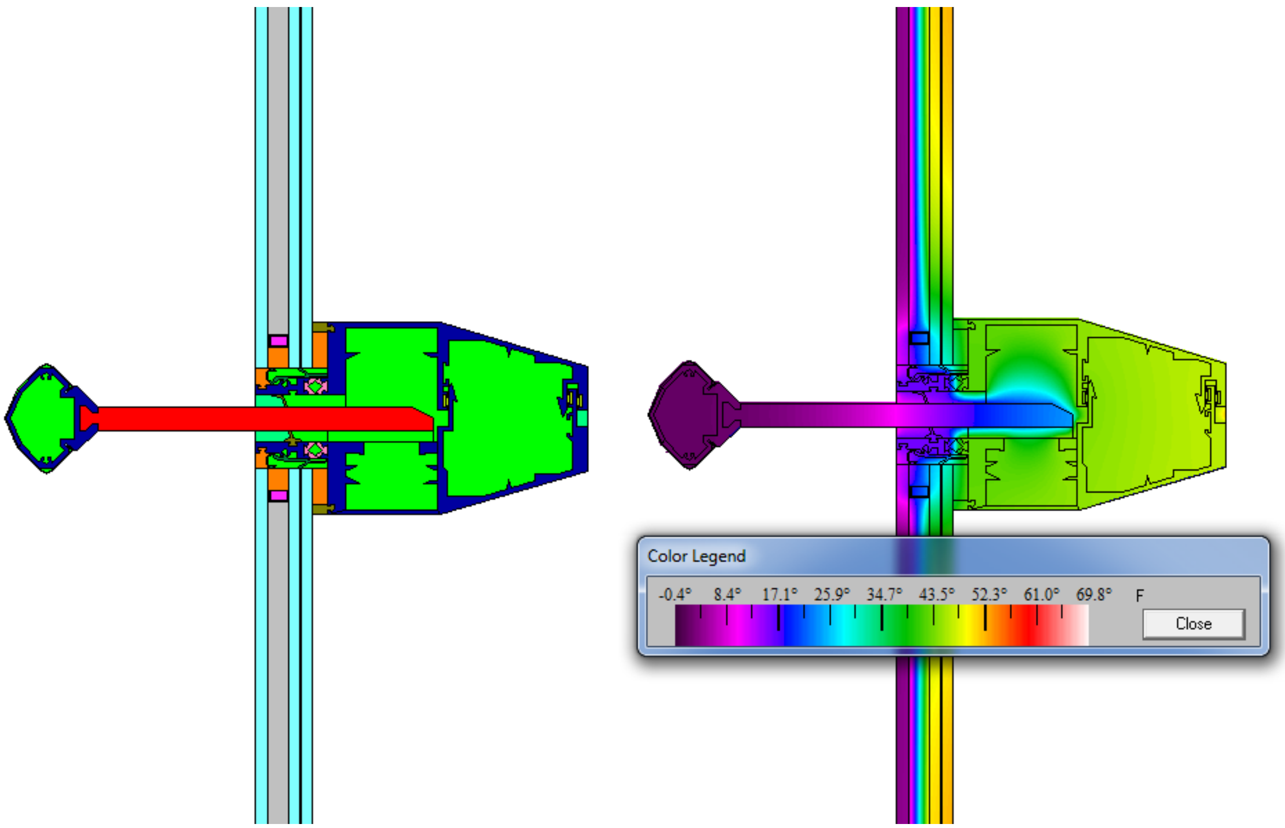

Figure 5: Dart Mullion – Vision/Vision: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.50 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.36 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.36 Btu/h.ft².F

5.3.3 Intermediate Mullion – Spandrel / Spandrel

In the following, the THERM model is presented graphically

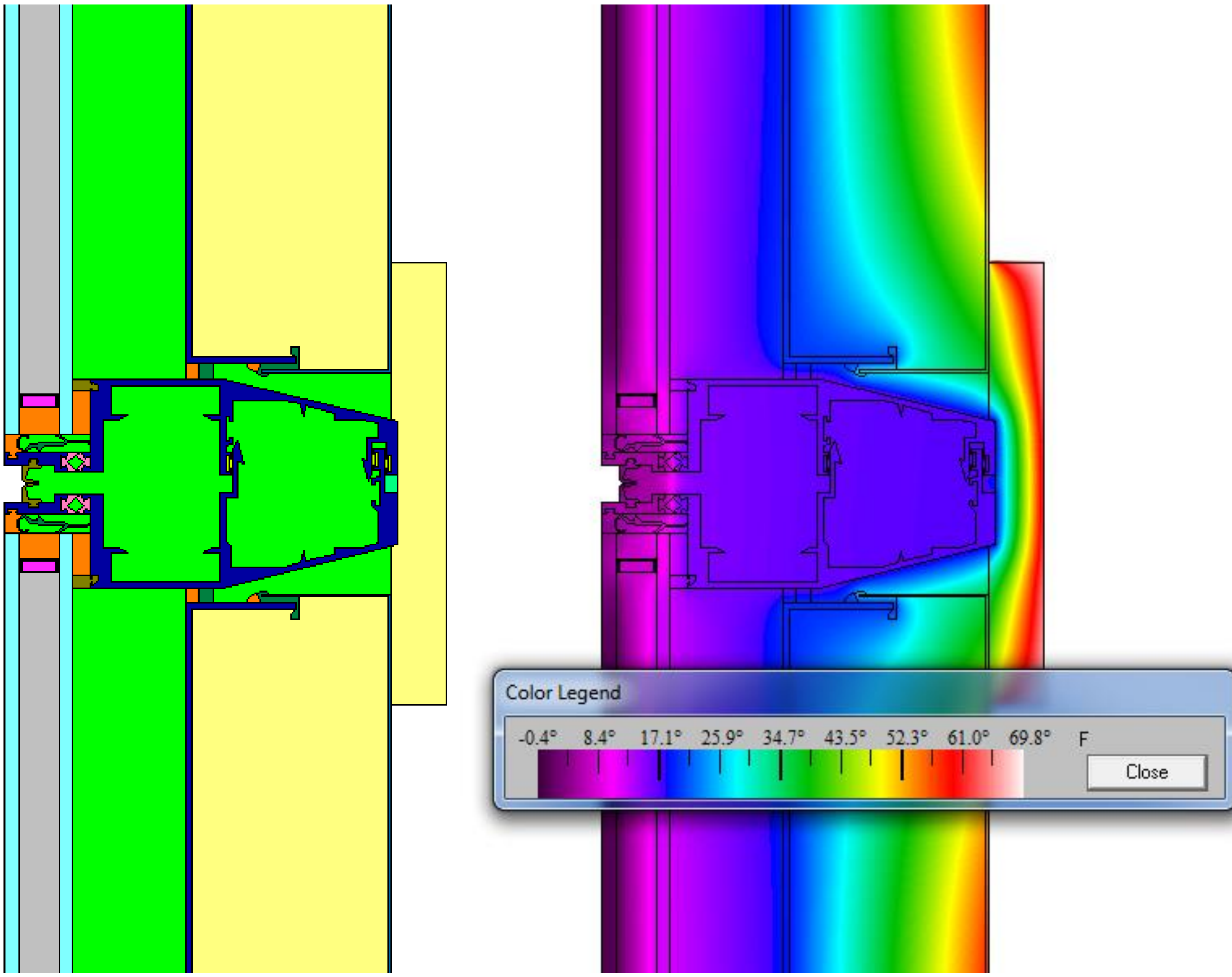

Figure 6: Intermediate Mullion – Spandrel/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.13 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.12 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.12 Btu/h.ft².F

5.3.4 Intermediate Mullion – Vision / Operable

In the following, the THERM model is presented graphically

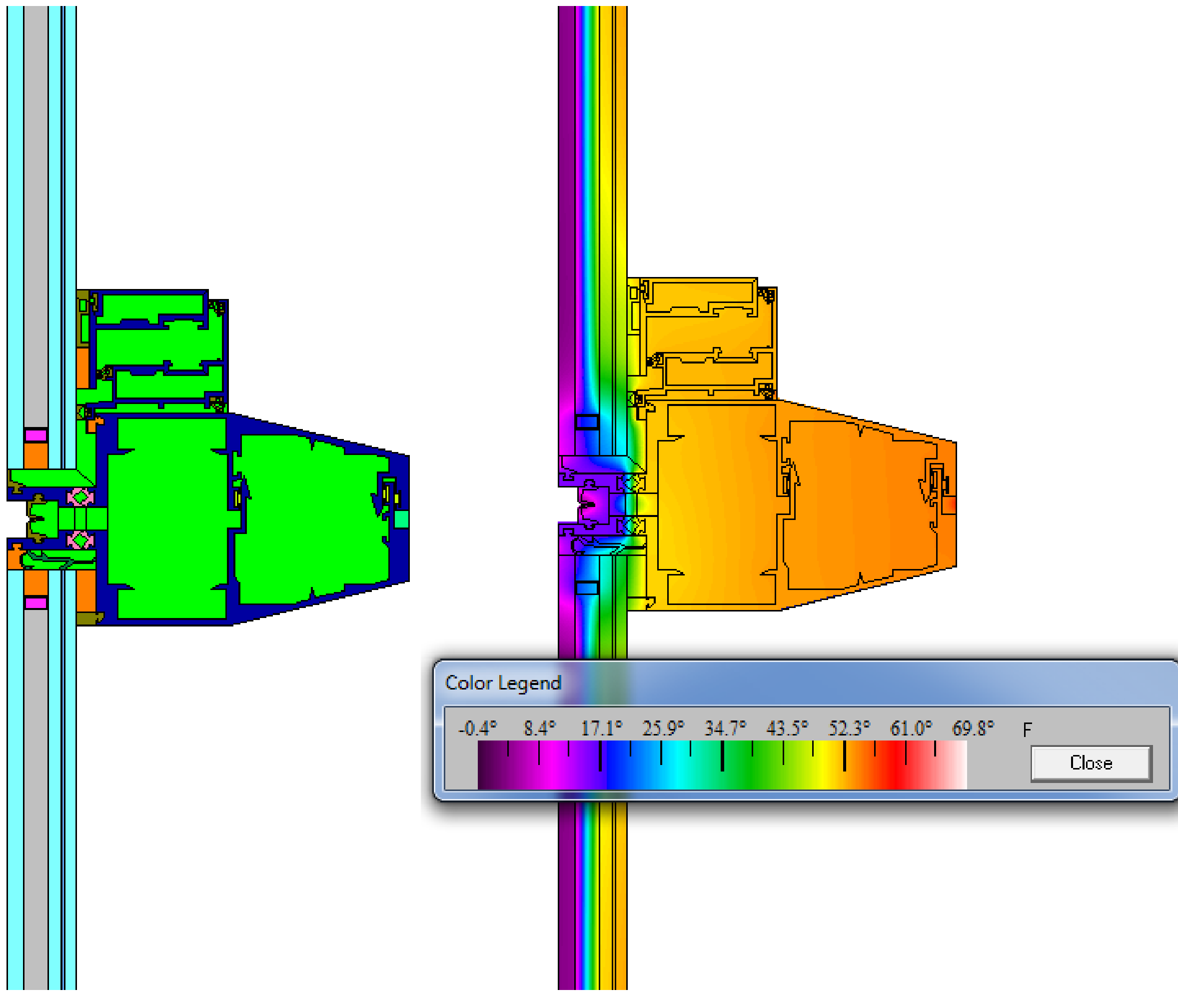

Figure 7: Intermediate Mullion – Vision/Operable: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.78 Btu/h.ft².F
Frame Projected Width	L_f = 6.70 in
Edge Effect Top Side	U_{e1} = 0.29 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.5 Intermediate Mullion – Vision / Vision

In the following, the THERM model is presented graphically

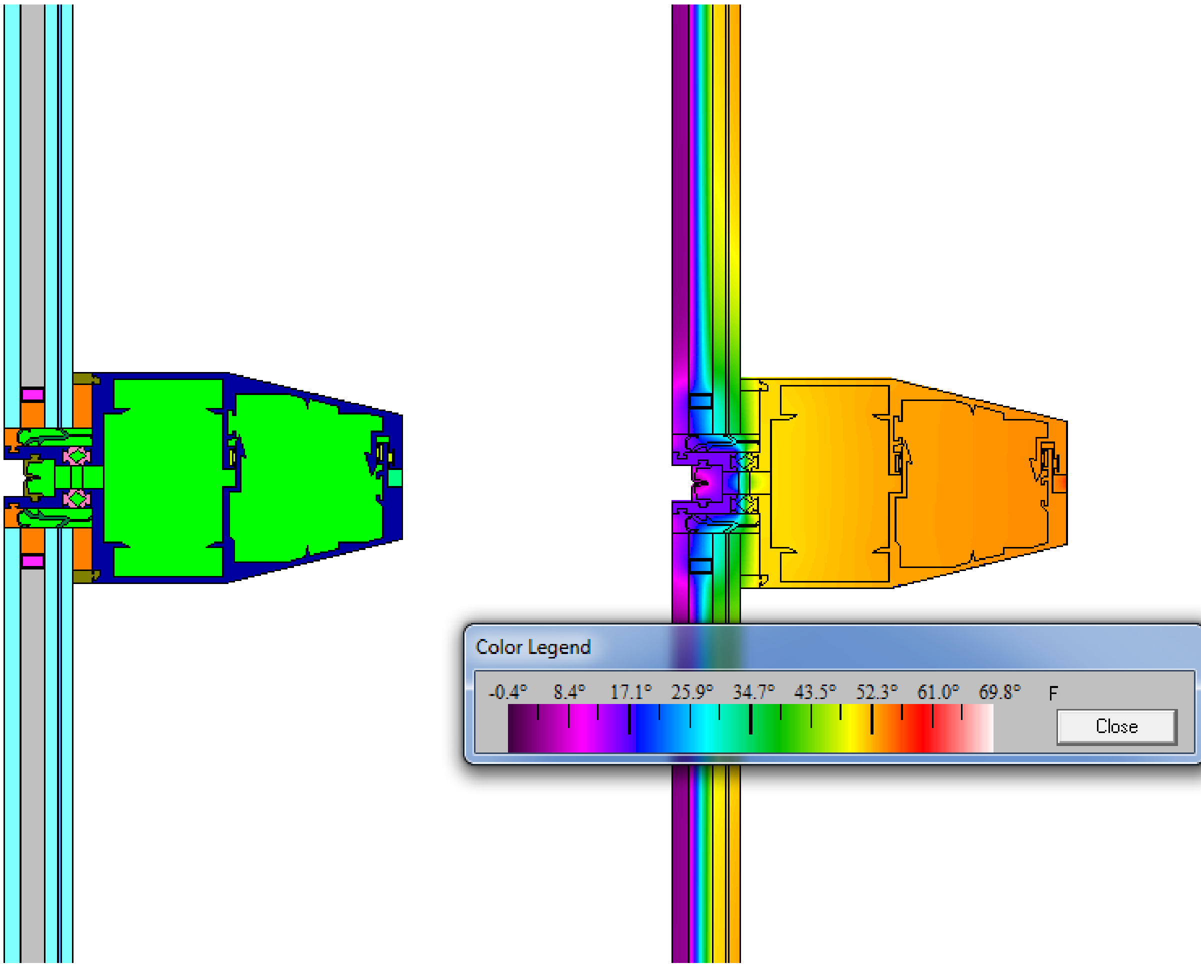

Figure 8: Intermediate Mullion – Vision/Vision: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.08 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.6 Mullion – Spandrel / Spandrel

In the following, the THERM model is presented graphically

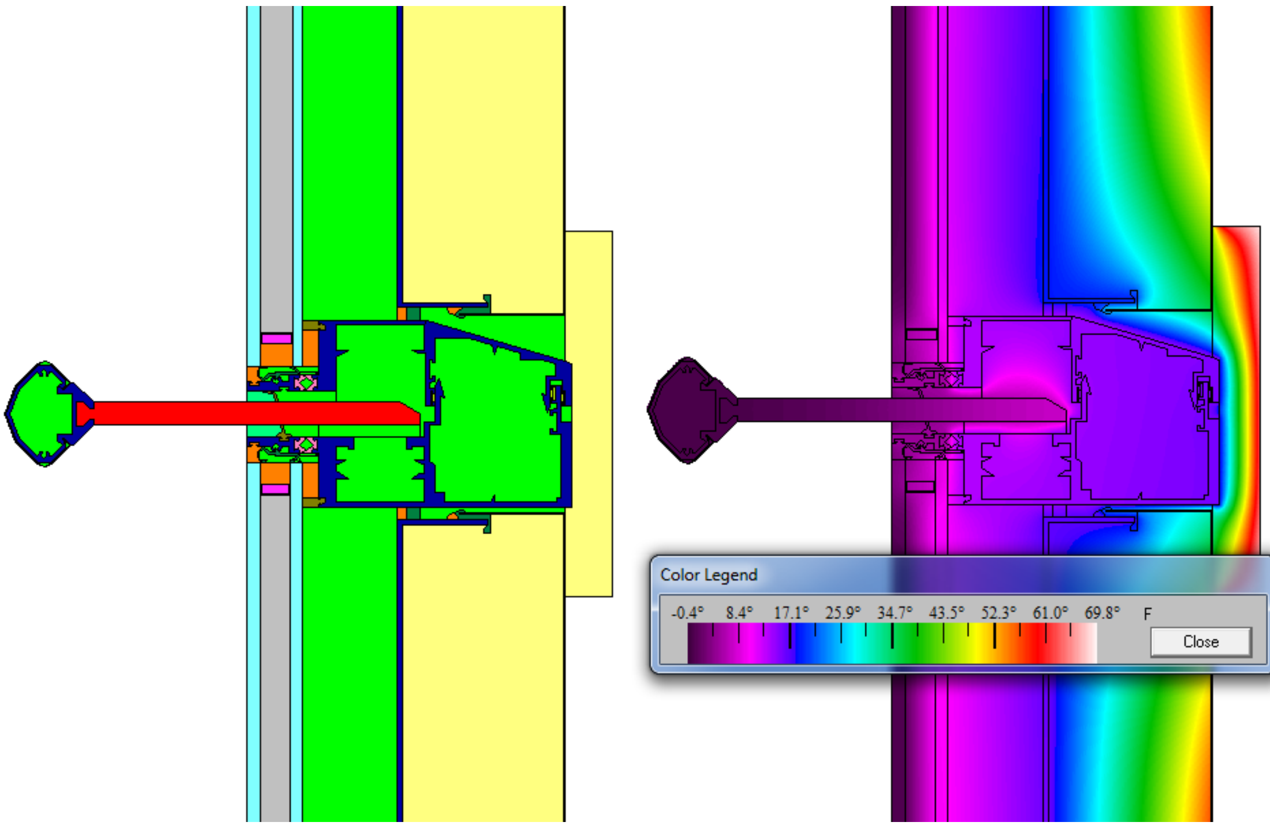

Figure 9: Mullion – Spandrel/Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.14 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.13 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.16 Btu/h.ft².F

5.3.7 Mullion – Operable / Spandrel

In the following, the THERM model is presented graphically

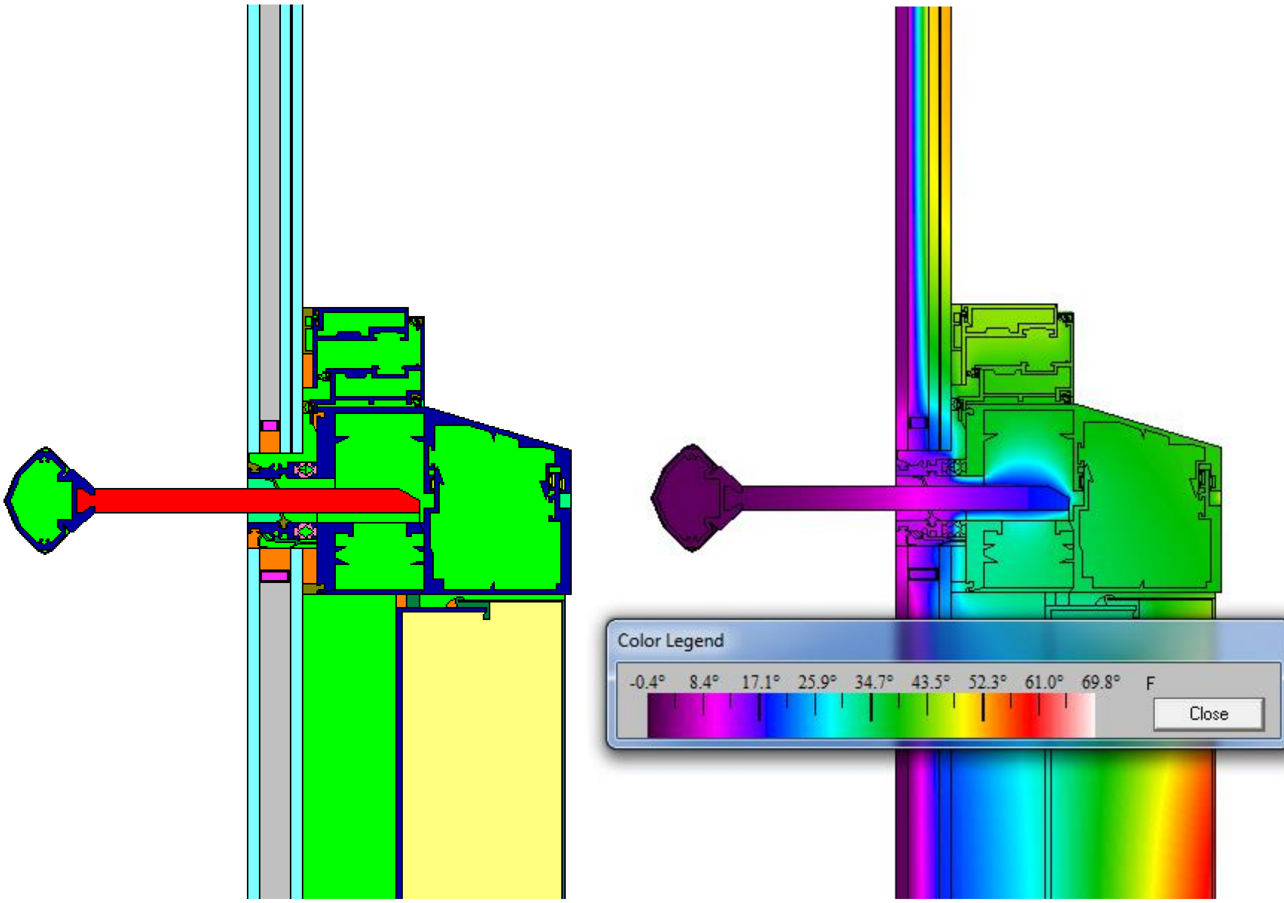

Figure 10: Mullion – Operable/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.92 Btu/h.ft².F
Frame Projected Width	L_f = 7.00 in
Edge Effect Top Side	U_{e1} = 0.31 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.23 Btu/h.ft².F

5.3.8 Mullion – Vision / Spandrel

In the following, the THERM model is presented graphically

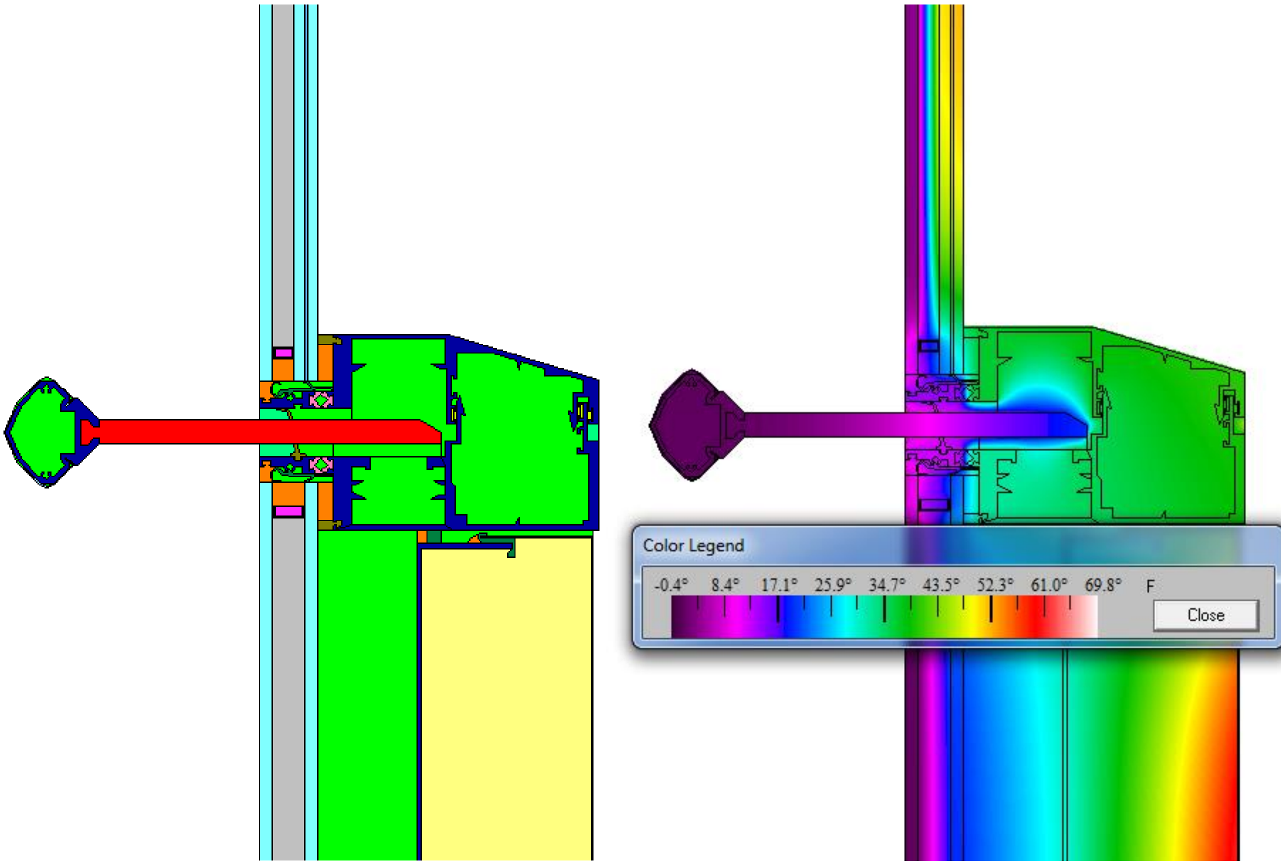

Figure 11: Mullion – Vision/Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.25 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.23 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.37 Btu/h.ft².F

5.3.9 Stack Joint – Vision / Spandrel

In the following, the THERM model is presented graphically

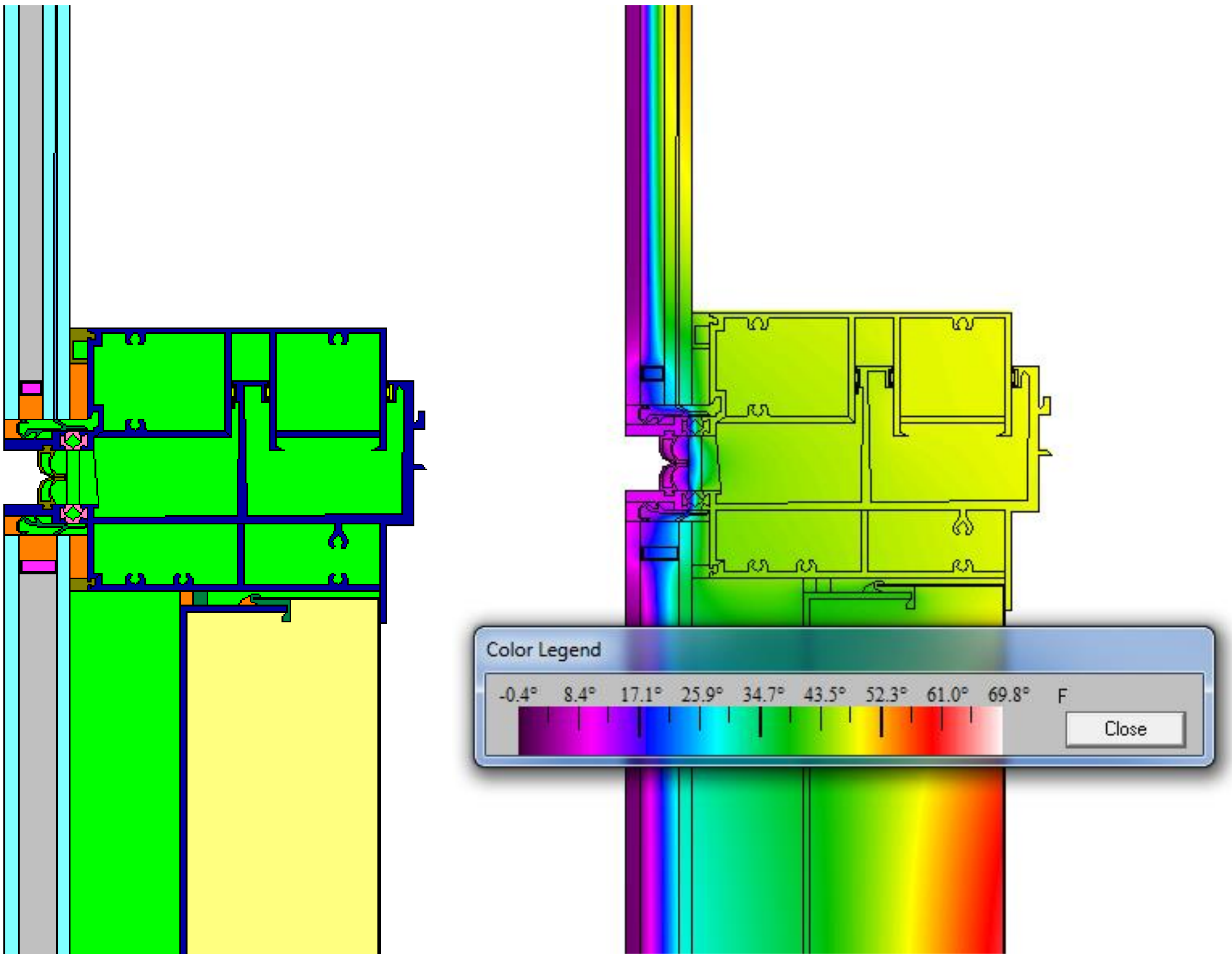

Figure 12: Stack Joint – Vision/Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.96 Btu/h.ft².F
Frame Projected Width	L_f = 5.50 in
Edge Effect Top Side	U_{e1} = 0.32 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.28 Btu/h.ft².F

5.3.10 Stack Joint – Spandrel / Spandrel

In the following, the THERM model is presented graphically

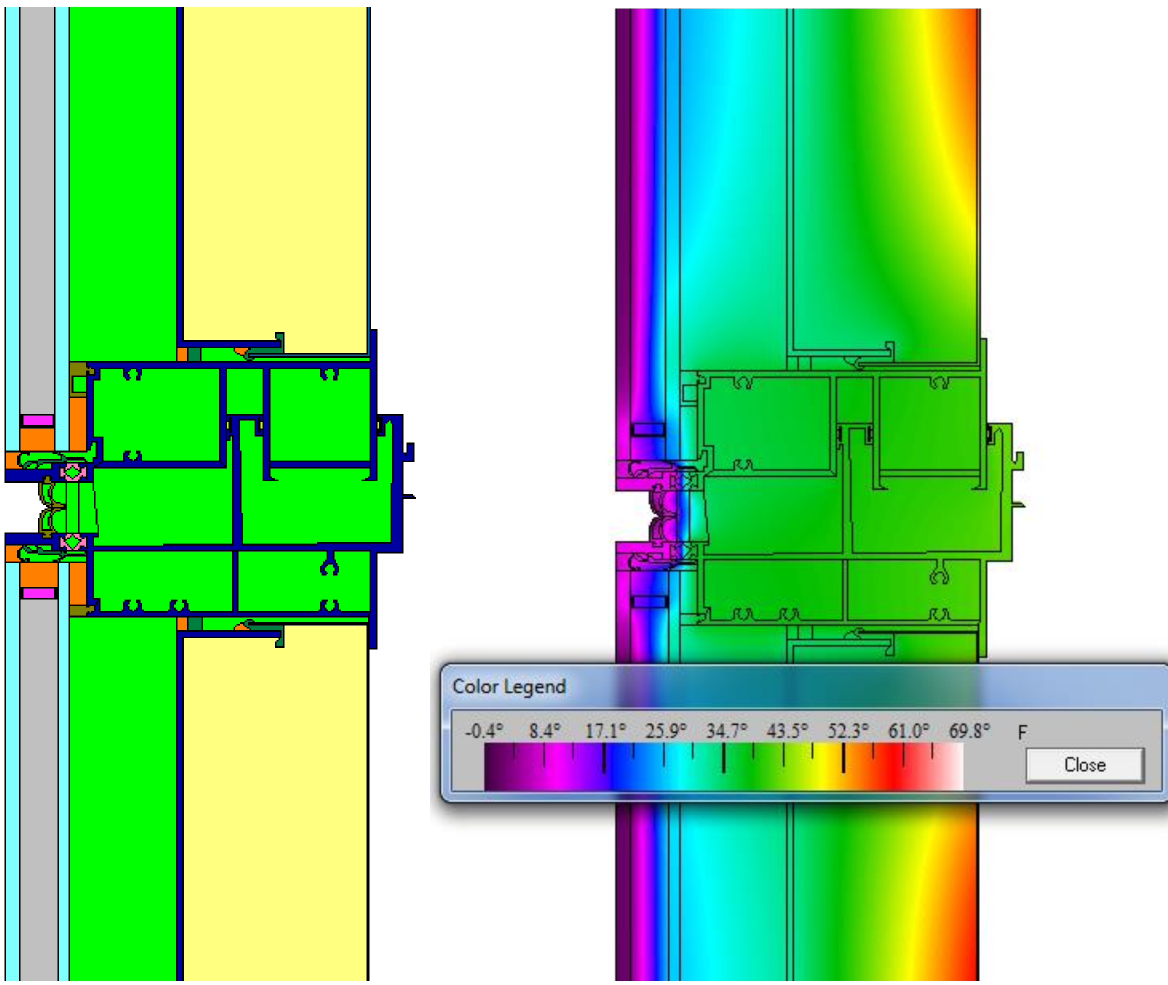

Figure 13: Stack Joint Spandrel/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.66 Btu/h.ft².F
Frame Projected Width	L_f = 5.50 in
Edge Effect Top Side	U_{e1} = 0.36 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.11 Transom – Vision / Spandrel

In the following, the THERM model is presented graphically

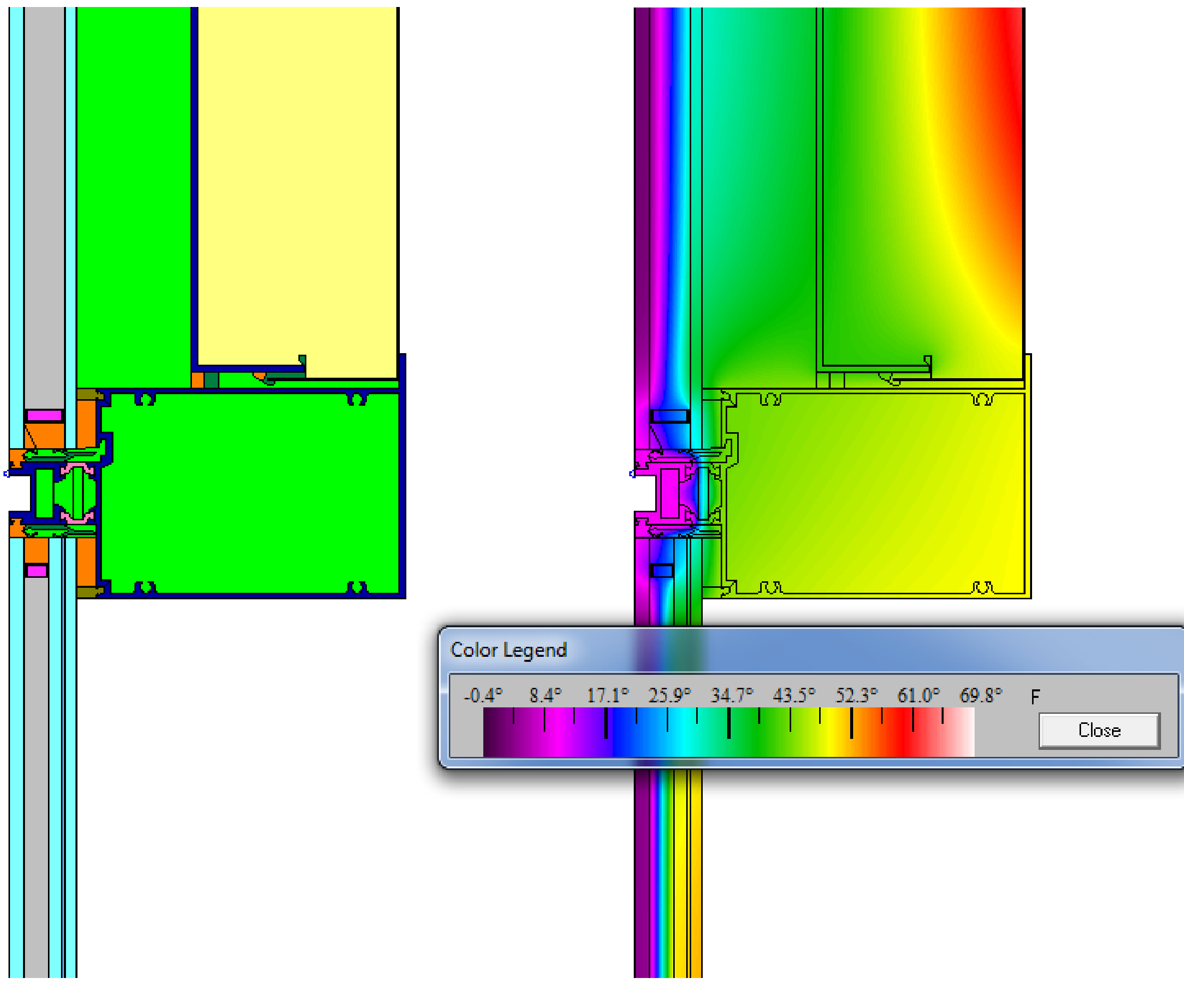

Figure 14: Transom – Vision/Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.98 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.27 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.12 Transom – Spandrel / Operable

In the following, the THERM model is presented graphically

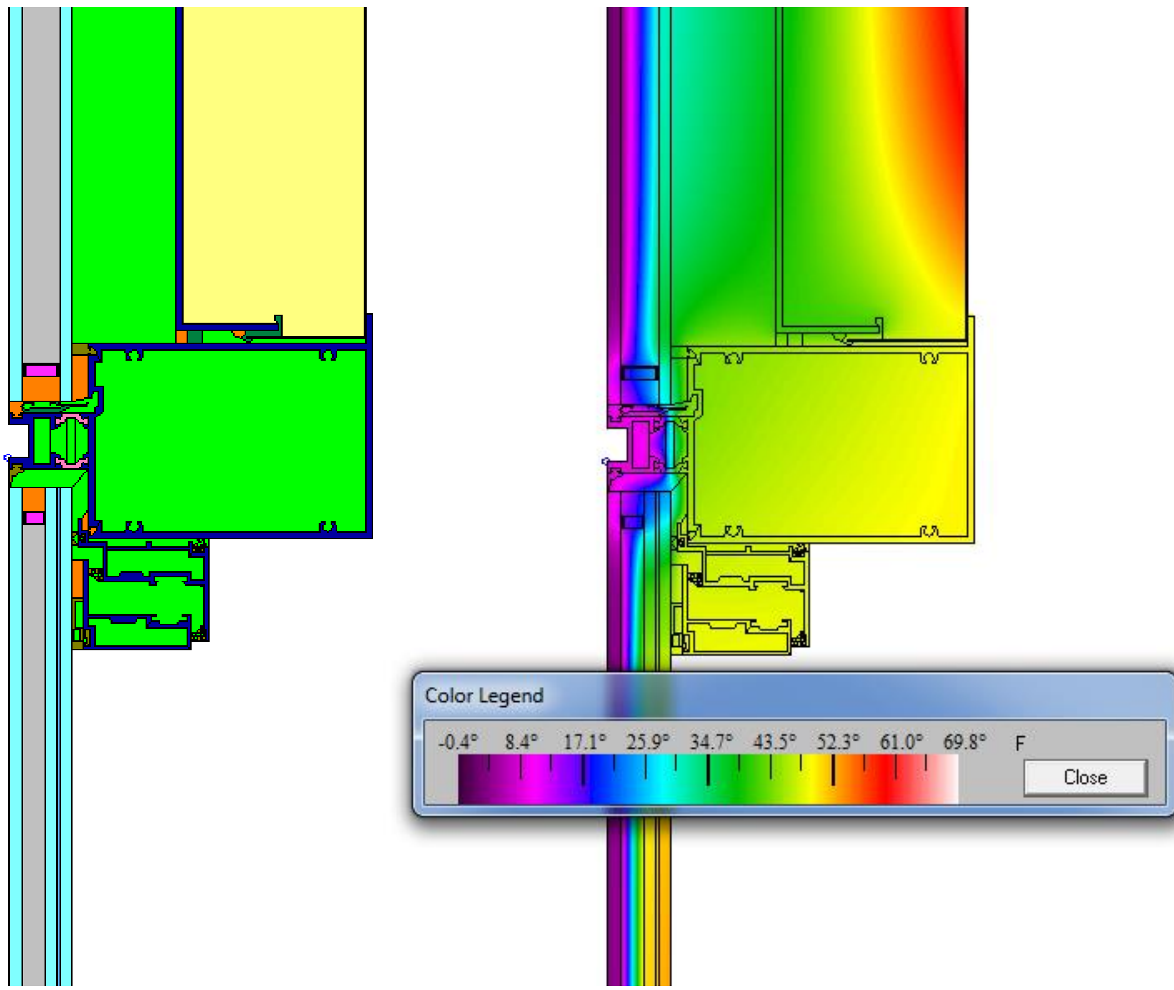

Figure 15: Transom – Spandrel/Operable: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.71 Btu/h.ft².F
Frame Projected Width	L_f = 6.70 in
Edge Effect Top Side	U_{e1} = 0.26 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.30 Btu/h.ft².F

5.3.13 Transom – Operable / Vision

In the following, the THERM model is presented graphically

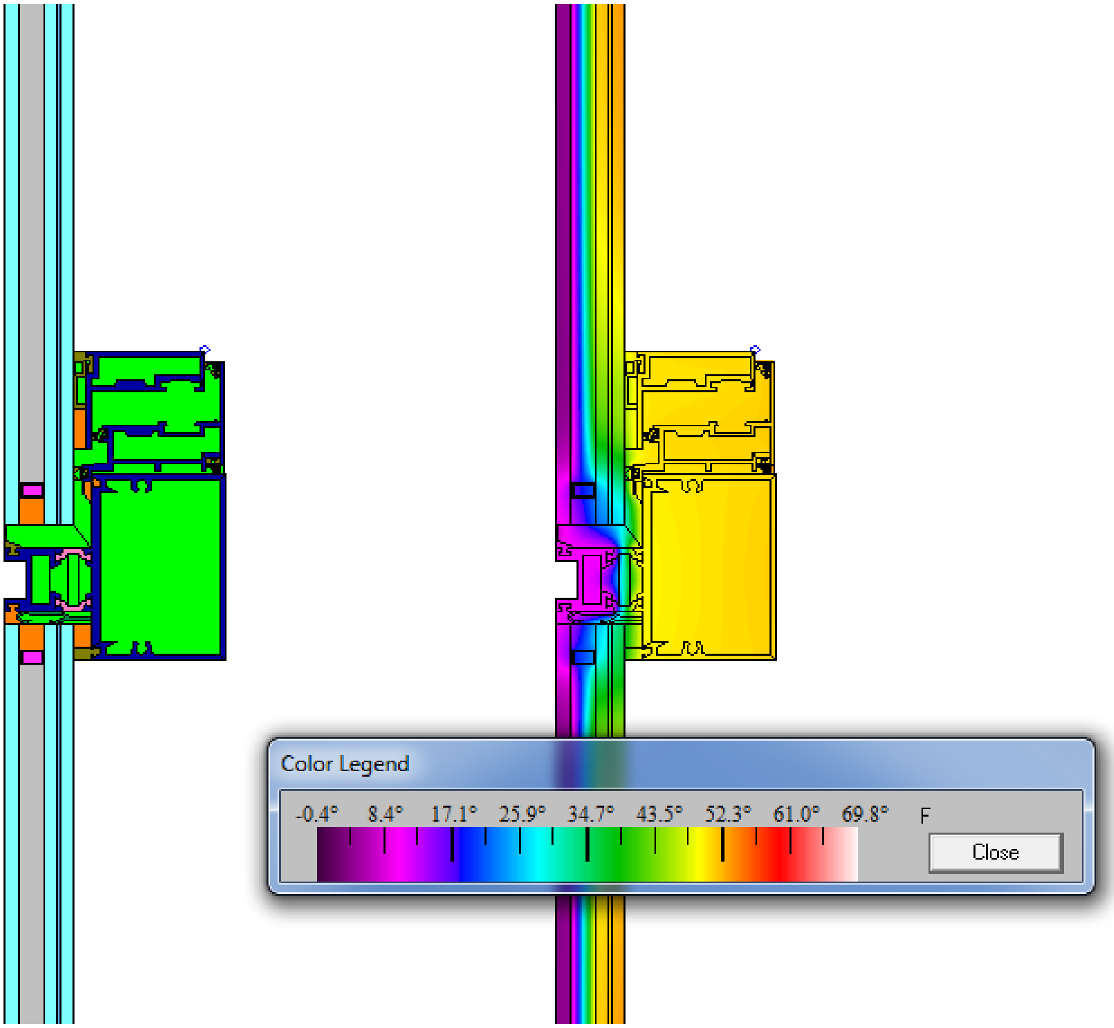

Figure 16: Transom – Operable/Vision: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.66 Btu/h.ft².F
Frame Projected Width	L_f = 6.19 in
Edge Effect Top Side	U_{e1} = 0.30 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.40 Btu/h.ft².F

5.3.14 Transom – Spandrel / Spandrel

In the following, the THERM model is presented graphically

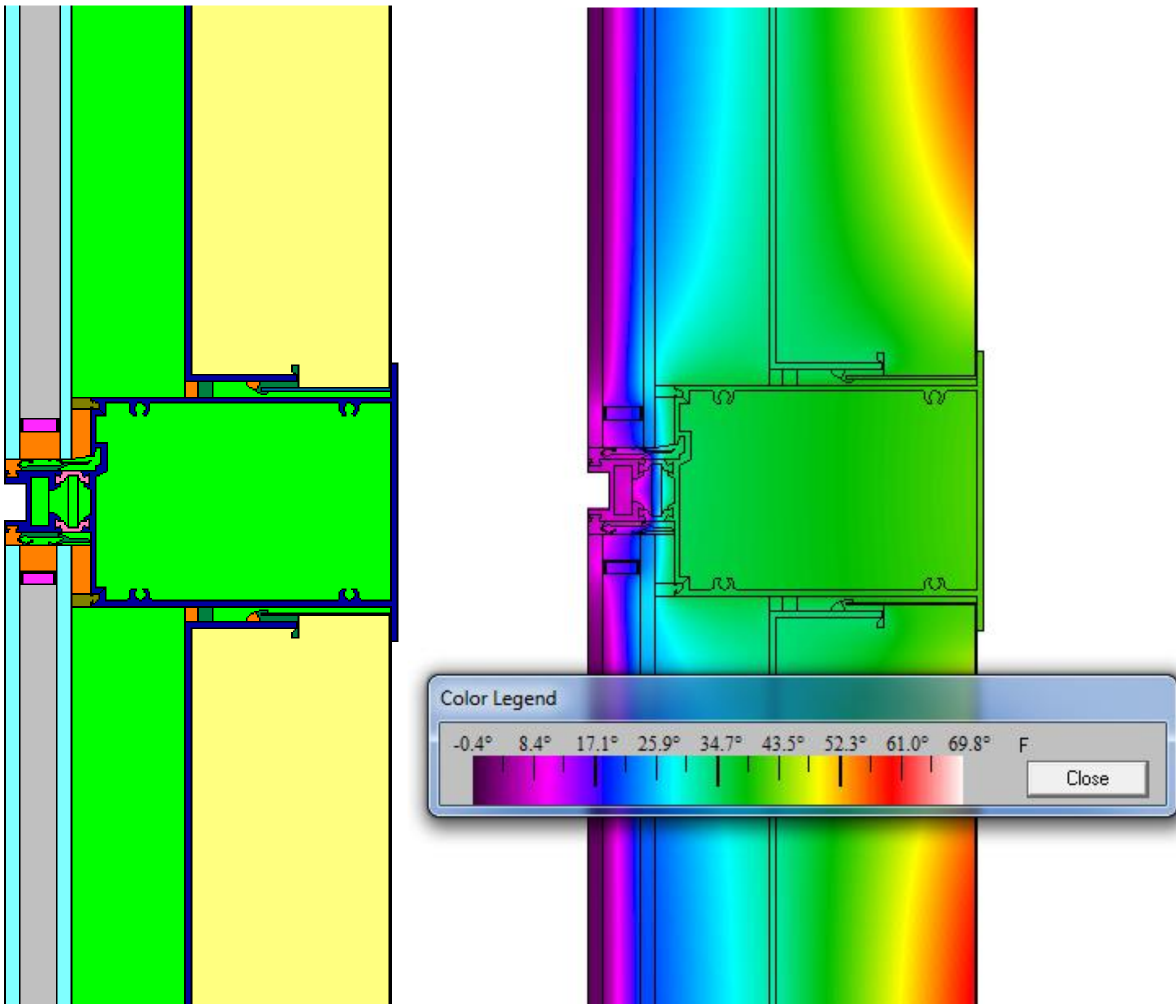

Figure 17: Transom – Spandrel/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.55 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.4 Overall U-Value

Area weighting of the U-values of all frames, glass and panels is used to calculate the overall U-value for each wall type.

Component	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Dart Mullion - Span/Span	0.14	92.60	0.64	0.09
Left Edge Effect	0.14	23.75	0.16	0.02
Right Edge Effect	0.14	23.75	0.16	0.02
Dart Mullion - Vis/Vis	1.50	620.42	4.31	6.46
Left Edge Effect	0.36	311.88	2.17	0.78
Right Edge Effect	0.36	311.88	2.17	0.78
Intermediate Mullion - Span/Span	0.13	85.00	0.59	0.08
Left Edge Effect	0.12	23.75	0.16	0.02
Right Edge Effect	0.12	23.75	0.16	0.02
Intermediate Mullion - Vis/Op	0.78	683.40	4.75	3.70
Left Edge Effect	0.29	225.75	1.57	0.45
Right Edge Effect	0.35	225.75	1.57	0.55
Intermediate Mullion - Vis/Vis	1.08	136.00	0.94	1.02
Left Edge Effect	0.35	52.03	0.36	0.13
Right Edge Effect	0.35	52.03	0.36	0.13
Mullion - Span/Span	0.14	92.60	0.64	0.09
Left Edge Effect	0.13	23.75	0.16	0.02
Right Edge Effect	0.16	23.75	0.16	0.03
Mullion - Op/Span	0.92	714.00	4.96	4.56
Left Edge Effect	0.31	231.88	1.61	0.50
Right Edge Effect	0.23	231.88	1.61	0.37
Mullion - Vis/Span	1.25	148.16	1.03	1.29
Left Edge Effect	0.23	67.50	0.47	0.11
Right Edge Effect	0.37	67.50	0.47	0.17
Stack Joint - Vis/Span	0.96	139.54	0.97	0.93
Top Edge Effect	0.32	50.93	0.35	0.11
Bottom Edge Effect	0.28	50.93	0.35	0.10
Transom - Vis/Span	0.98	107.82	0.75	0.73
Top Edge Effect	0.27	50.93	0.35	0.10
Bottom Edge Effect	0.35	50.93	0.35	0.12
Stack Joint - Vis/Span	0.96	141.63	0.98	0.94
Top Edge Effect	0.32	51.88	0.36	0.12
Bottom Edge Effect	0.28	51.88	0.36	0.10

Transom - Span/Op	0.71	156.11	1.08	0.77
Top Edge Effect	0.26	45.75	0.32	0.08
Bottom Edge Effect	0.30	45.75	0.32	0.10
Transom - Op/Vis	0.66	159.39	1.11	0.73
Top Edge Effect	0.30	51.88	0.36	0.11
Bottom Edge Effect	0.40	51.88	0.36	0.14
Stack Joint - Span/Span	0.66	304.54	2.11	1.40
Top Edge Effect	0.36	125.93	0.87	0.31
Bottom Edge Effect	0.35	125.93	0.87	0.31
Transom - Span/Span	0.55	225.25	1.56	0.86
Top Edge Effect	0.35	120.00	0.83	0.29
Bottom Edge Effect	0.35	120.00	0.83	0.29
Vision Glass	0.28	4625.46	32.12	8.99
Spandrel Region	0.05	7133.00	49.53	2.48

Totals	18480.00	128.33	41.51

Overall U-Value	**0.32**	**[Btu/h.ft².F]**

Table 5: Thermal Transmittance of Wall Type A

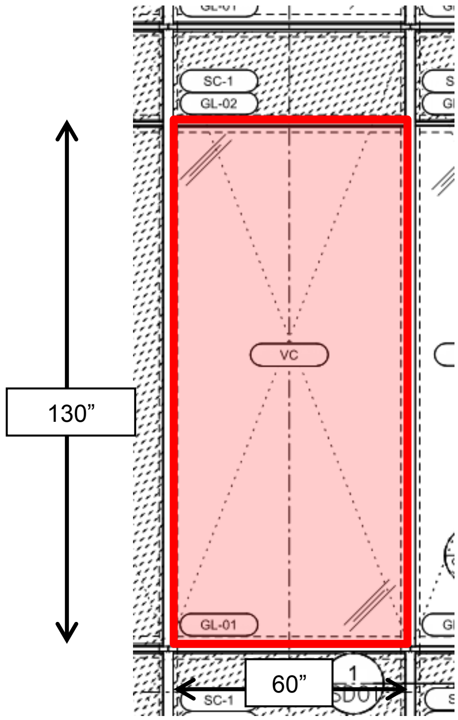

Figure 18: Typical Vision Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Spandrel	1.25	601.90	4.18	5.22
Left Section	0.23	308.13	2.14	0.49
Right Section	0.37	308.13	2.14	0.79
Transom - Spandrel / Vision	0.98	235.32	1.63	1.60
Top Section	0.27	132.18	0.92	0.25
Bottom Section	0.35	132.18	0.92	0.32
Vision Glass	0.28	6082.18	42.24	11.83
Totals		7800	54	20.51

Vision U-Value	0.38	[Btu/h.ft².F]

Table 6: Wall Type A Vision U-Value

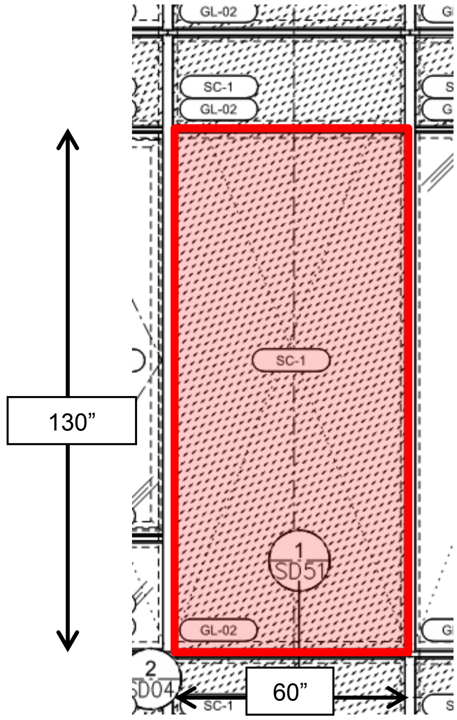

Figure 19: Typical Spandrel Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Dart Mullion - Spandrel / Spandrel	0.14	601.90	4.18	0.59
Left Section	0.14	308.13	2.14	0.30
Right Section	0.14	308.13	2.14	0.30
Transom - Spandrel / Spandrel	0.55	235.32	1.63	0.90
Top Section	0.35	132.18	0.92	0.32
Bottom Section	0.35	132.18	0.92	0.32
Spandrel Region	0.05	6082.18	42.24	2.11
Totals		7800	54	4.84

Spandrel U-Value	0.09	[Btu/h.ft².F]

Table 7: Wall Type A Spandrel U-Value

6 CONDENSATION ASSESSMENT

The minimum internal surface temperature of the curtain wall has been assessed for each model using THERM 6.3 software using the specified Boundary Conditions. The absolute Minimum Temperature in the surface was found to be $t_{si,min}$=39.2°F on the Mullion – Vision/Spandrel location of the façade (see following table).

Wall Type	Components	Dew Point Temperature (°F)	Minimum Surface Temperature (°F)	Maximum Allowed Relative Humidity (%)
Wall Type A	*Dart Mullion – Spandrel/Spandrel*	39.1	53.4	59.5
	Dart Mullion – Vision/Vision		39.2	35.0
	Intermediate Mullion – Spandrel/Spandrel		54.4	61.8
	Intermediate Mullion – Vision/Operable		42.5	39.5
	Intermedaite Mullion – Vision/Vision		42.4	39.4
	Mullion – Spandrel/Spandrel		52.0	56.6
	Mullion – Operable/Spandrel		39.8	35.6
	Mullion – Vision/Spandrel		39.2	35.0
	Stack Joint – Vision/Spandrel		43.3	40.8
	Stack Joint – Spandrel/Spandrel		41.8	38.5
	Transom – Vision/Spandrel		39.9	35.7
	Transom – Spandrel/Operable		47.2	47.3
	Transom – Operable/Vision		39.3	35.1
	Transom – Spandrel/Spandrel		42.6	39.7

Table 8: Condensation Assessment for Typical Details

With internal temperature of 68°F and Relative Humidity of 35% RH the Dew Point Temperature is 39.1°F. For the given Boundary Conditions, condensation will not occur on the interior surface of the façade and the performance is acceptable. Following THERM models of some critical sections are presented along with the Dew Point Isothermal Line as well as a temperature distribution for the specified Boundary Conditions.

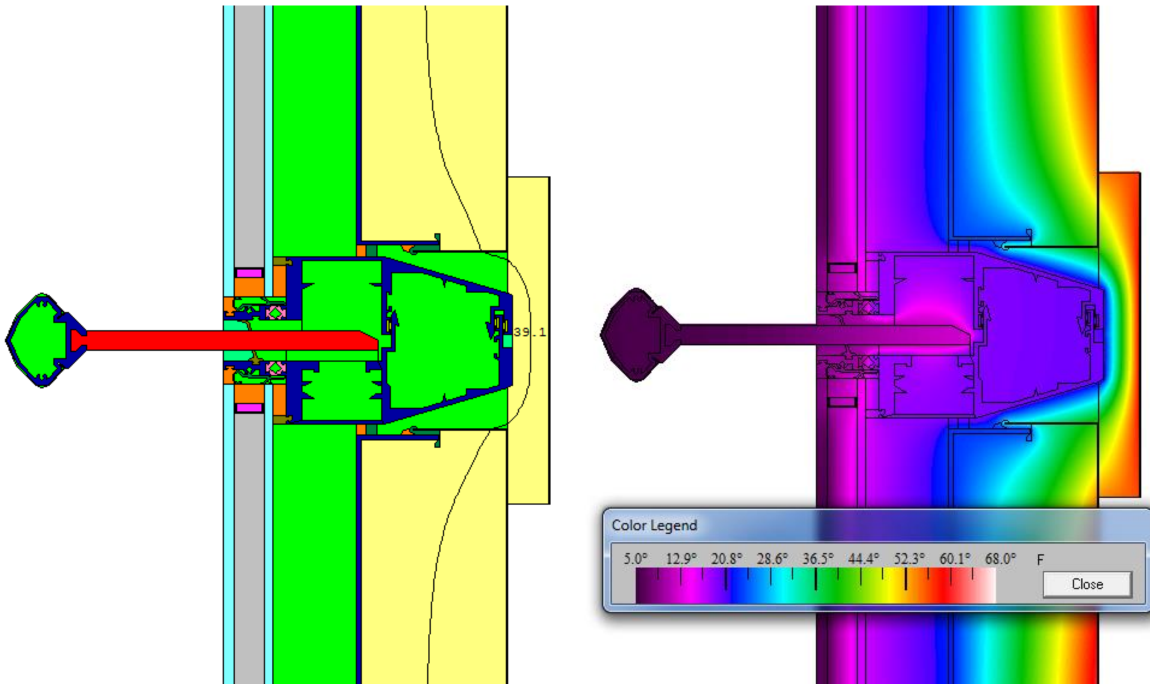

Figure 20: Dart Mullion – Spandrel/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

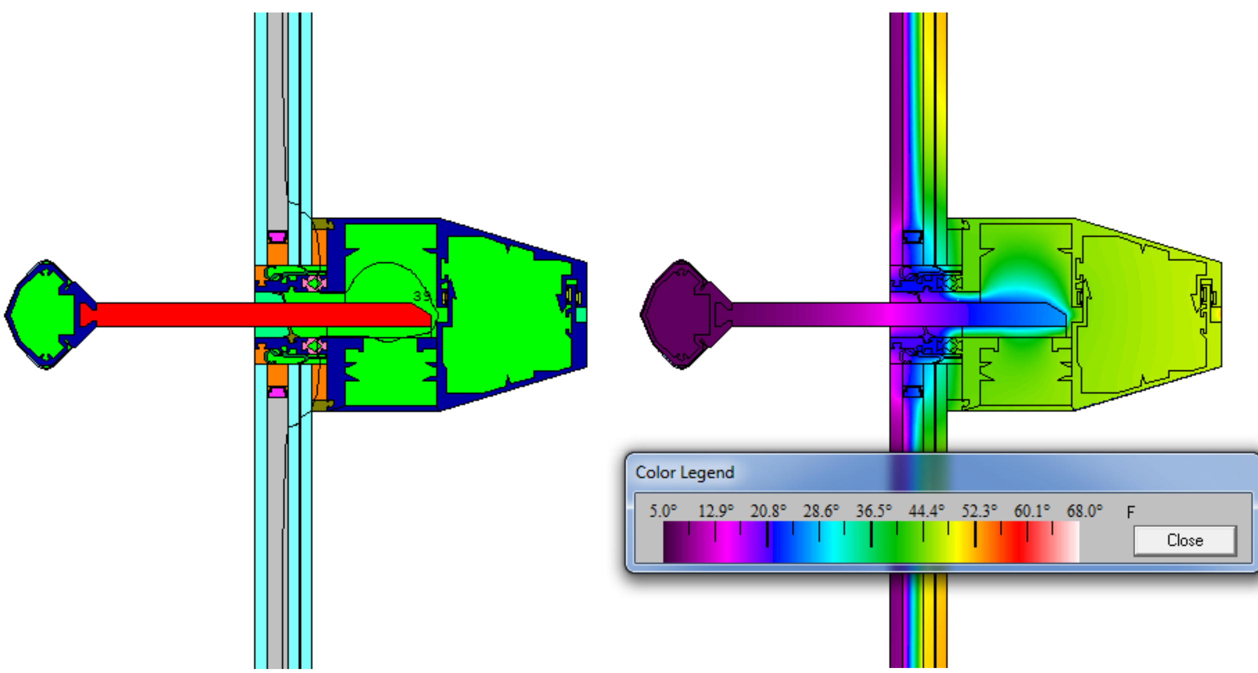

Figure 21: Dart Mullion – Vision/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

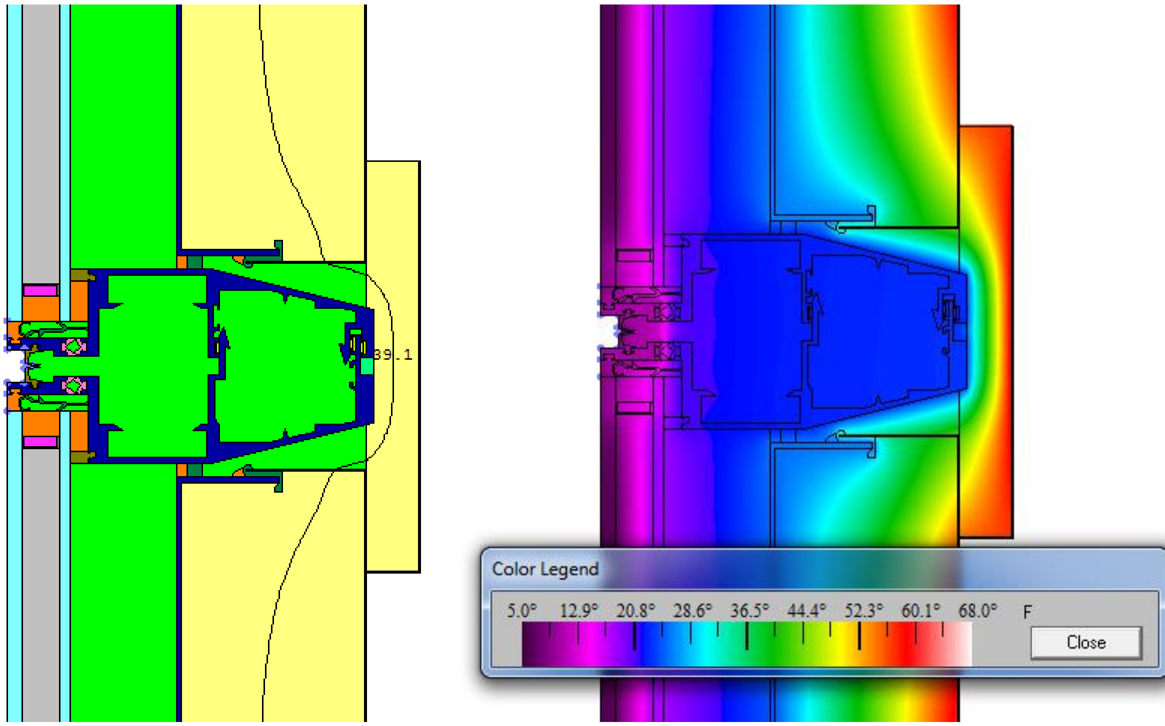

Figure 22: Intermediate Mullion – Span/Span: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

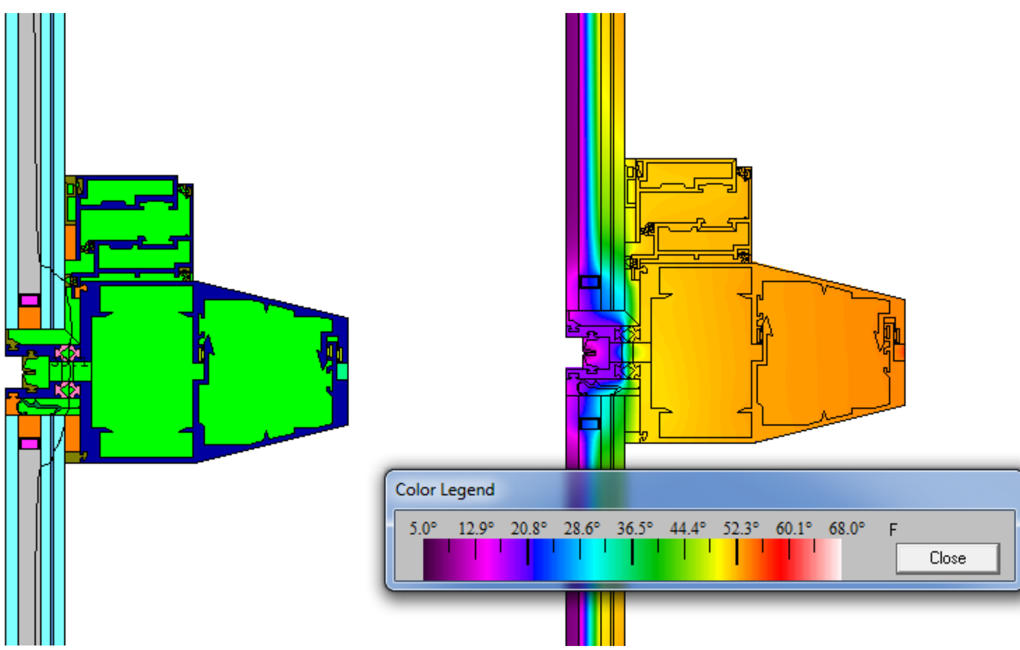

Figure 23: Intermediate Mullion – Vision/Operable: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

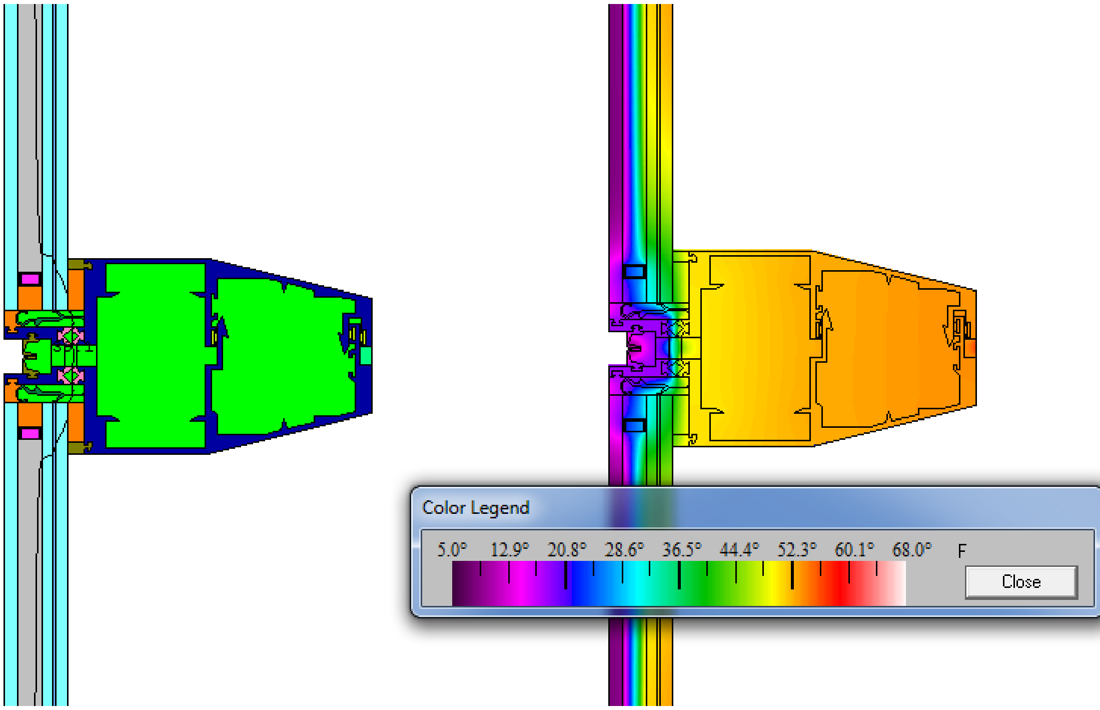

Figure 24: Intermediate Mullion – Vision/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

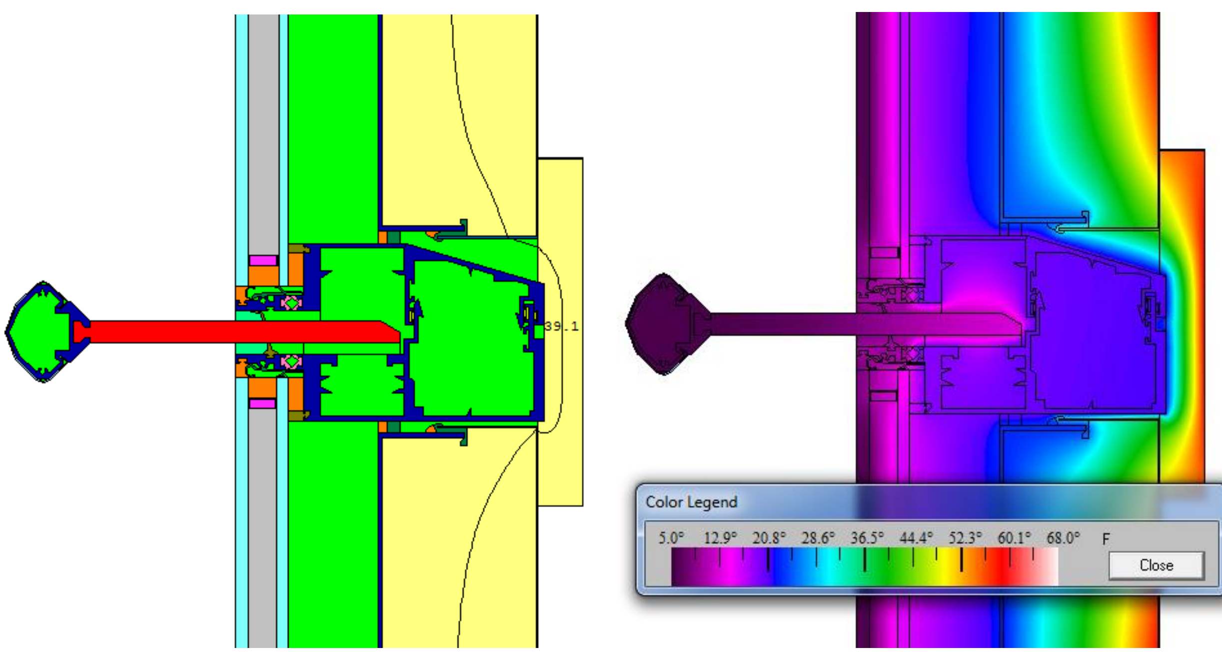

Figure 25: Mullion – Spandrel/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

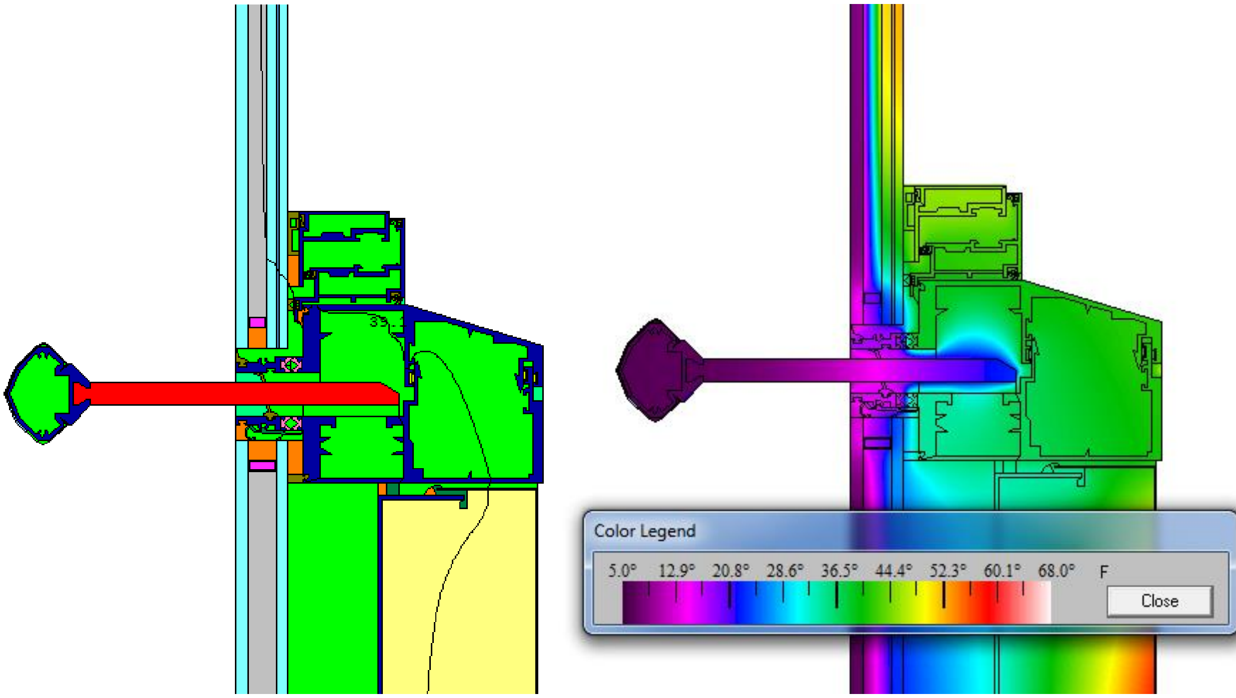

Figure 26: Mullion – Operable/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

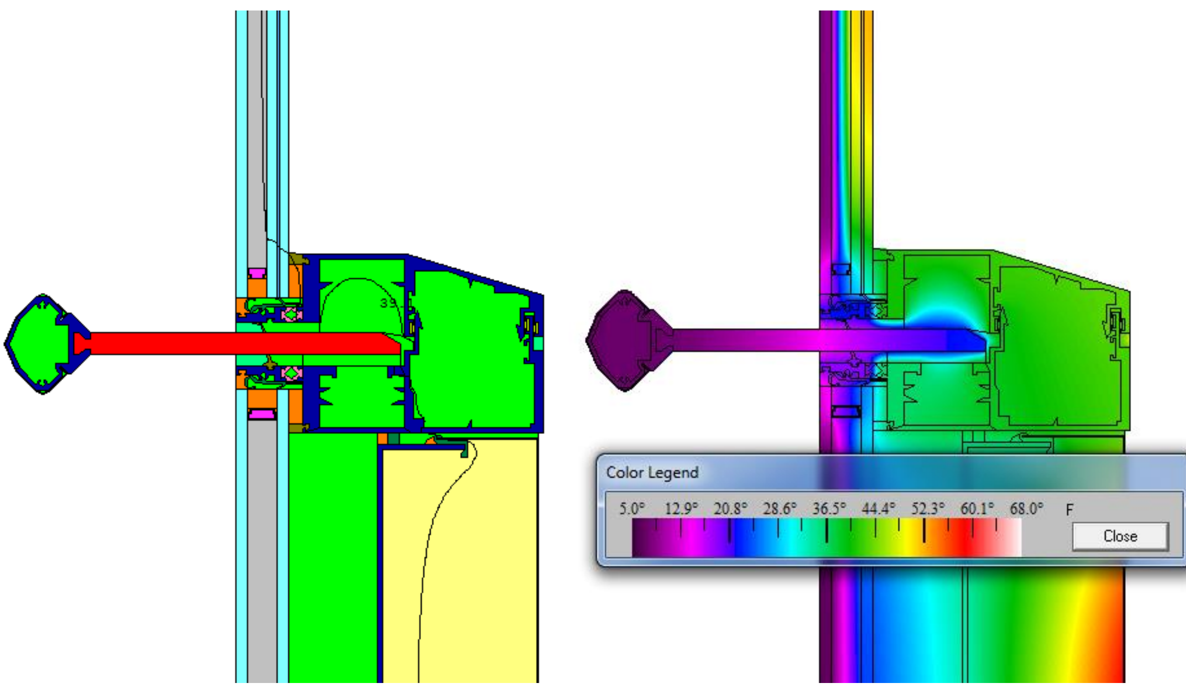

Figure 27: Mullion – Vision/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

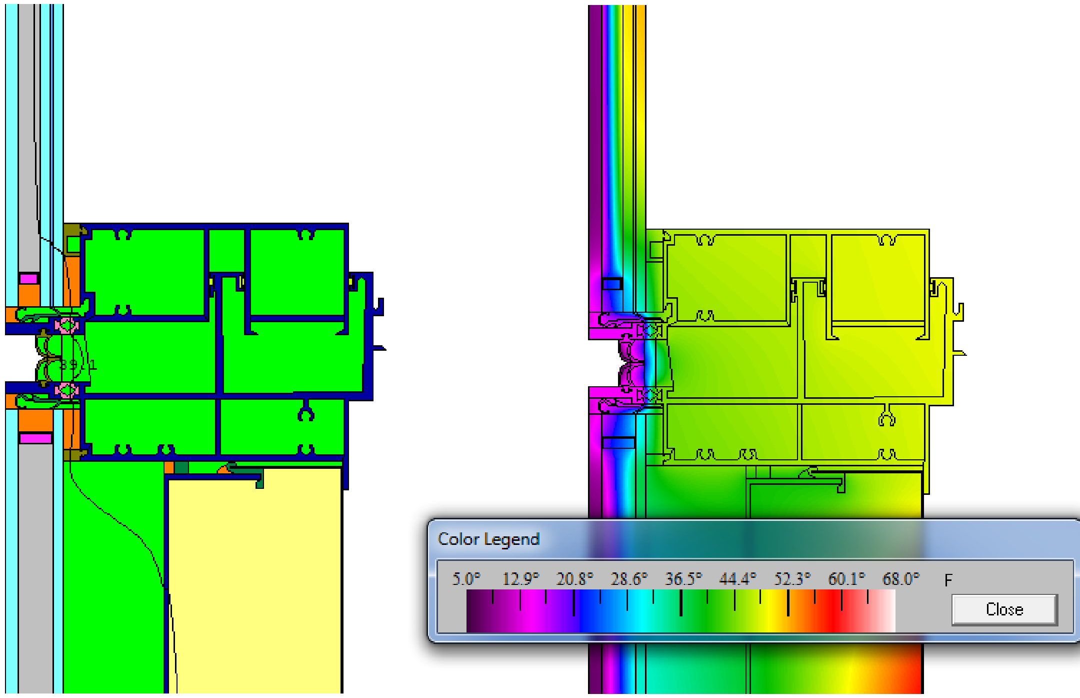

Figure 28: Stack Joint – Vision/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

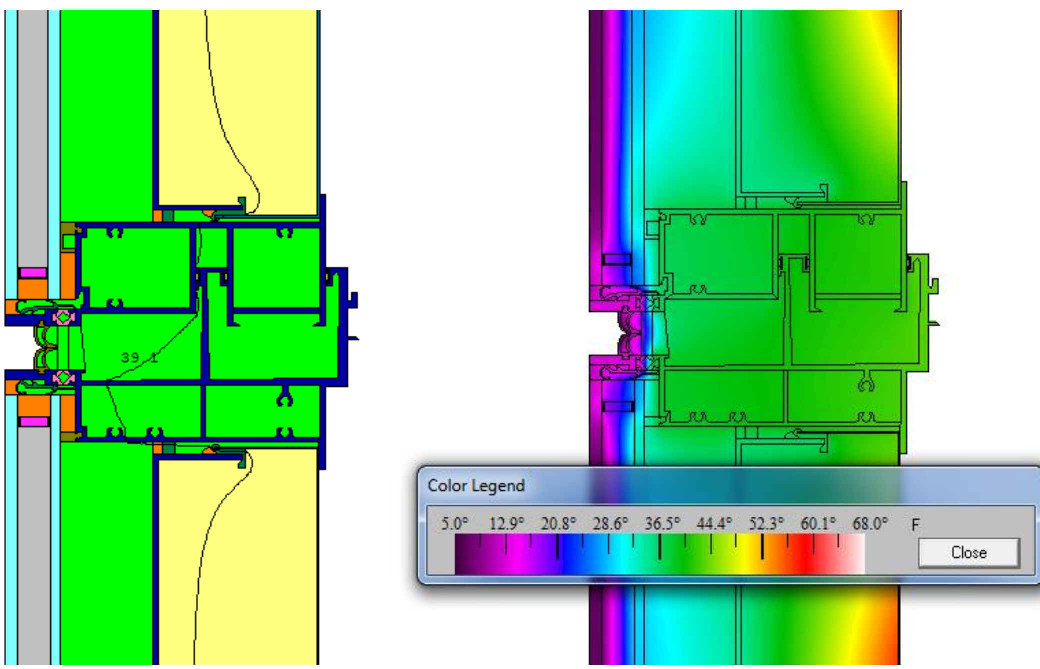

Figure 29: Stack Joint – Spandrel/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

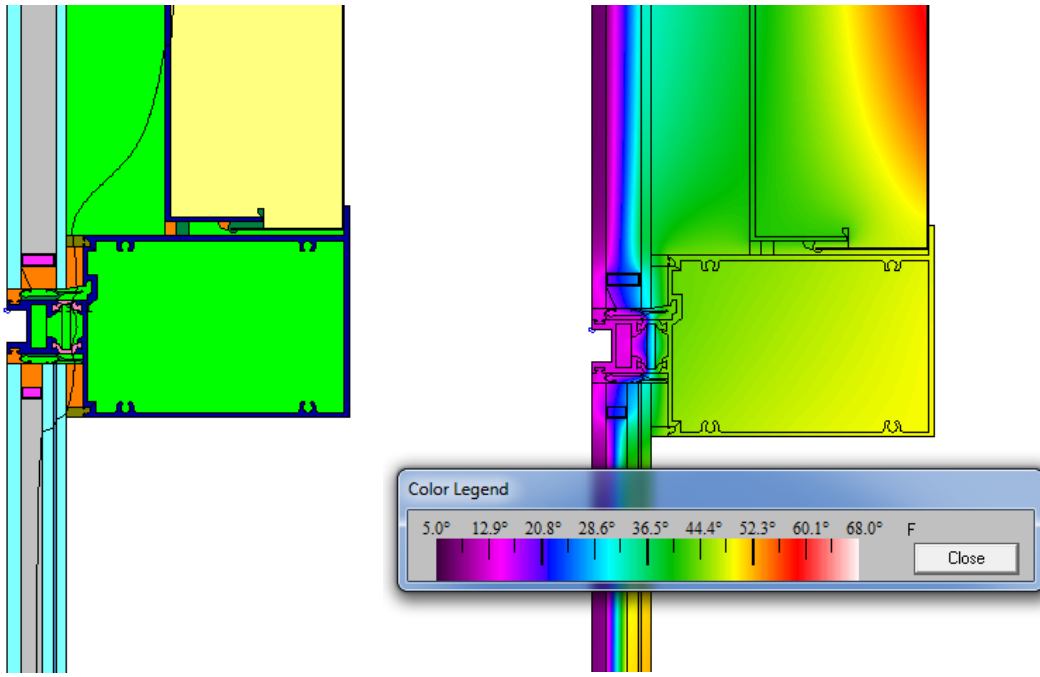

Figure 30: Transom – Vision/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

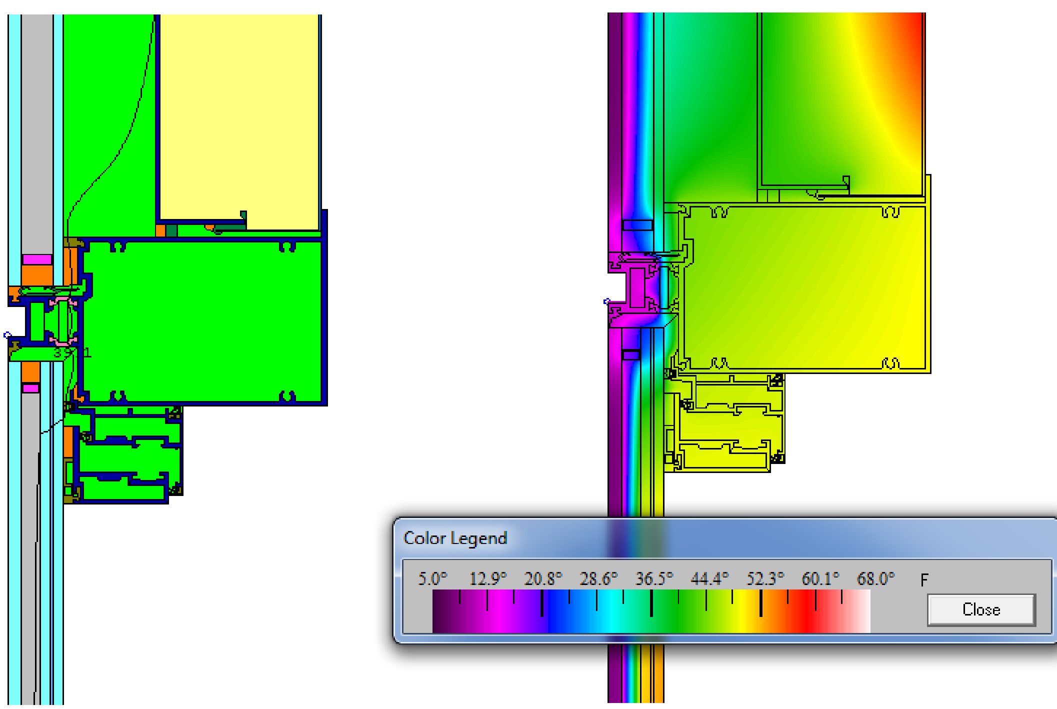

Figure 31: Transom – Spandrel/Operable: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

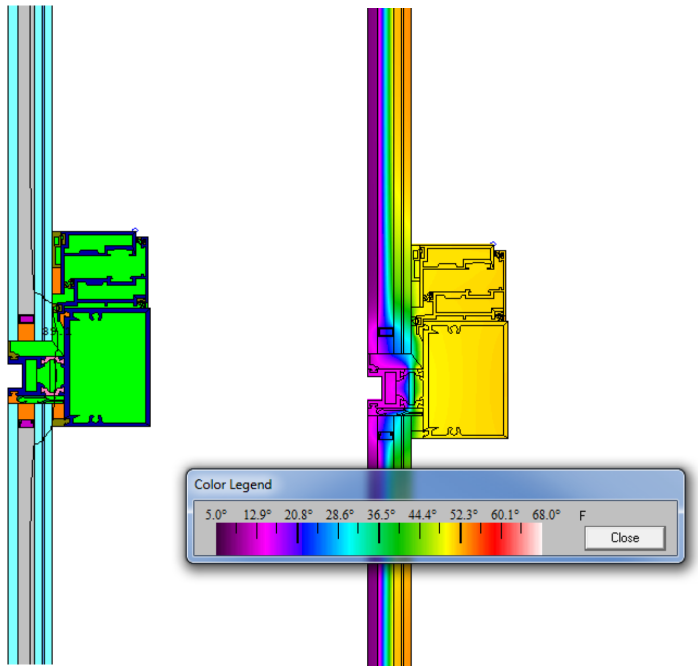

Figure 32: Transom – Operable/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

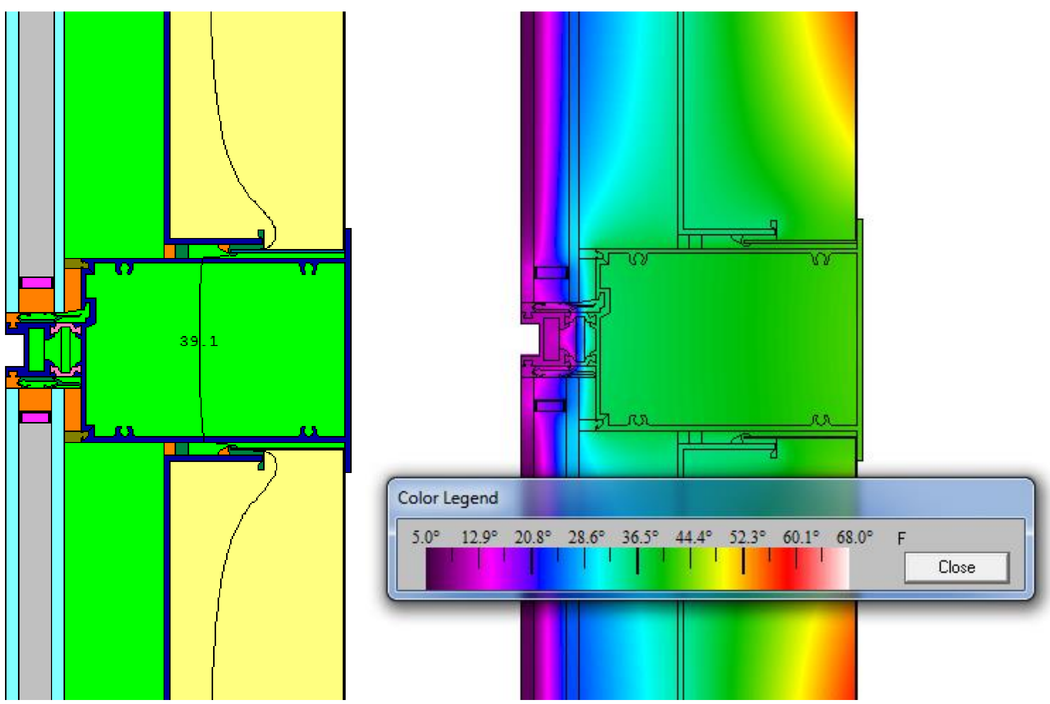

Figure 33: Transom – Spandrel/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

7 REFERENCES

ASHRAE	ASHRAE Handbook of Fundamentals 1998-2001, American Society of Heating, Refrigerating, and Air-Conditioning Engineering, Atlanta, GA, USA, 2004.
ISO 6946: 2007	Building components and building elements - Thermal resistance and thermal transmittance - Calculation method
ISO 10077-1: 2006	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General
ISO 10077-2: 2003	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames
ISO 10211: 2007	Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations
ISO 13788:2001	Hydrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods
ISO 15099: 2003	Thermal performance of windows, doors and shading devices - Detailed calculations
NFRC 100: 2010	Procedure for Determining Fenestration Product U-Factors.
NFRC 200: 2010	Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence
NFRC 300: 2010	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems
THERM	THERM 6.3 Program description. Windows and Daylighting Group. Lawrence Berkeley National Laboratory, 2002.
PHYSIBEL	BISCO 9.0w Software TRISCO 12.0w Software

PERMASTEELISA NORTH AMERICA

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LEND LEASE (US) CONSTRUCTION LMB, INC.
RECEIVED
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0007-08 4 13-2
SUBMITTAL NUMBER

217 WEST 57TH STREET

PROJECT 865

NEW YORK, NY

EXTERIOR WALL PACKAGE

SYSTEM DESIGN - THERMAL CALCULATIONS (WALL TYPE B)

DOC NAME: 90918 TC 002-02-150812 JH

EXTELL DEVELOPMENT COMPANY

ADRIAN SMITH & GORDON GILL

AJLP CONSULTING

LEND LEASE

Rev.	Date	Description	Prepared by	Checked by
02	08/12/2015	Third Submission	JH	JH
01	05/29/2015	Second Submission	JH	AF
00	03/09/2015	First Submission	JH	AF

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TABLE OF CONTENTS

1 SUMMARY

THERM 6.3 software was used to analyze the two-dimensional heat transfer through the frame and glazing edge areas. The frame U-values have been derived using THERM 6.3 according to NFRC standard.

Main results are reported in the following:

Wall Type		U - Factor BTU/(h·ft²·°F)	Overall U - Factor BTU/(h·ft²·°F)	SHGC (Dimensionless)	Condensation Resistance (%)
WT-B	WT-B Vision	0.37	0.30	0.28	35.1
	WT-B Opaque	0.17			

Table 1: Summary of Results

2 THERM KEY

Material	Thermal Conductivity (Btu/h.ft².F)	Model Color
Aluminum Alloy (Painted)	92.45	
Butyl Rubber	0.14	
Ethylene Propylene Diene Monomer (EPDM)	0.14	
Frame Cavity NFRC	Calculated by THERM	
Frame Cavity Slightly Ventilated	Calculated by THERM	
Glass (Plate or Float)	0.58	
IGU Gap Cavity	0.02	
Insulation	0.02	
Neoprene (Polychloroprene)	0.13	
PVC	0.10	
Polyamide 6.6 with 25% Glass Fiber	0.17	
Polyurethane Foam	0.03	
Silica Gel (Desiccant)	0.08	
Silicone Gasket	0.20	
Silicone Sealant	0.20	
Steel – Galvanized Sheet (0.14%C)	35.82	
Steel – Stainless (Buffed)	9.82	

Table 2: THERM Material Color Key

3 BOUNDARY CONDITIONS

Calculation	Standard	Cold-Side Environmental Temperature	Warm-Side Environmental Temperature	External Wind Speed	External Heat Transfer Coefficient	Internal Relative Humidity	Internal Heat Transfer Coefficient
Thermal Transmittance	NFRC (100-2010)	-0.4°F	69.8°F	12.3mph	4.58 Btu/h-ft²-F	----	0.53 Btu/h-ft²-F
Condensation Assessment	Project Specification (06/02/14)	5.0°F	68.0°F	15.0mph	5.43 Btu/hft²-F	35%	0.53 Btu/h-ft²-F

Table 3: Boundary Conditions

4 GENERAL DESCRIPTION

This report must be read in conjunction with Permasteelisa's system drawings August 20th 2015. The thermal performance of the typical façade type is stated in the following report. The overall U-value, as well as Condensation Assessment of the curtain wall panels have been performed according to the (NFRC), (ASHRAE) and (ISO) Standards.

Typical elevation and sections are shown in the following figure.

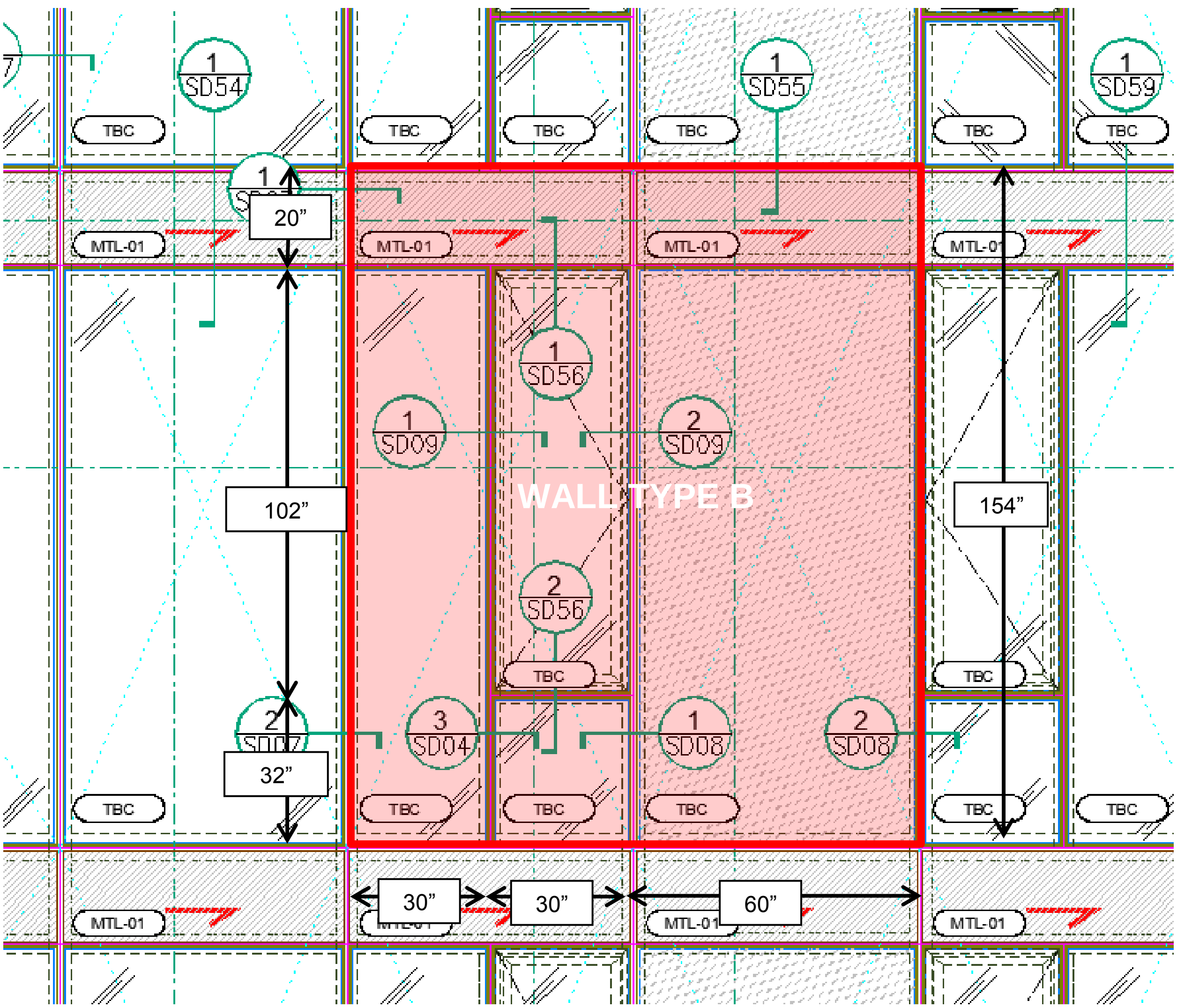

Figure 1: Wall Type B (SE02)

5 THERMAL TRANSMITTANCE

5.1 Thermal Transmittance Calculation Method

The heat transfer through the frame and glazing is assessed as described in the thermal guide (NFRC) and (ISO15099). There are then the following thermal transmittances (U-values):

- Centre-glazing U-value U_g, which is assumed to apply to the whole of the glazing (defined in section 5.2.1);
- Centre-panel U-value U_{sp}, which is assumed to apply to the whole of the spandrel panel (defined in section 5.2.2);
- Frame U-value U_f (defined in section 5.3);
- Edge U-value U_{edge1}, U_{edge2}, to take into account the heat transfer due to the interaction (edge effect) between the framing and glazing/spandrel panel (defined in section 5.3).

The overall U-value of the curtain wall is then calculated by using the principle of the area weighting of U-values of the frames and glass (as explained in section 5.4).

5.2 Center U-Value

One-dimensional center U-value calculation has been performed for glass and spandrel.

5.2.1 Glazing

The calculations have been performed with the following glass for the typical elevation. (Calculated with Window 6.3 Software according to NFRC):

Glass Makeup:

Outer-lite:	5/16" IPASOL PLATIN 46/31 on Surface # 2 (Interpane)
Cavity:	½" Air with Stainless Steel Spacers
Inner-lite:	¼" – 0.060" – ¼" Laminate

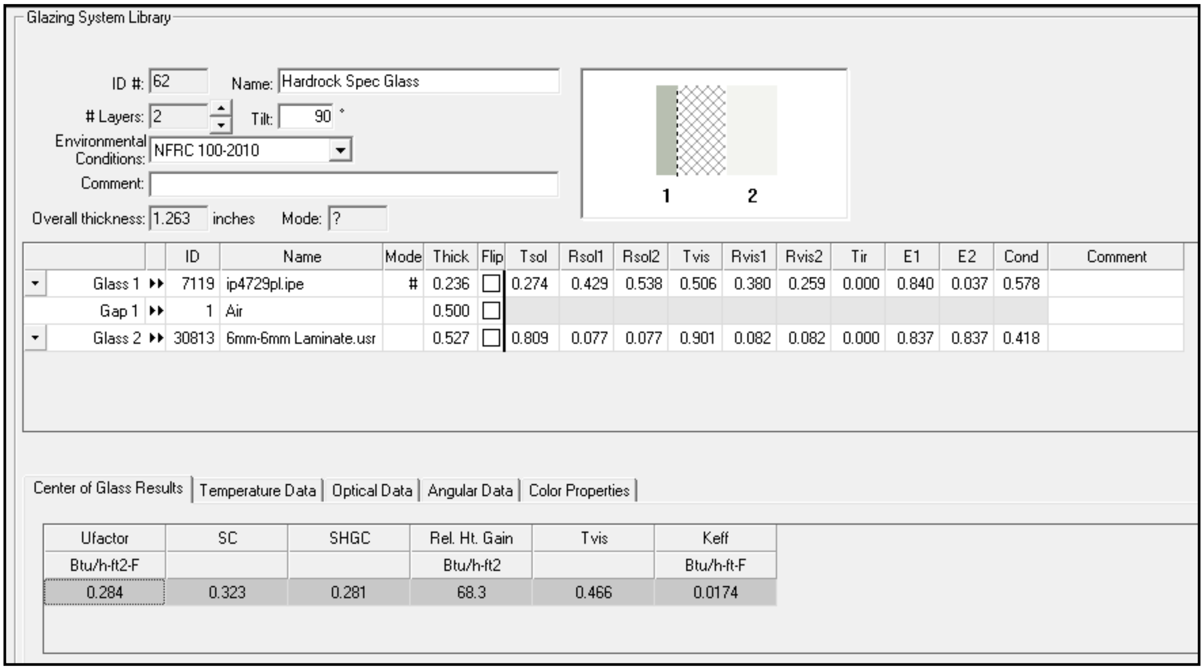

Figure 2: WINDOW 6 Model

Standard	Glass Characteristics	Value
NFRC 100 -2010	Thermal Transmittance (Btu/h.ft².F)	0.28
NFRC 200 – 2010	Solar Heat Gain Coefficient	0.28

Table 4: 1 Dimensional Analysis Summary

5.2.2 Spandrel Panel (Wall Type B)

In the following, the THERM model is presented graphically

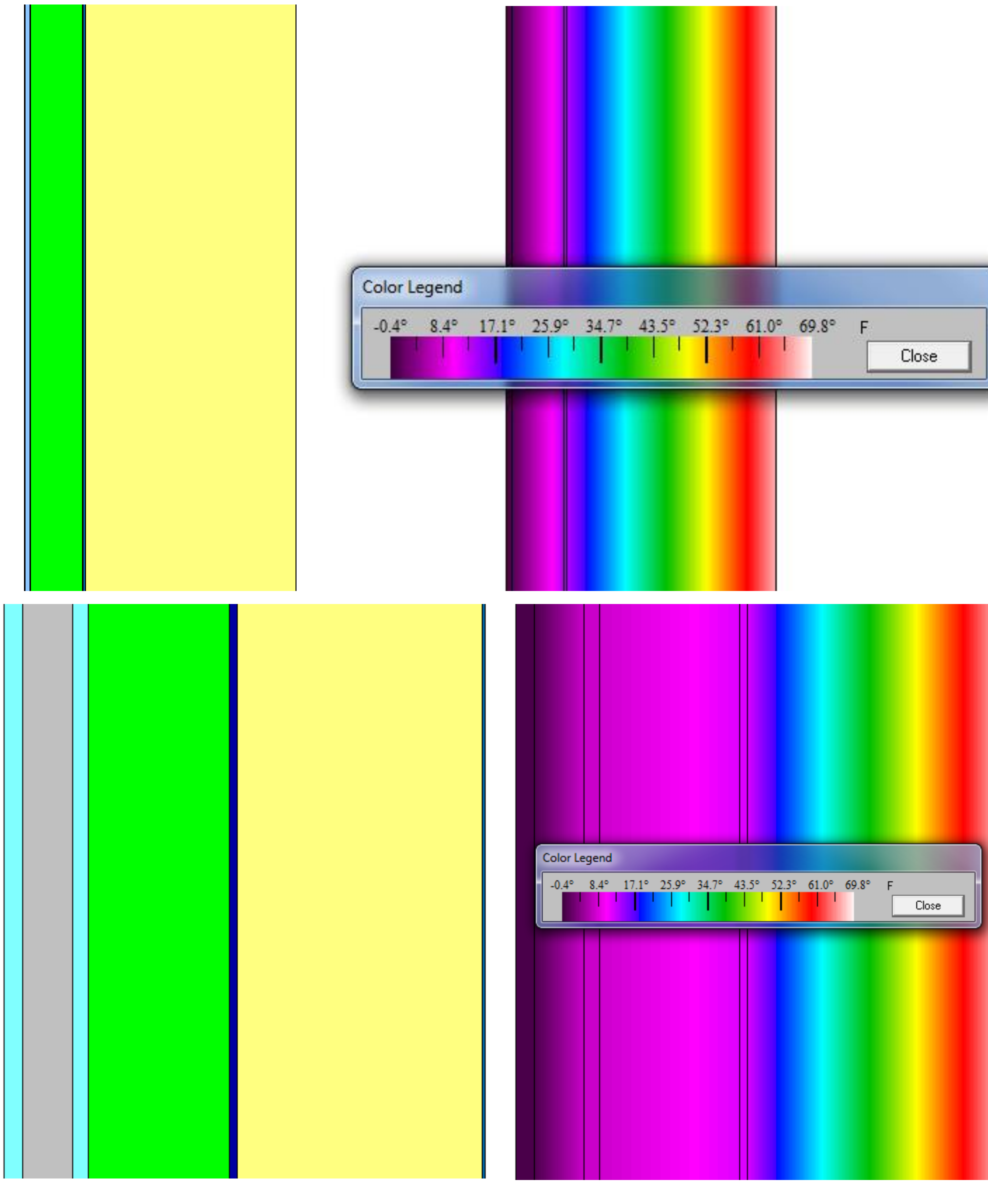

Figure 3: Spandrel Region: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Thermal Transmittance	U_{sp} = 0.05 Btu/h.ft².F

5.3 Wall Type B Frame U-Value

The frames have been modeled by means of 2-dimensional FEM analysis, using the THERM program (version 6.3) by the Lawrence Berkeley National Laboratory. Material properties have been assigned as per THERM internal library.

The frame has been modeled including stainless steel glazing spacers.

The projected width of the solid part of the framing (excluding the glazing gaskets) is measured from the inside. For each of the models, the projected width of the frames is stated along with the frame U-value.

5.3.1 Mullion - Metal / Metal

In the following, the THERM model is presented graphically

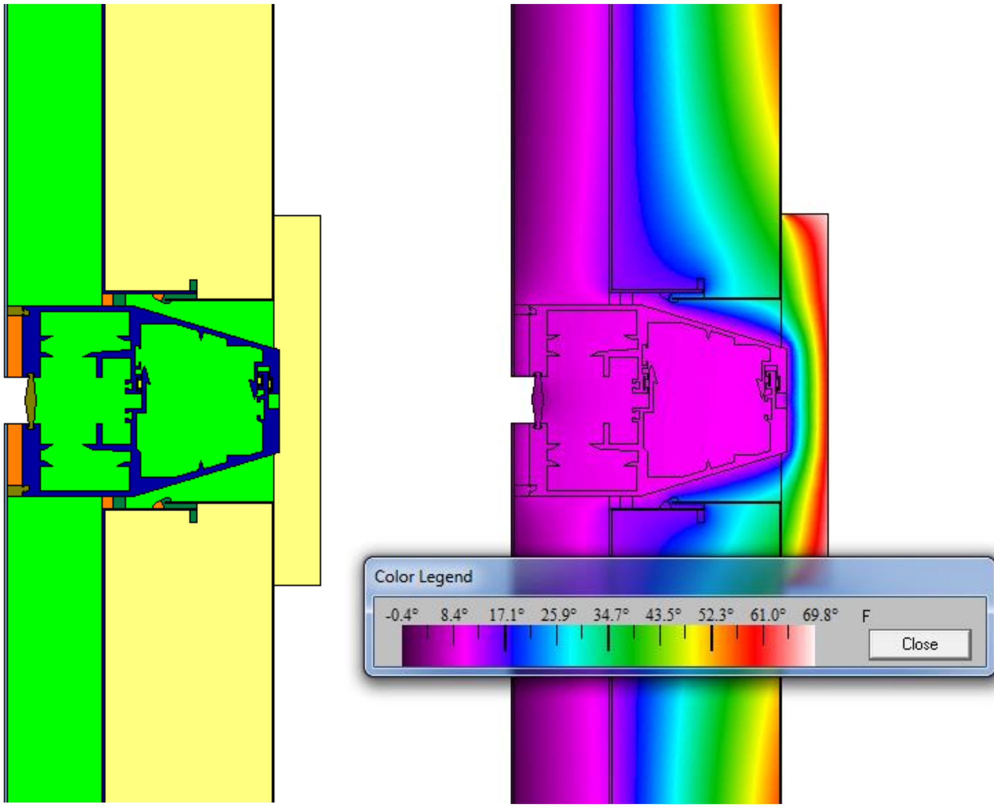

Figure 4: Mullion – Metal/Metal: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.15 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.15 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.15 Btu/h.ft².F

5.3.2 Mullion – Vision / Vision

In the following, the THERM model is presented graphically

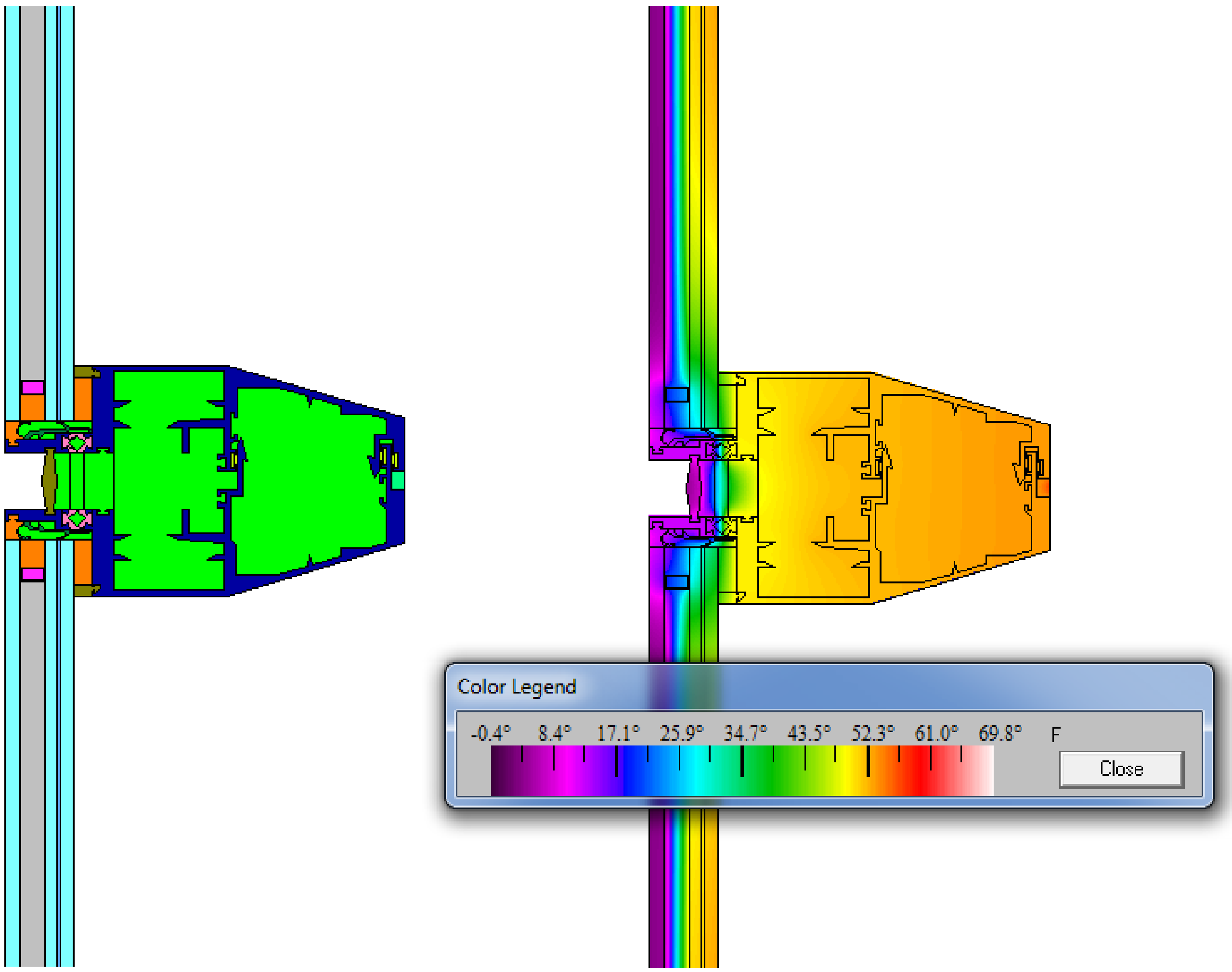

Figure 5: Mullion – Vision/Vision: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.05 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.3 Intermediate Mullion – Vision / Operable

In the following, the THERM model is presented graphically

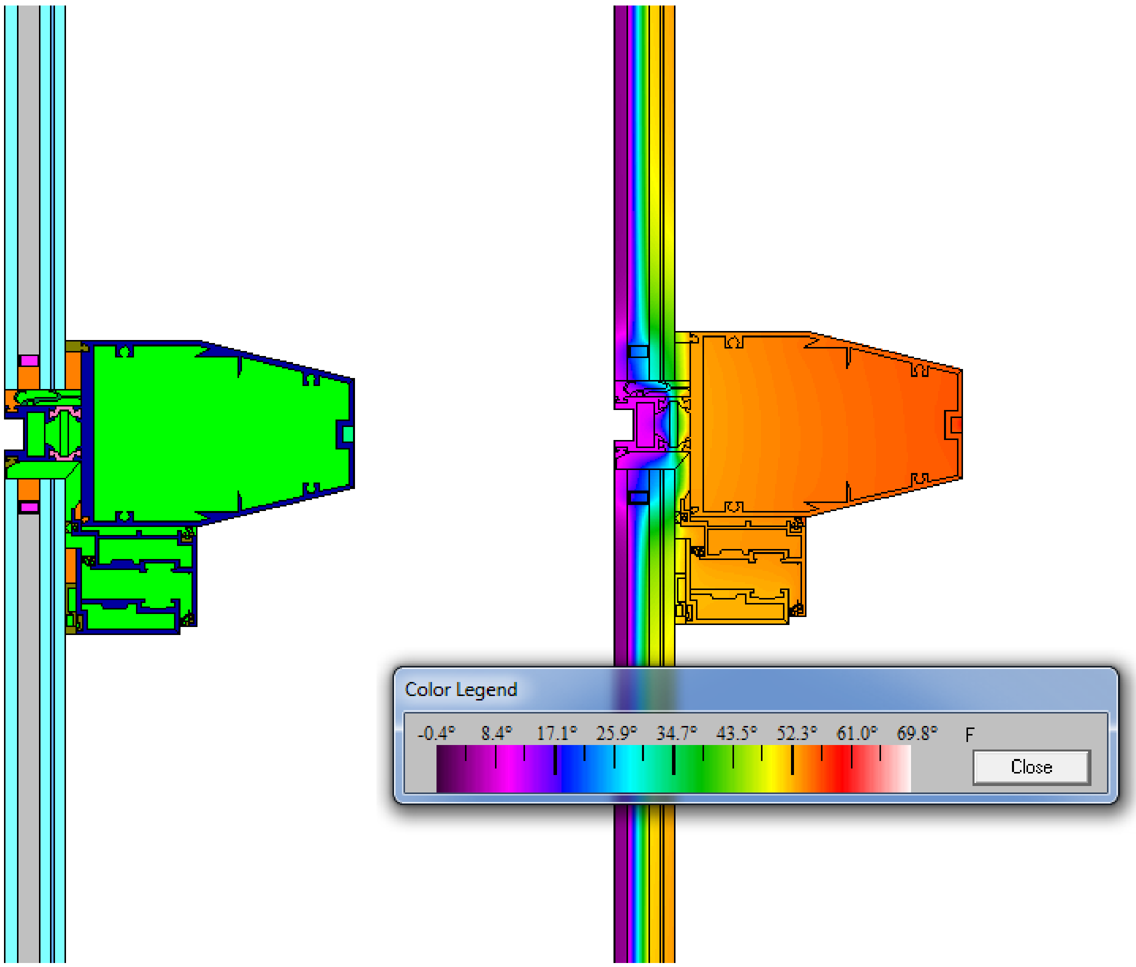

Figure 6: Intermediate Mullion – Vision/Operable: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.70 Btu/h.ft².F
Frame Projected Width	L_f = 6.70 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.29 Btu/h.ft².F

5.3.4 Intermediate Mullion – Vision / Vision

In the following, the THERM model is presented graphically

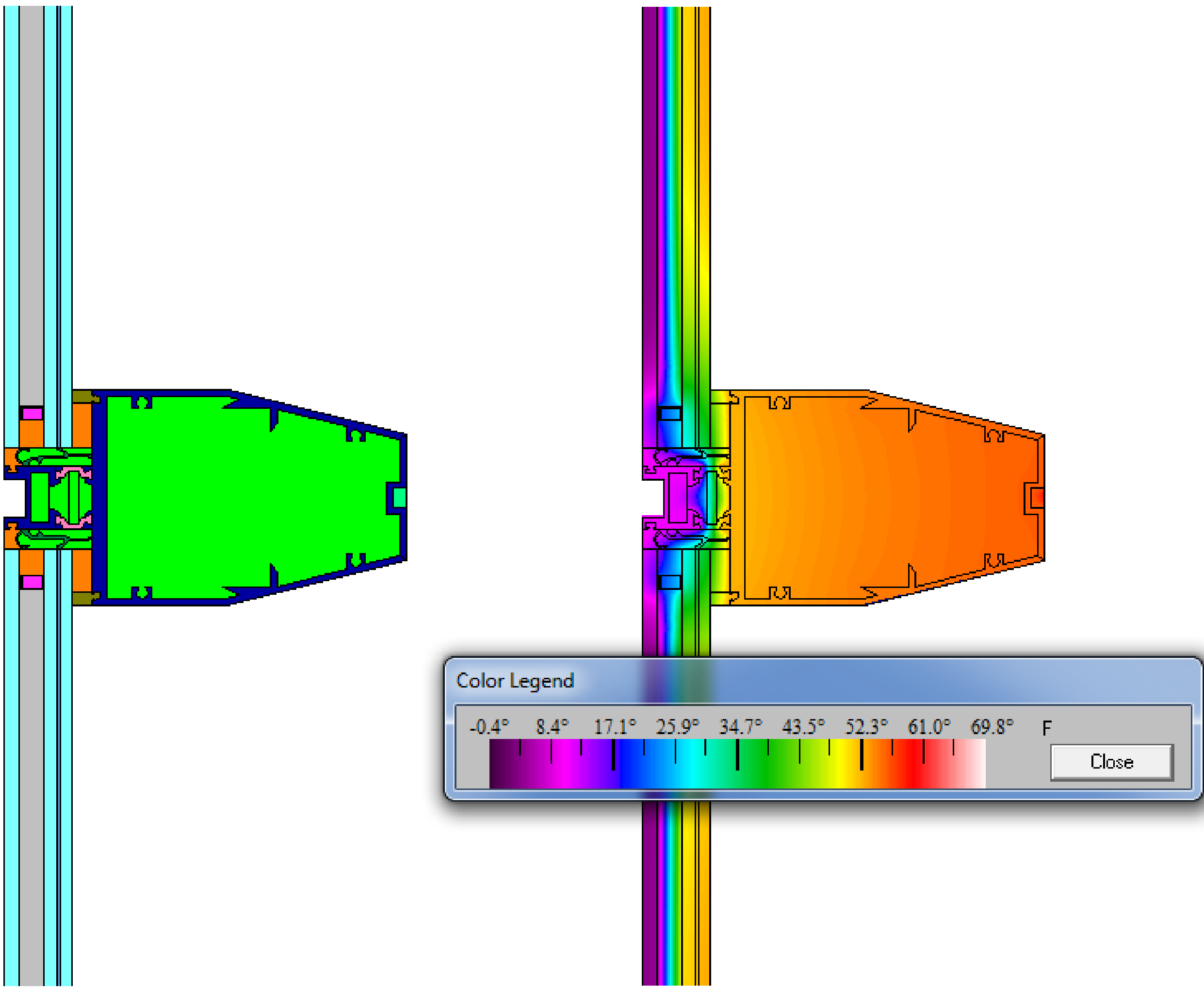

Figure 7: Intermediate Mullion – Vision/Vision: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.96 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.5 Mullion 2 – Operable / Spandrel

In the following, the THERM model is presented graphically

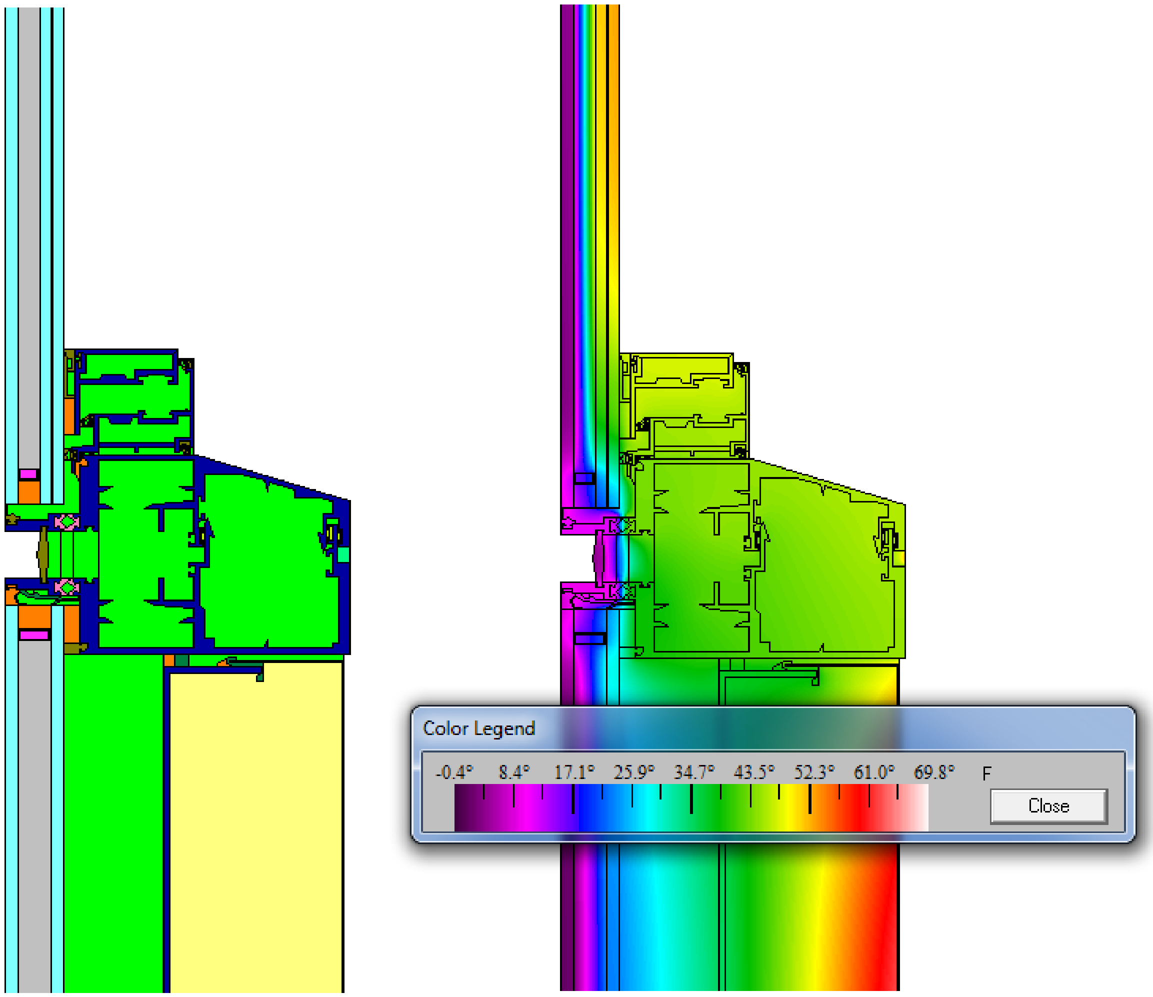

Figure 8: Mullion – Operable/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.75 Btu/h.ft².F
Frame Projected Width	L_f = 7.00 in
Edge Effect Top Side	U_{e1} = 0.30 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.19 Btu/h.ft².F

5.3.6 Mullion 2 – Vision / Spandrel

In the following, the THERM model is presented graphically

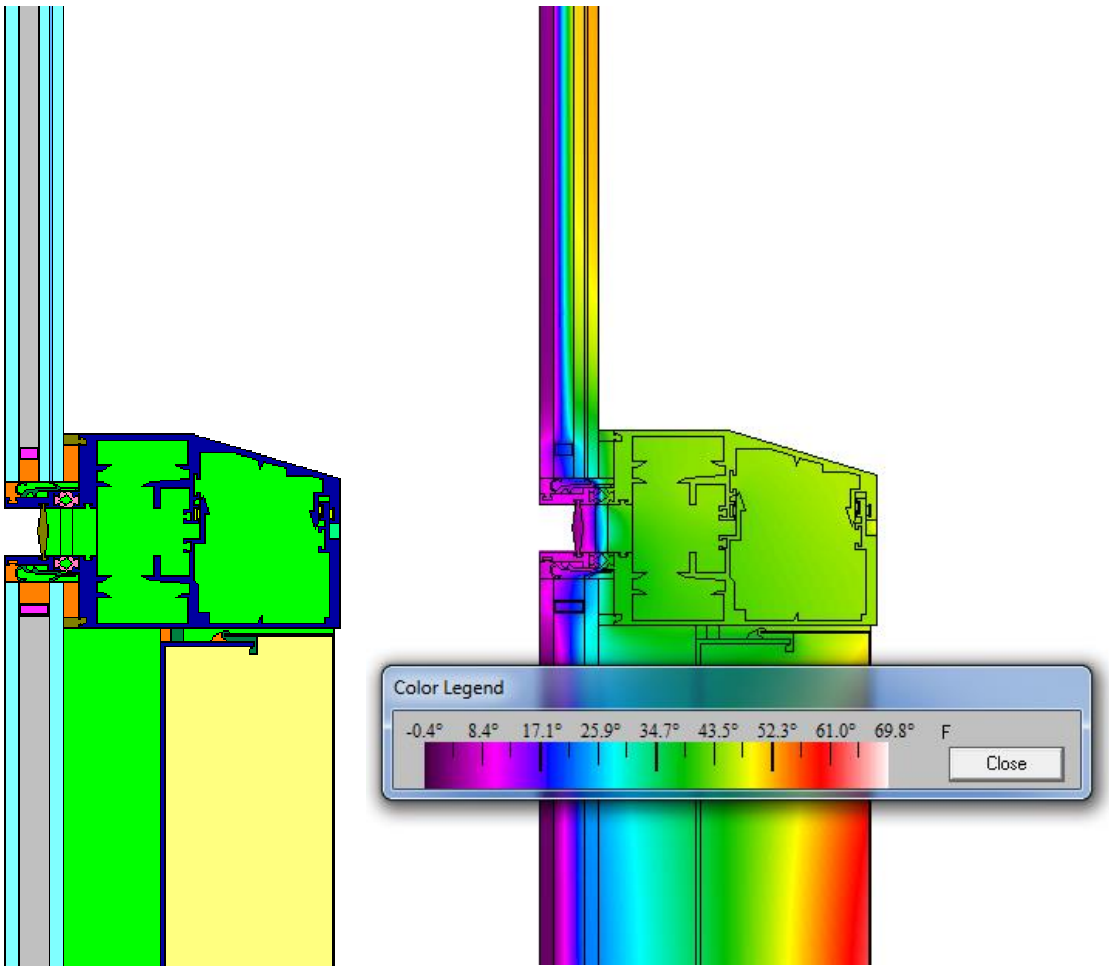

Figure 9: Mullion – Vision/Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.98 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.37 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.19 Btu/h.ft².F

5.3.7 Stack Joint – Vision / Metal

In the following, the THERM model is presented graphically

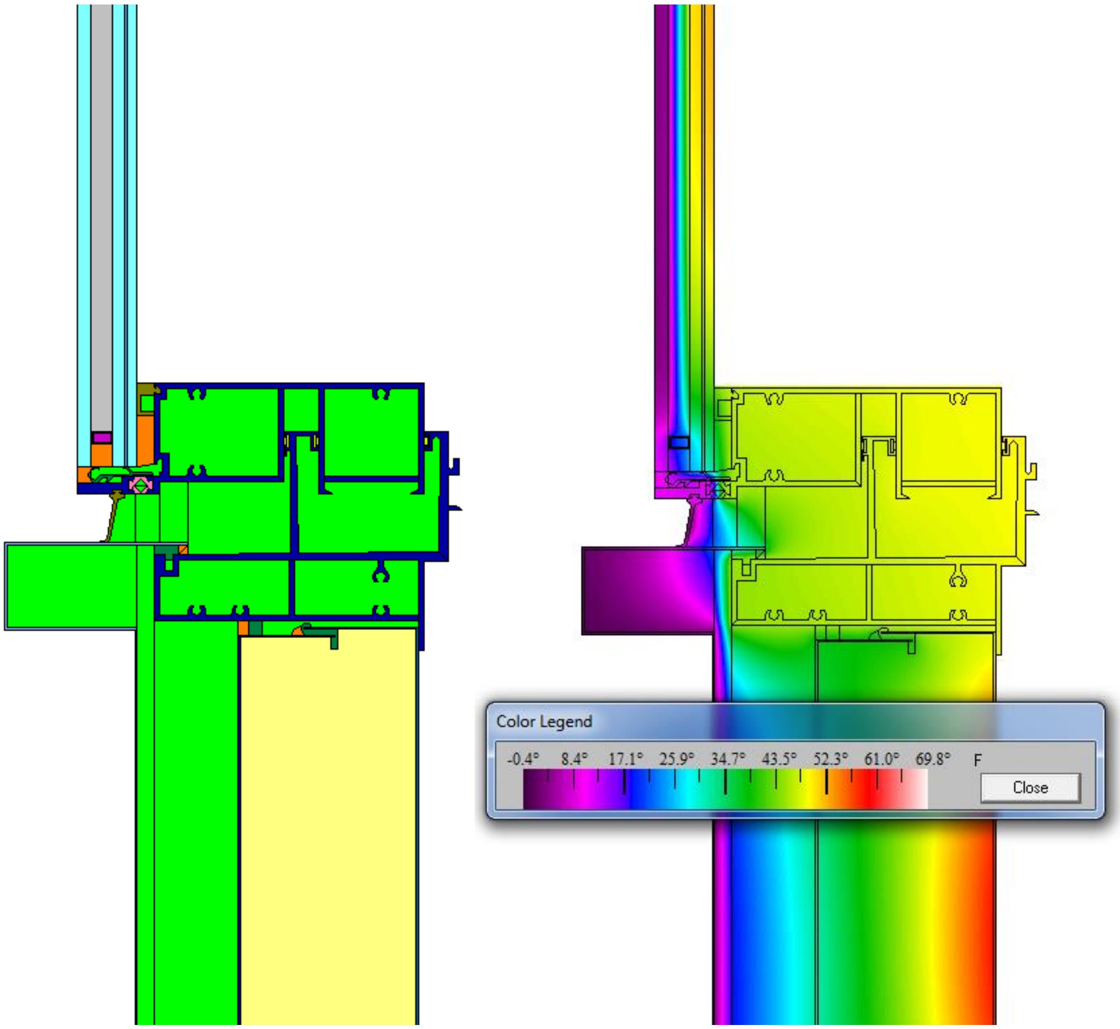

Figure 10: Stack Joint – Vision/Metal: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.94 Btu/h.ft².F
Frame Projected Width	L_f = 5.50 in
Edge Effect Top Side	U_{e1} = 0.32 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.27 Btu/h.ft².F

5.3.8 Stack Joint – Spandrel / Metal

In the following, the THERM model is presented graphically

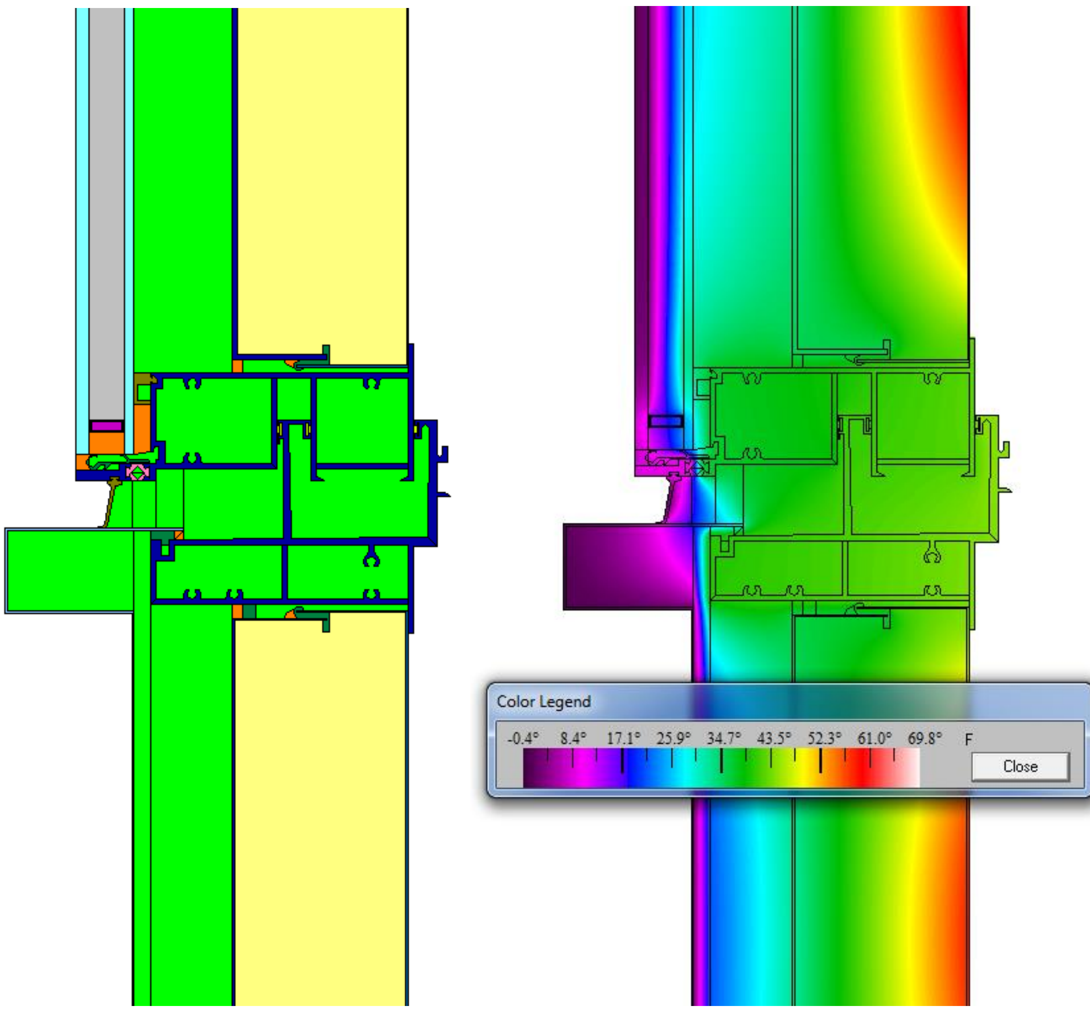

Figure 11: Stack Joint – Spandrel/Metal: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.63 Btu/h.ft².F
Frame Projected Width	L_f = 5.50 in
Edge Effect Top Side	U_{e1} = 0.34 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.33 Btu/h.ft².F

5.3.9 Transom – Metal / Vision

In the following, the THERM model is presented graphically

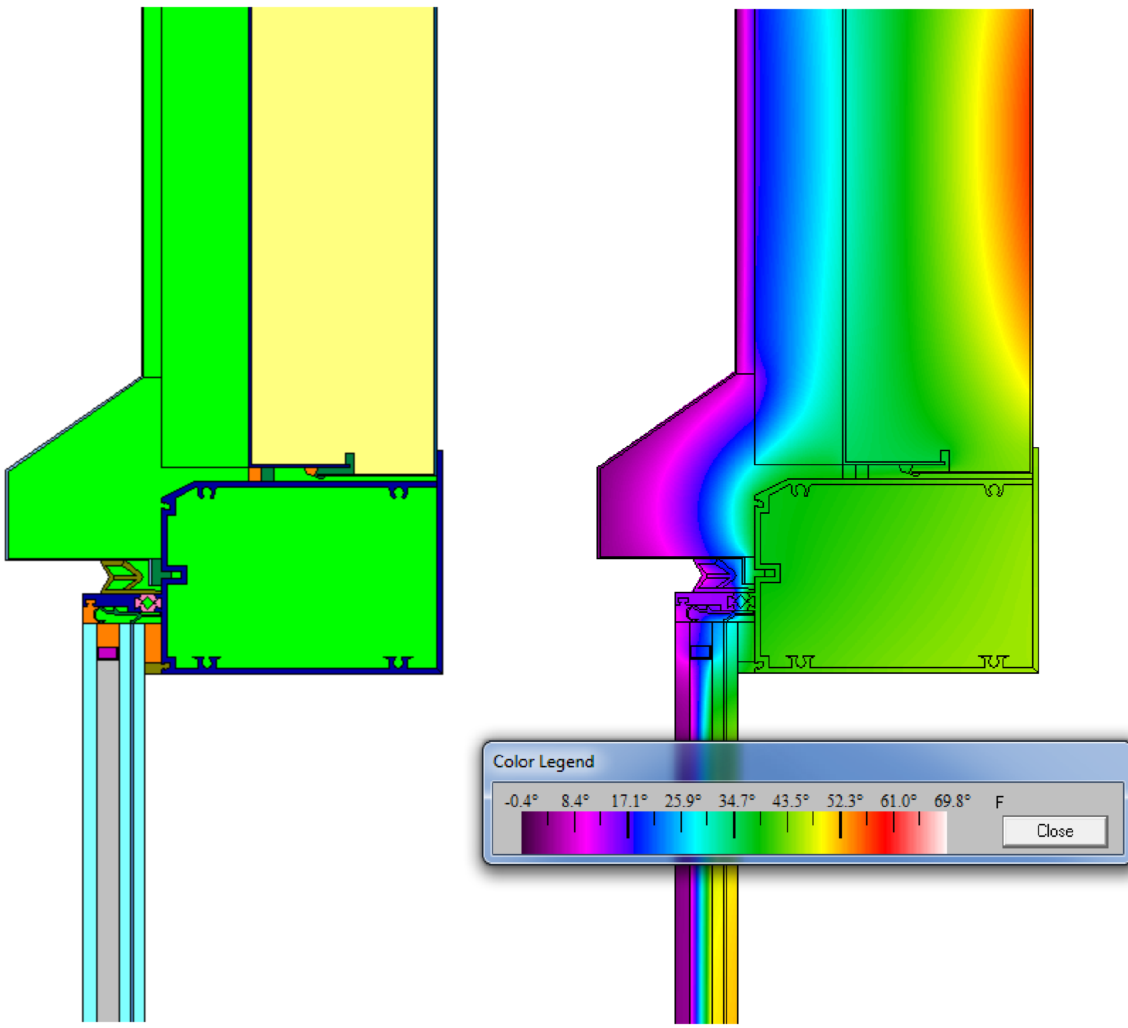

Figure 12: Transom – Metal/Vision: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.14 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.32 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.36 Btu/h.ft².F

5.3.10 Transom – Metal / Operable

In the following, the THERM model is presented graphically

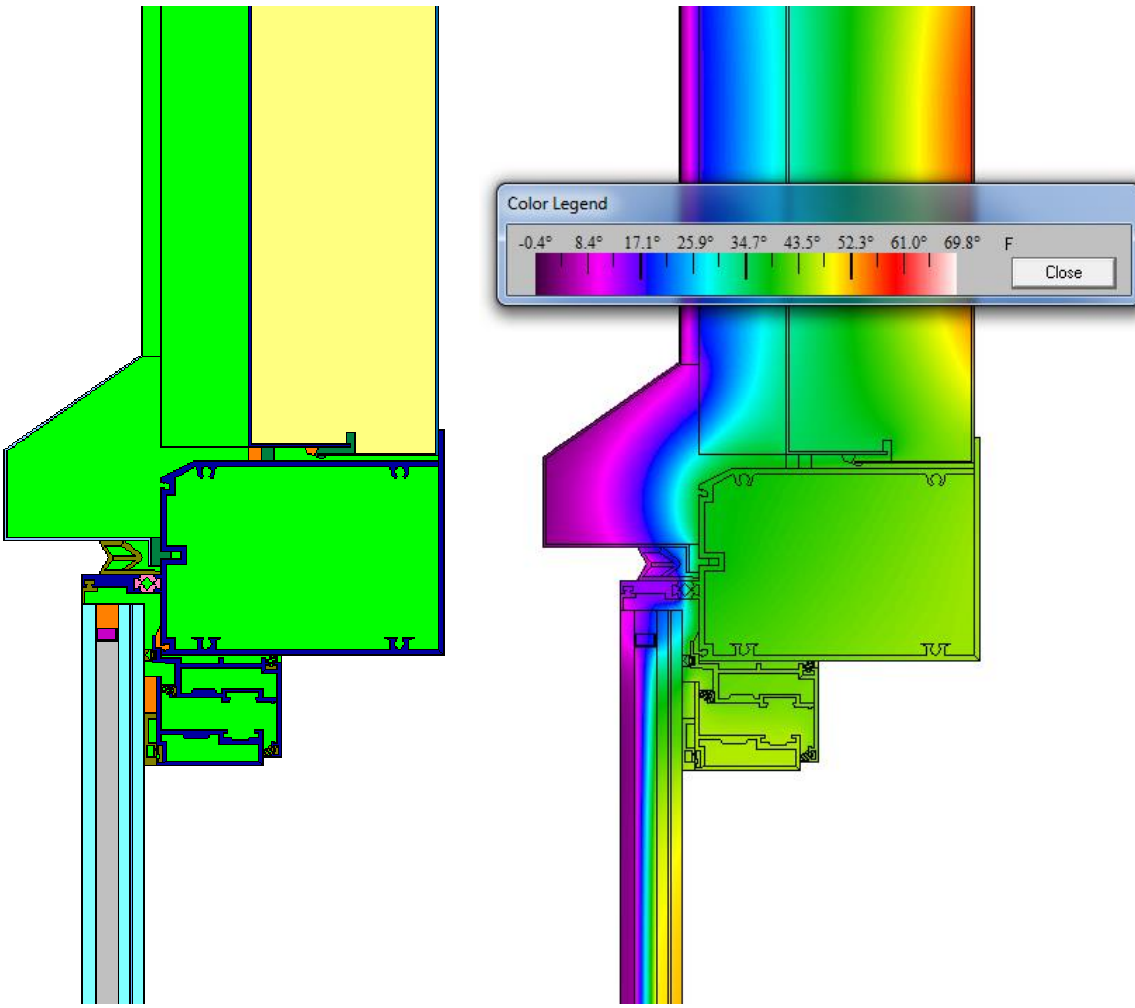

Figure 13: Transom – Metal/Operable: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.85 Btu/h.ft².F
Frame Projected Width	L_f = 6.70 in
Edge Effect Top Side	U_{e1} = 0.32 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.31 Btu/h.ft².F

5.3.11 Transom – Operable / Vision

In the following, the THERM model is presented graphically

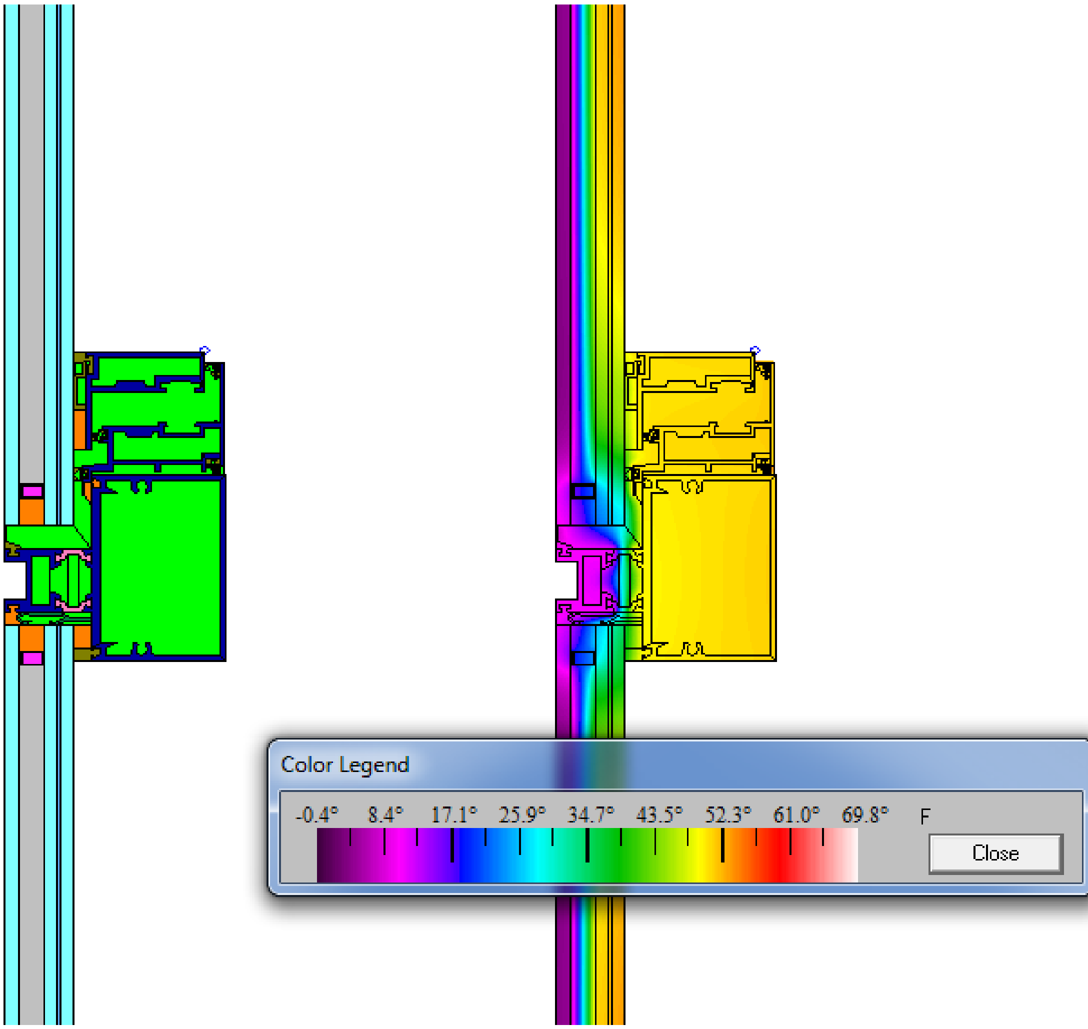

Figure 14: Transom – Operable/Vision: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.66 Btu/h.ft².F
Frame Projected Width	L_f = 6.19 in
Edge Effect Top Side	U_{e1} = 0.30 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.40 Btu/h.ft².F

5.3.12 Transom – Metal / Spandrel

In the following, the THERM model is presented graphically

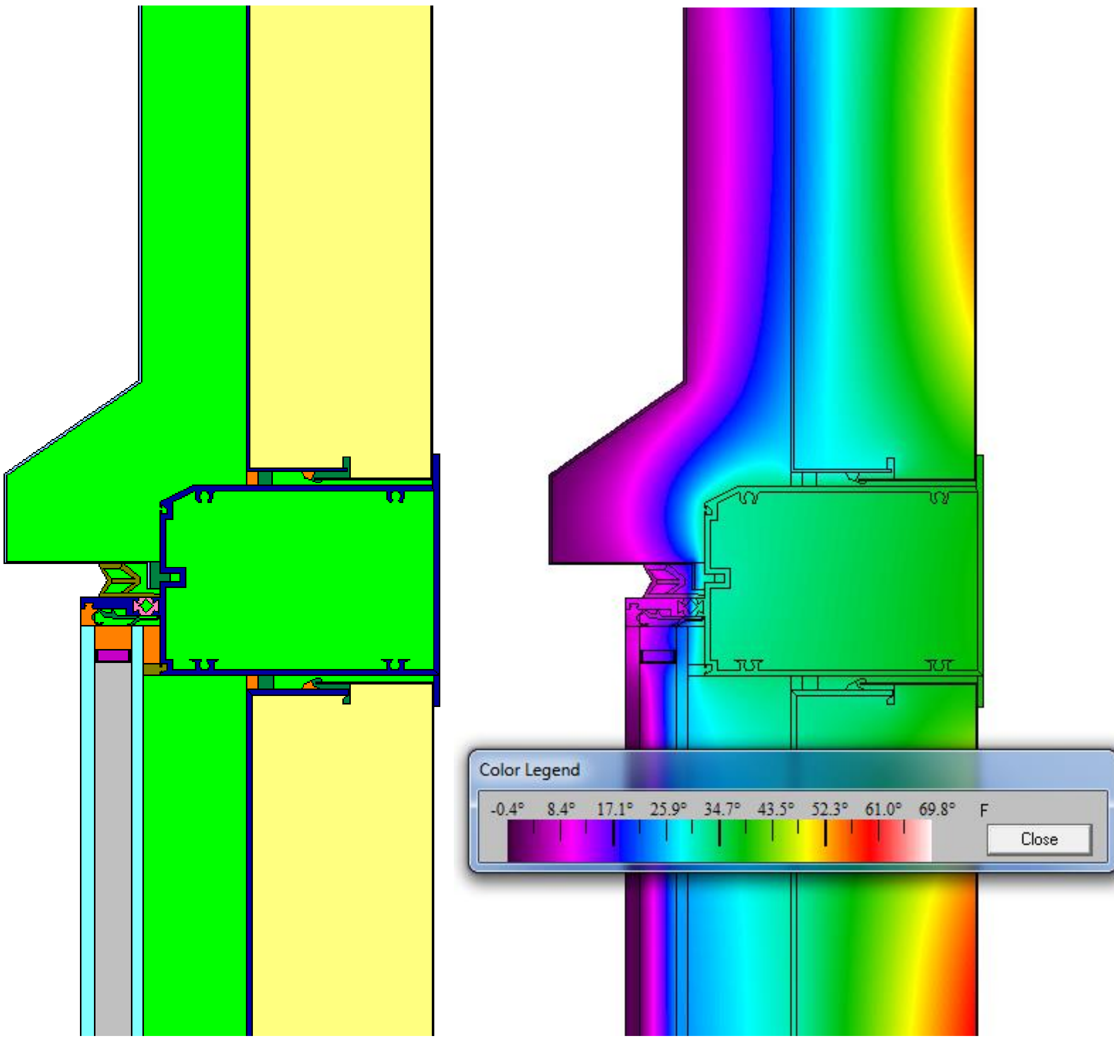

Figure 15: Transom – Metal/Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.61 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.40 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.39 Btu/h.ft².F

5.4 Overall U-Value

Area weighting of the U-values of all frames, glass and panels is used to calculate the overall U-value for each wall type.

Component	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Metal/Metal	0.15	92.60	0.64	0.10
Left Edge Effect	0.15	23.75	0.16	0.02
Right Edge Effect	0.15	23.75	0.16	0.02
Mullion - Vision/Vision	1.05	620.42	4.31	4.52
Left Edge Effect	0.35	311.88	2.17	0.76
Right Edge Effect	0.35	311.88	2.17	0.76
Intermediate Mullion - Vision/Operable	0.70	683.40	4.75	3.32
Left Edge Effect	0.35	225.75	1.57	0.55
Right Edge Effect	0.29	225.75	1.57	0.45
Intermediate Mullion - Vision/Vision	0.96	136.00	0.94	0.91
Left Edge Effect	0.35	52.03	0.36	0.13
Right Edge Effect	0.35	52.03	0.36	0.13
Mullion - Metal/Metal	0.15	92.60	0.64	0.10
Left Edge Effect	0.15	23.75	0.16	0.02
Right Edge Effect	0.15	23.75	0.16	0.02
Mullion 2 - Operable/Spandrel	0.75	714.00	4.96	3.72
Left Edge Effect	0.30	231.88	1.61	0.48
Right Edge Effect	0.19	231.88	1.61	0.31
Mullion 2 - Vision/Spandrel	0.98	148.16	1.03	1.01
Left Edge Effect	0.37	67.50	0.47	0.17
Right Edge Effect	0.19	67.50	0.47	0.09
Stack Joint - Vision/Metal	0.94	304.54	2.11	1.99
Top Edge Effect	0.32	125.93	0.87	0.28
Bottom Edge Effect	0.27	125.93	0.87	0.24
Transom - Metal/Vision	1.14	107.82	0.75	0.85
Top Edge Effect	0.32	50.93	0.35	0.11
Bottom Edge Effect	0.36	50.93	0.35	0.13
Transom - Metal/Operable	0.85	156.11	1.08	0.92
Top Edge Effect	0.32	45.75	0.32	0.10
Bottom Edge Effect	0.31	45.75	0.32	0.10
Transom - Operable/Vision	0.66	159.39	1.11	0.73
Top Edge Effect	0.30	51.88	0.36	0.11
Bottom Edge Effect	0.40	51.88	0.36	0.14

Stack Joint - Spandrel/Metal	0.63	304.54	2.11	1.33
Top Edge Effect	0.34	125.93	0.87	0.30
Bottom Edge Effect	0.33	125.93	0.87	0.29
Transom - Metal/Spandrel	0.61	225.25	1.56	0.95
Top Edge Effect	0.40	120.00	0.83	0.33
Bottom Edge Effect	0.39	120.00	0.83	0.33
Vision Glass	0.28	4625.46	32.12	8.99
Spandrel Region	0.05	7195.87	49.97	2.50
Totals		18480.00	128.33	38.32
Overall U-Value	**0.30**	**Btu/h.ft².F]**		

Table 5: Thermal Transmittance of Wall Type B

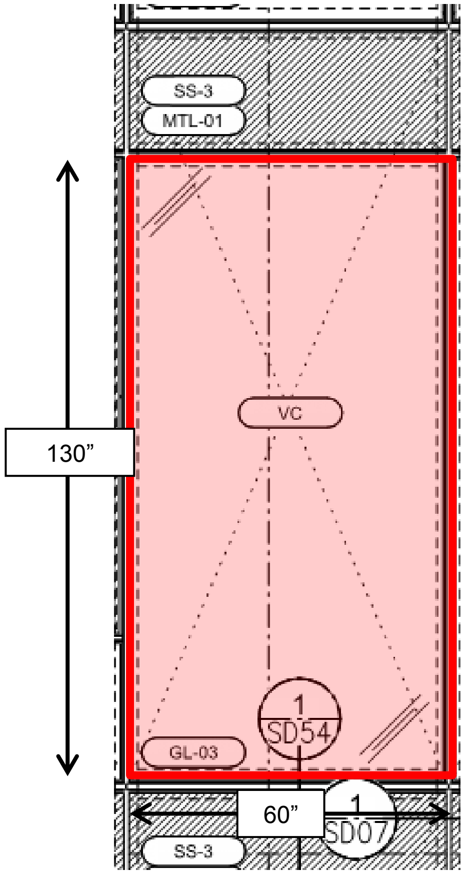

Figure 16: Typical Vision Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Vision	1.05	601.90	4.18	4.39
Left Section	0.35	308.13	2.14	0.75
Right Section	0.35	308.13	2.14	0.75
Transom - Metal / Vision	1.17	235.32	1.63	1.91
Top Section	0.32	132.18	0.92	0.29
Bottom Section	0.36	132.18	0.92	0.33
Glass Vision	0.28	6082.18	42.24	11.83
Totals		7800	54	20.25

Vision U-Value	0.37	[Btu/h.ft².F]

Table 6: Wall Type B Vision U-Value

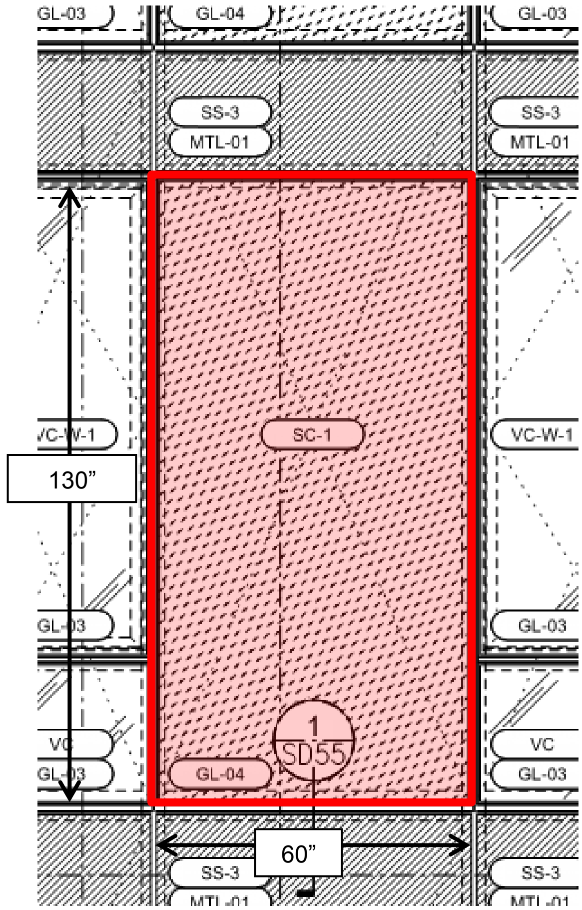

Figure 17: Typical Spandrel Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Spandrel	0.98	601.90	4.18	4.10
Left Section	0.37	308.13	2.14	0.79
Right Section	0.19	308.13	2.14	0.41
Transom - Metal / Spandrel	0.60	235.32	1.63	0.98
Top Section	0.39	132.18	0.92	0.36
Bottom Section	0.38	132.18	0.92	0.35
Spandrel Region	0.05	6082.18	42.24	2.11
Totals		7800	54	9.09

Overall U-Value	0.17	[Btu/h.ft².F]

Table 7: Wall Type B Spandrel U-Value

6 CONDENSATION ASSESSMENT

The minimum internal surface temperature of the curtain wall has been assessed for each model using THERM 6.3 software using the specified Boundary Conditions. The absolute Minimum Temperature in the surface was found to be $t_{si,min}$=40.7°F on the Mullion 2 – Vision/Spandrel location of the façade (see following table).

Wall Type	Components	Dew Point Temperature (°F)	Minimum Surface Temperature (°F)	Maximum Allowed Relative Humidity (%)
Wall Type B	*Mullion – Metal/Metal*	39.1	50.9	54.3
	Mullion – Vision/Vision		41.6	38.2
	Intermediate Mullion – Vision/Operable		43.4	40.9
	Intermediate Mullion – Vision/Vision		43.1	40.4
	Mullion 2 – Operable/Spandrel		46.6	46.2
	Mullion 2 – Vision/Spandrel		40.7	36.9
	Stack Joint – Vision/Metal		43.5	41.1
	Stack Joint – Spandrel/Metal		43.0	40.3
	Transom – Metal/Vision		39.3	35.1
	Transom – Metal/Operable		43.5	41.1
	Transom – Operable/Vision		39.3	35.1
	Transom – Metal/Spandrel		40.0	35.9

Table 8: Condensation Assessment for Typical Details

With internal temperature of 68°F and Relative Humidity of 35% RH the Dew Point Temperature is 39.1°F. For the given Boundary Conditions, condensation will not occur on the interior surface of the façade and the performance is acceptable. Following THERM models of some critical sections are presented along with the Dew Point Isothermal Line as well as a temperature distribution for the specified Boundary Conditions.

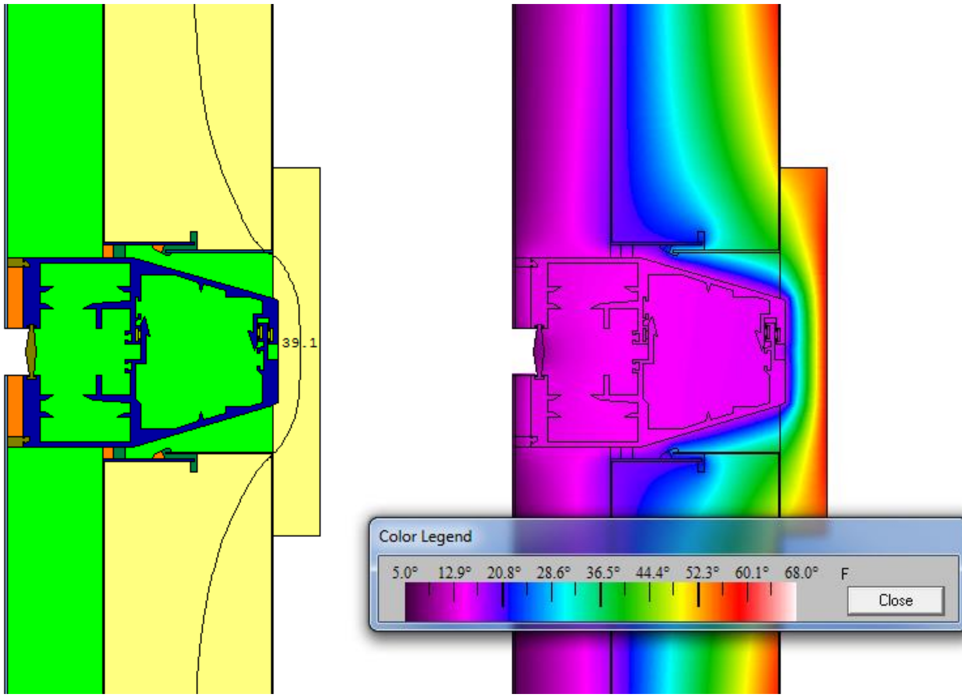

Figure 18: Mullion – Metal/Metal: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

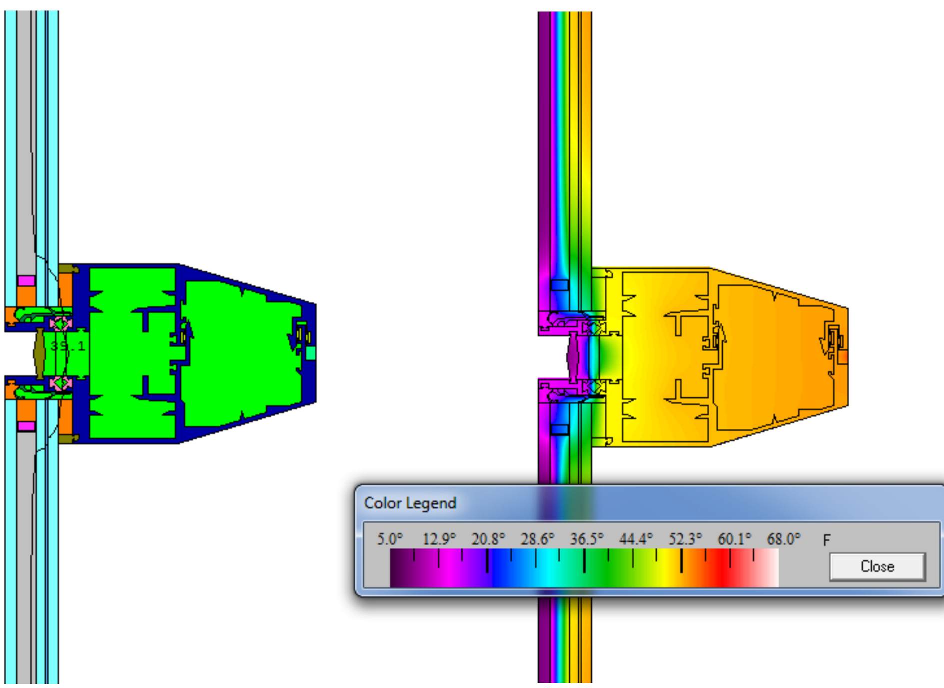

Figure 19: Mullion – Vision/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

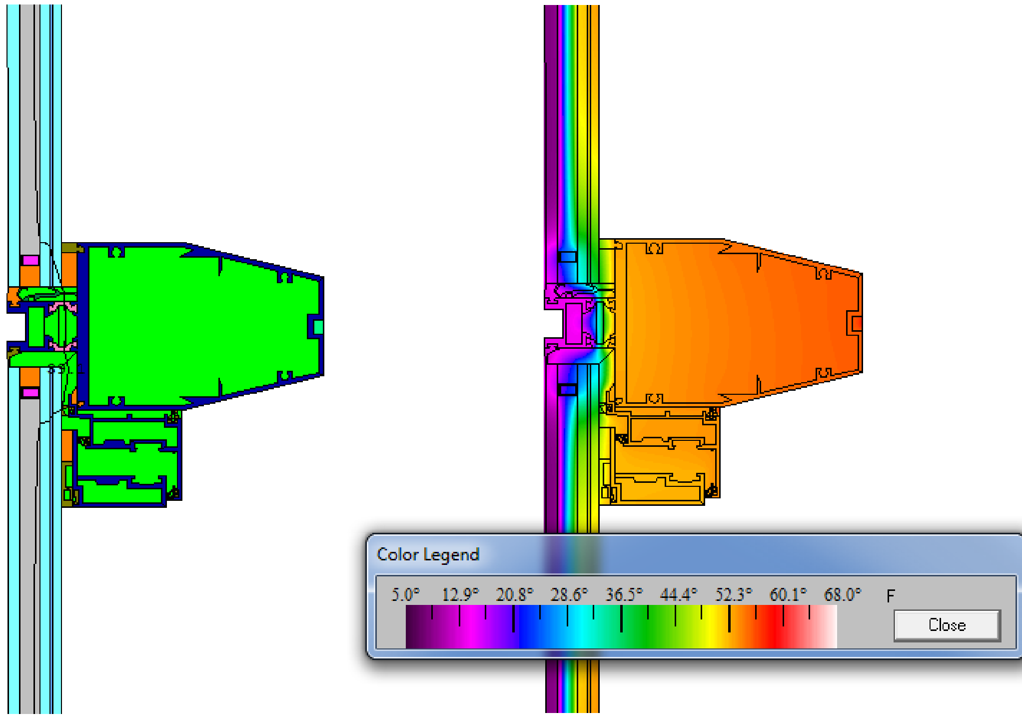

Figure 20: Intermediate Mullion – Vision/Operable: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

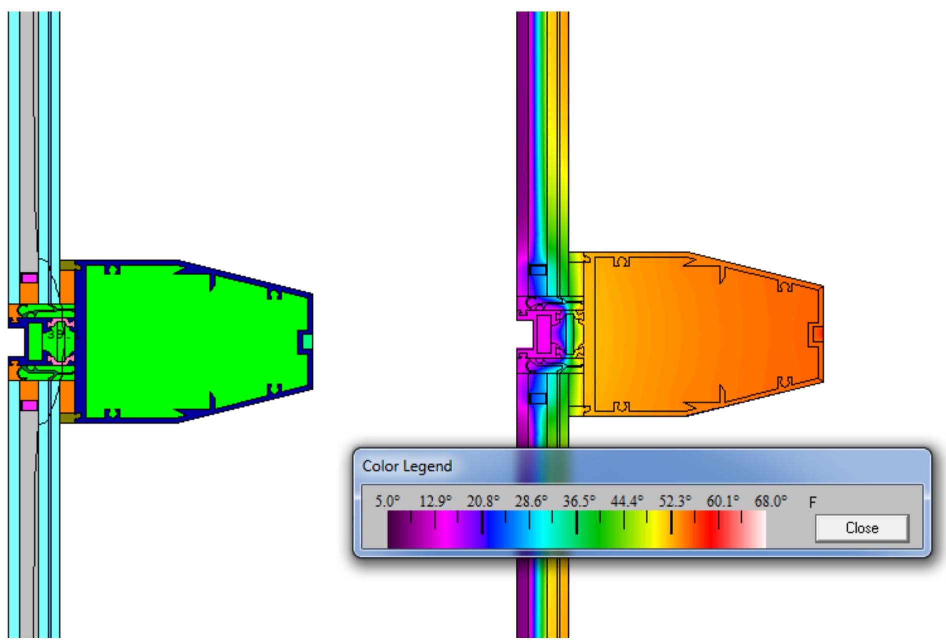

Figure 21: Intermediate Mullion – Vision/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

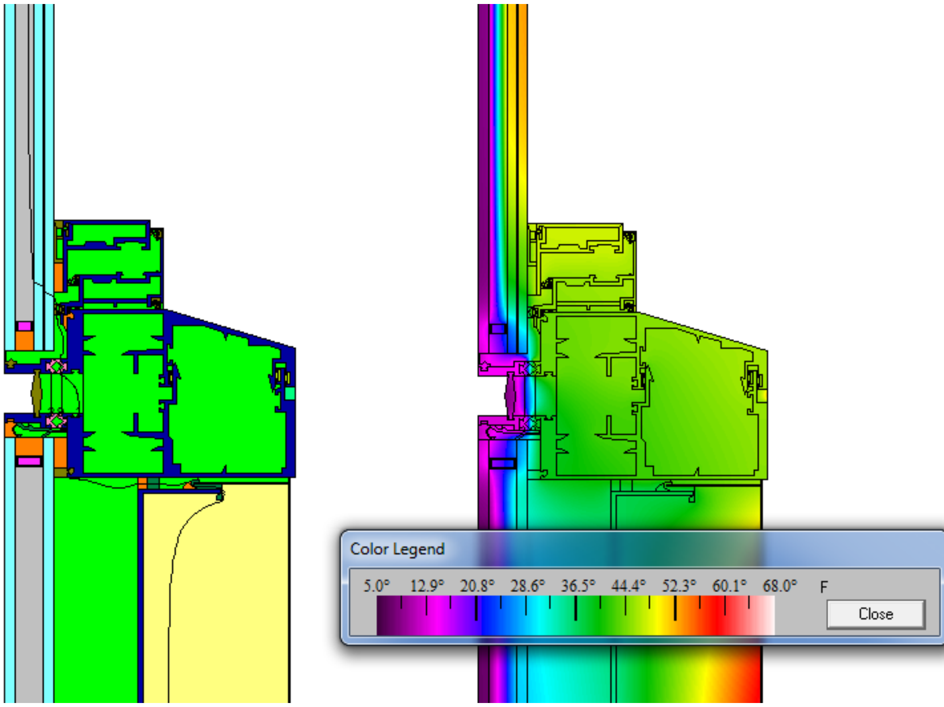

Figure 22: Mullion 2 – Operable/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

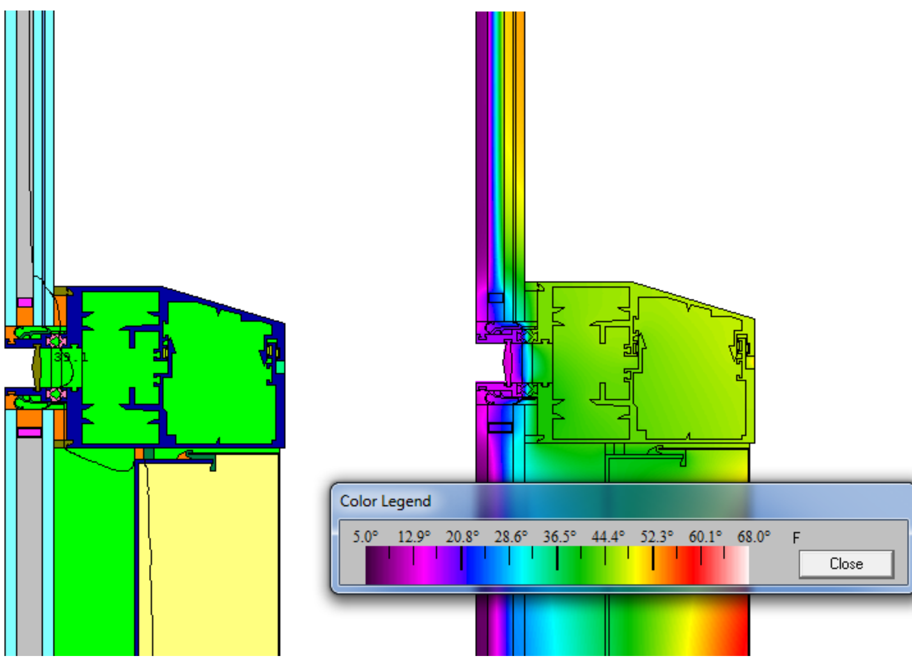

Figure 23: Mullion 2 – Vision/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

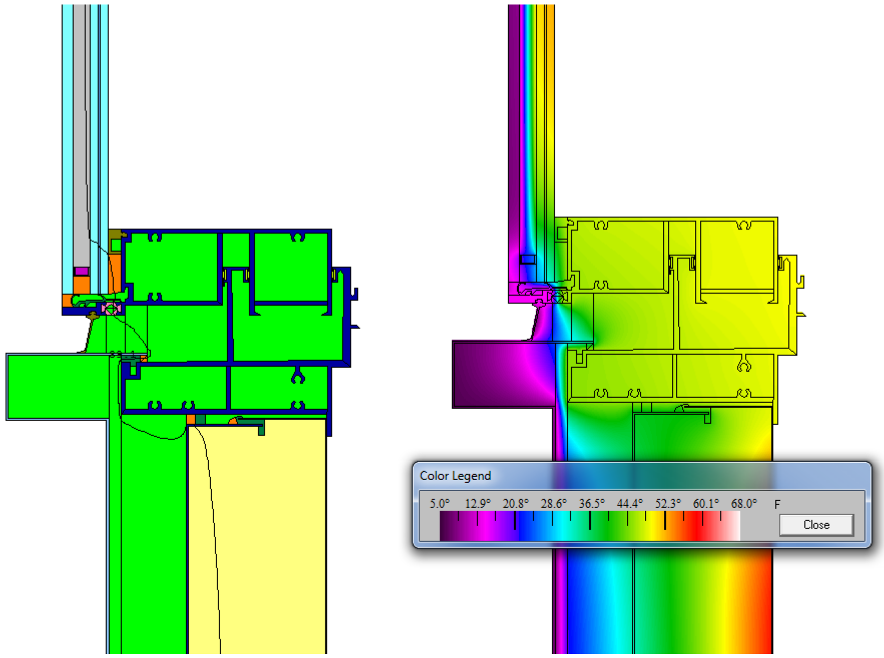

Figure 24: Stack Joint – Vision/Metal: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

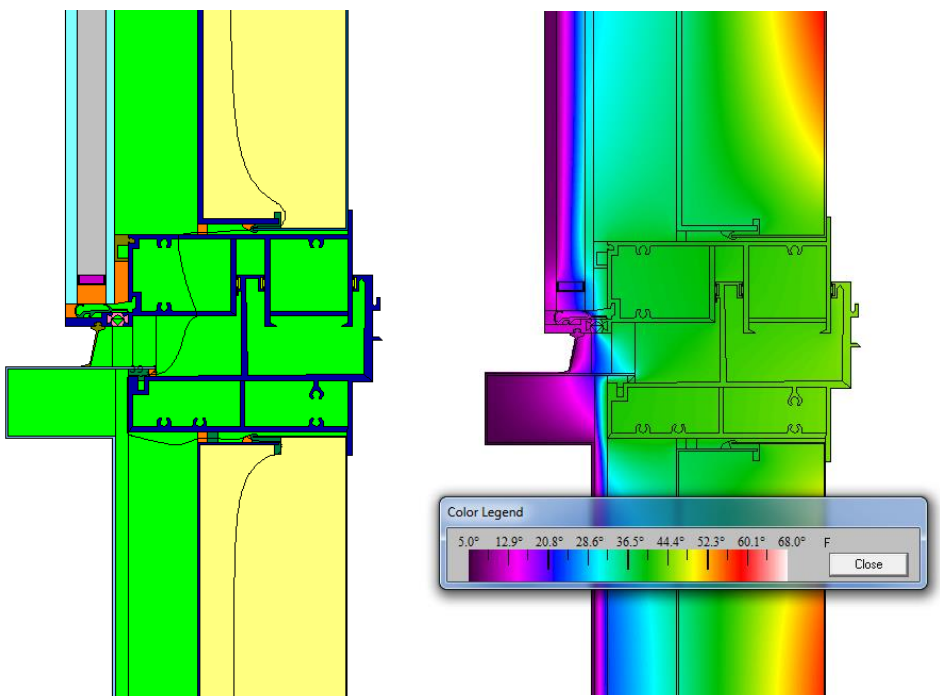

Figure 25: Stack Joint – Spandrel/Metal: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

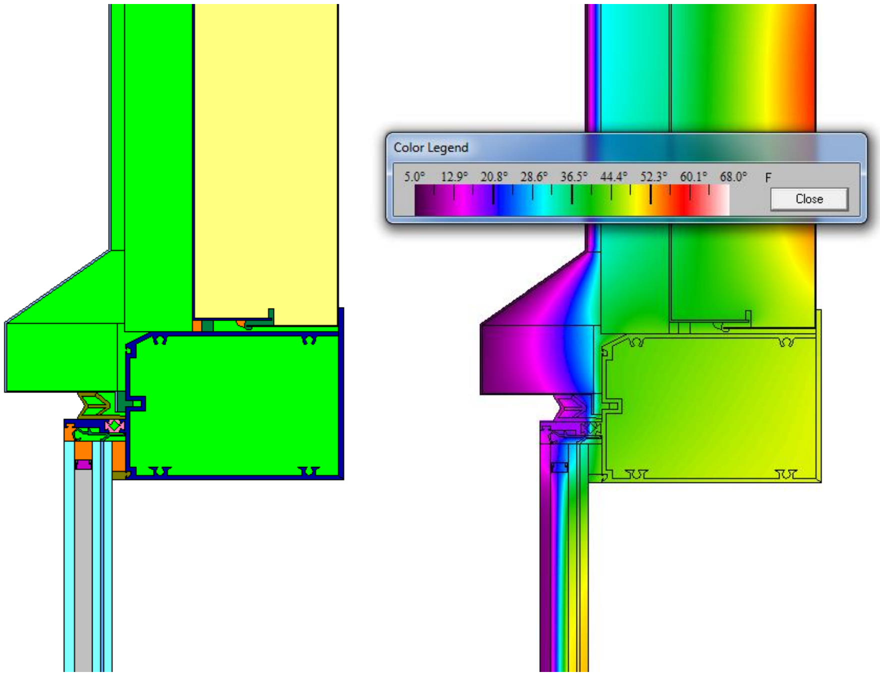

Figure 26: Transom – Metal/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

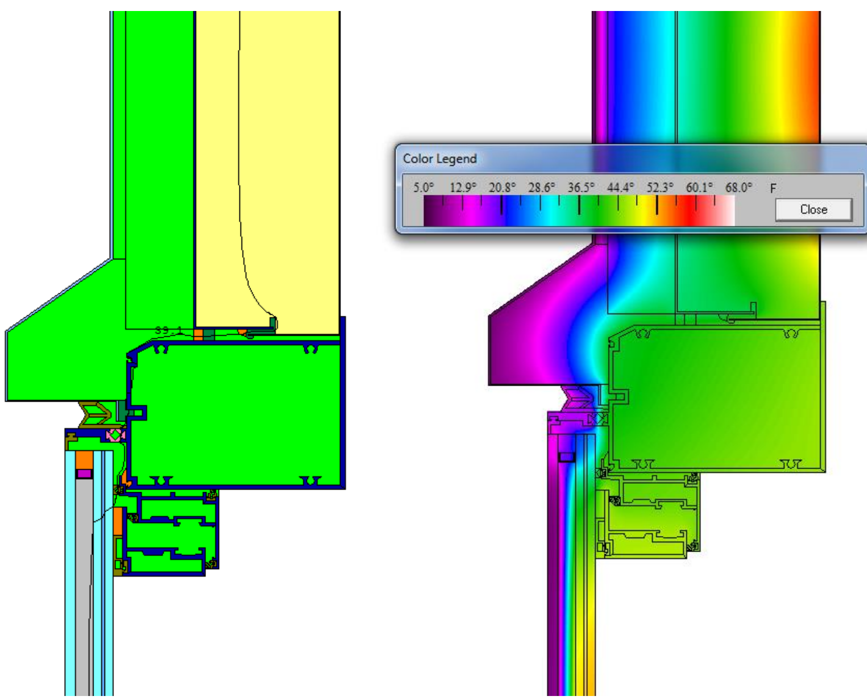

Figure 27: Transom – Metal/Operable: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

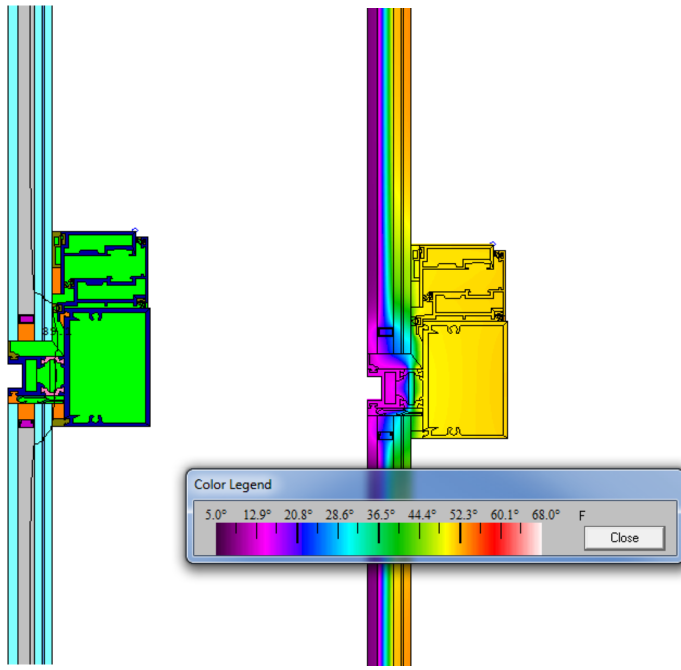

Figure 28: Transom – Operable/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

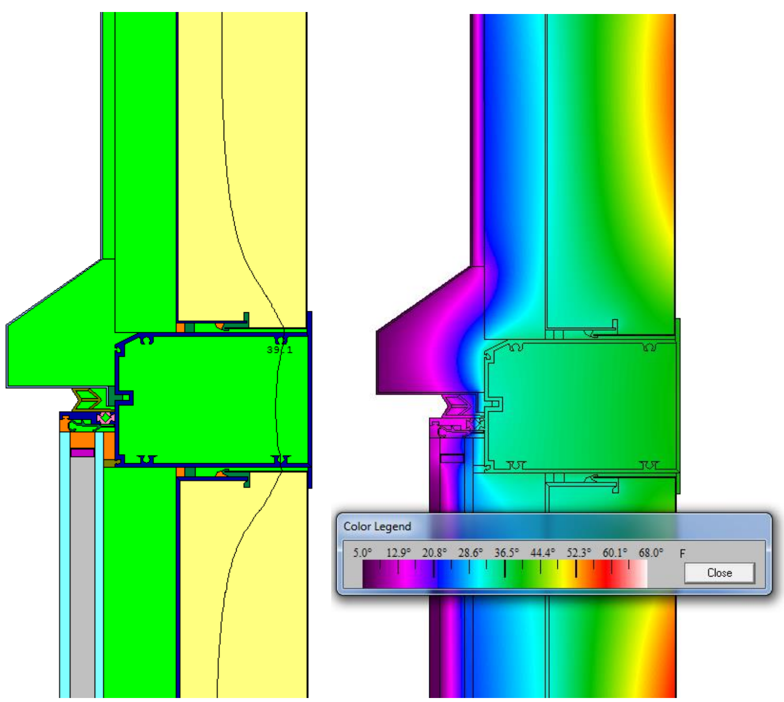

Figure 29: Transom – Metal/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

7 REFERENCES

ASHRAE ASHRAE Handbook of Fundamentals 1998-2001, American Society of Heating, Refrigerating, and Air-Conditioning Engineering, Atlanta, GA, USA, 2004.

ISO 6946: 2007 Building components and building elements - Thermal resistance and thermal transmittance - Calculation method

ISO 10077-1: 2006 Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General

ISO 10077-2: 2003 Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames

ISO 10211: 2007 Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations

ISO 13788:2001 Hydrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods

ISO 15099: 2003 Thermal performance of windows, doors and shading devices - Detailed calculations

NFRC 100: 2010 Procedure for Determining Fenestration Product U-Factors.

NFRC 200: 2010 Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence

NFRC 300: 2010 Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems

THERM THERM 6.3 Program description. Windows and Daylighting Group. Lawrence Berkeley National Laboratory, 2002.

PERMASTEELISA NORTH AMERICA

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SUBMITTAL NUMBER

217 West 57th Street

Project 865

New York, NY

Exterior Wall Package

System Design - Thermal Calculations (Wall Type E)

DOC NAME: 90918 TC 003-02-150813 JH

Extell Development Company

Adrian Smith & Gordon Gill

AJLP Consulting

Lend Lease

Rev.	Date	Description	Prepared by	Checked by
02	08/13/2015	Third Submission	JH	JH
01	05/07/2015	Second Submission	JH	AF
00	03/09/2015	First Submission	JH	AF

TABLE OF CONTENTS

1 SUMMARY

THERM 6.3 software was used to analyze the two-dimensional heat transfer through the frame and glazing edge areas. The frame U-values have been derived using THERM 6.3 according to NFRC standard.

Main results are reported in the following:

Wall Type		U - Factor BTU/(h·ft²·°F)	Overall U - Factor BTU/(h·ft²·°F)	SHGC (Dimensionless)	Condensation Resistance (%)
WT-E	WT-E Vision	0.38	0.25	0.28	35.1
	WT-E Opaque	0.13			

Table 1: Summary of Results

2 THERM KEY

Material	Thermal Conductivity (Btu/h.ft².F)	Model Color
* Bracket Thermal Conductivity (WTC)	24.04	
Aluminum Alloy (Painted)	92.45	
Butyl Rubber	0.14	
Ethylene Propylene Diene Monomer (EPDM)	0.14	
Frame Cavity NFRC	Calculated by THERM	
Frame Cavity Slightly Ventilated	Calculated by THERM	
Glass (Plate or Float)	0.58	
IGU Gap Cavity	0.02	
Insulation	0.02	
Neoprene (Polychloroprene)	0.13	
PVC	0.10	
Polyamide 6.6 with 25% Glass Fiber	0.17	
Polyurethane Foam	0.03	
Silica Gel (Desiccant)	0.08	
Silicone Gasket	0.20	
Silicone Sealant	0.20	
Steel – Galvanized Sheet (0.14%C)	35.82	
Steel – Stainless (Buffed)	9.82	
Zinc	65.29	

Table 2: THERM Material Color Key

* Given a thermal conductivity of 0.024 W/m.K for air and 160.00 W/m.K for aluminum, an average thermal conductivity can be calculated for the setting block based on an area weighted method. The calculation can be seen below.

$$\left(26\% * 160\frac{W}{m.K}\right) + \left(74\% * 0.024\frac{W}{m.K}\right) = 41.62\frac{W}{m.K}$$

3 BOUNDARY CONDITIONS

Calculation	Standard	Cold-Side Environmental Temperature	Warm-Side Environmental Temperature	External Wind Speed	External Heat Transfer Coefficient	Internal Relative Humidity	Internal Heat Transfer Coefficient
Thermal Transmittance	NFRC (100-2010)	-0.4°F	69.8°F	12.3mph	4.58 Btu/h-ft²-F	----	0.53 Btu/h-ft²-F
Condensation Assessment	Project Specification (06/02/14)	5.0°F	68.0°F	15.0mph	5.43 Btu/hft²-F	35%	0.53 Btu/h-ft²-F

Table 3: Boundary Conditions

4 GENERAL DESCRIPTION

This report must be read in conjunction with Permasteelisa's system drawings dated August 20th. The thermal performance of the typical façade type is stated in the following report. The overall U-value, as well as Condensation Assessment of the curtain wall panels have been performed according to the (NFRC), (ASHRAE) and (ISO) Standards.

Typical elevation and sections are shown in the following figure.

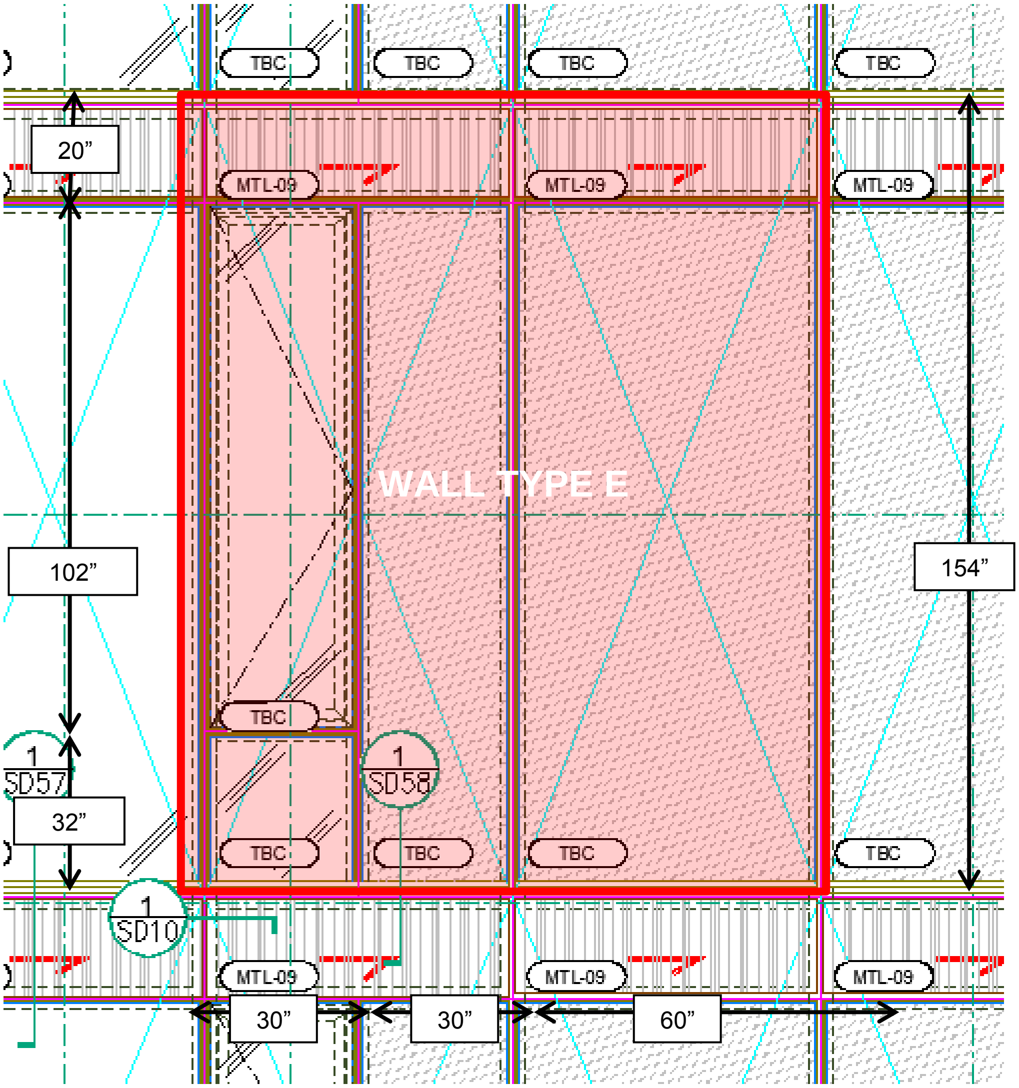

Figure 1: Wall Type E (SE03)

5 THERMAL TRANSMITTANCE

5.1 Thermal Transmittance Calculation Method

The heat transfer through the frame and glazing is assessed as described in the thermal guide (NFRC) and (ISO15099).

There are then the following thermal transmittances (U-values):

- Centre-glazing U-value U_g, which is assumed to apply to the whole of the glazing (defined in section 5.2.1);
- Centre-panel U-value U_{sp}, which is assumed to apply to the whole of the spandrel panel (defined in section 5.2.2);
- Frame U-value U_f (defined in section 5.3);
- Edge U-value U_{edge1}, U_{edge2}, to take into account the heat transfer due to the interaction (edge effect) between the framing and glazing/spandrel panel (defined in section 5.3).

The overall U-value of the curtain wall is then calculated by using the principle of the area weighting of U-values of the frames and glass (as explained in section 5.4).

5.2 Center U-Value

One-dimensional center U-value calculation has been performed for glass and spandrel.

5.2.1 Glazing

The calculations have been performed with the following glass for the typical elevation. (Calculated with Window 6.3 Software according to NFRC):

Glass Makeup:

Outer-lite:	5/16" IPASOL PLATIN 46/31 on Surface # 2 (Interpane)
Cavity:	½" Air with Stainless Steel Spacers
Inner-lite:	¼" – 0.060" – ¼" Laminate

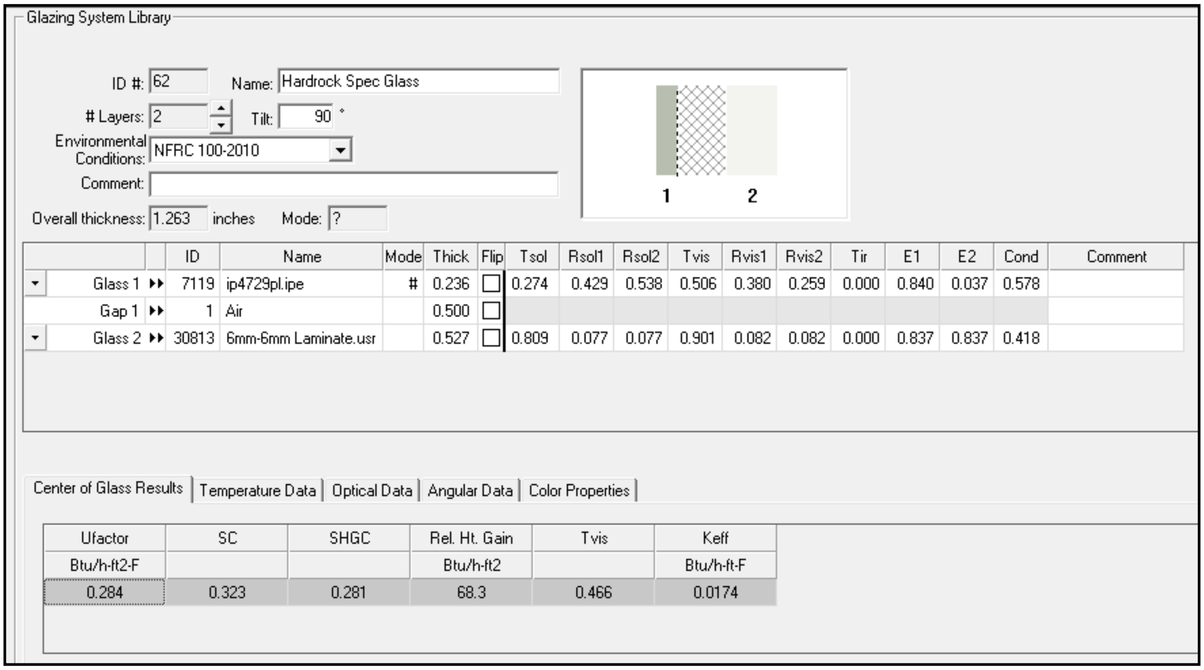

Figure 2: WINDOW 6 Model

Standard	Glass Characteristics	Value
NFRC 100 -2010	Thermal Transmittance (Btu/h.ft².F)	0.28
NFRC 200 – 2010	Solar Heat Gain Coefficient	0.28

Table 4: 1 Dimensional Analysis Summary

5.2.2 Spandrel Panel (Wall Type E)

In the following, the THERM model is presented graphically

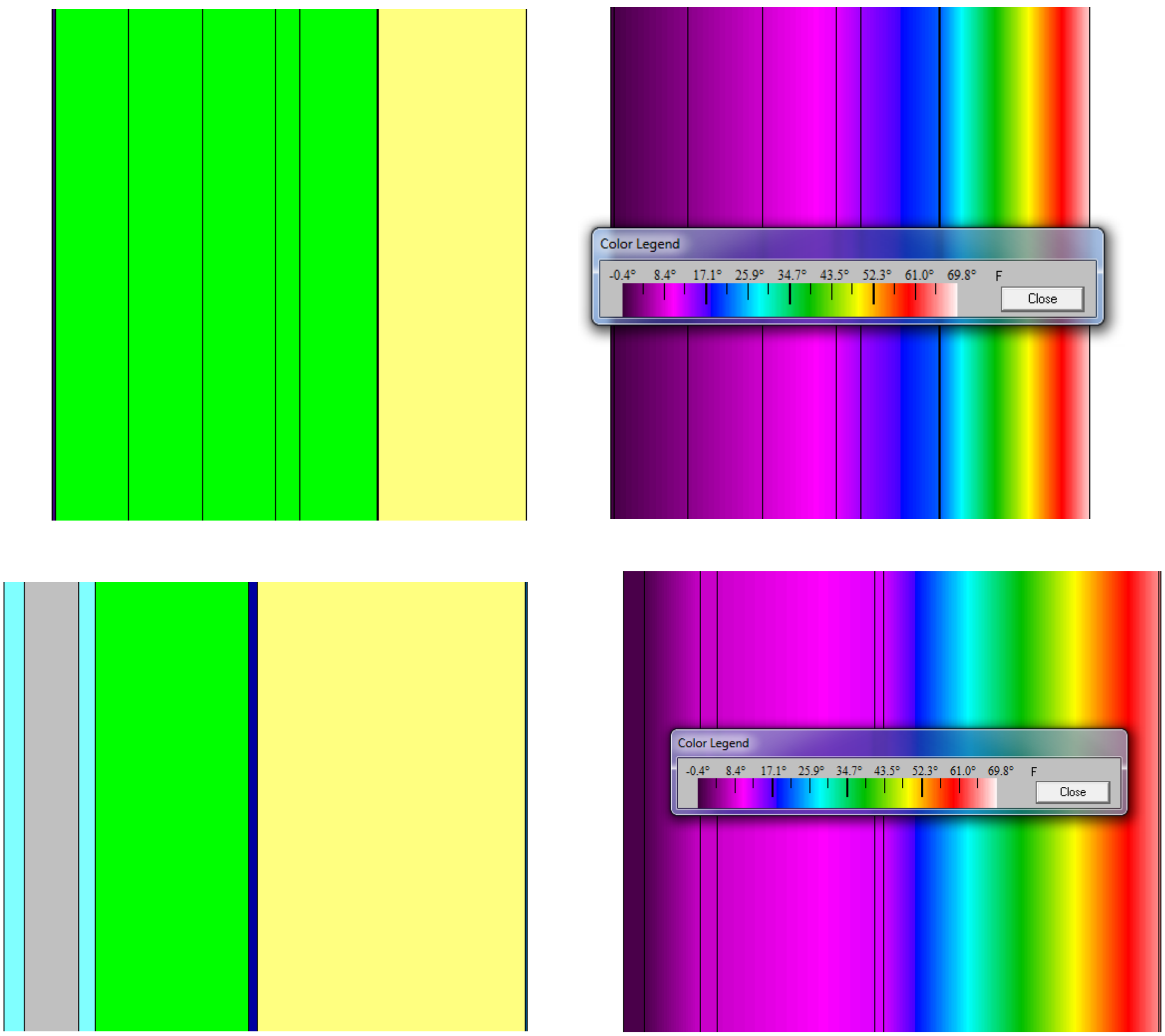

Figure 3: Spandrel Panels: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Thermal Transmittance (Top)	U_{sp} = 0.04 Btu/h.ft².F
Thermal Transmittance (Bottom)	U_{sp} = 0.04 Btu/h.ft².F

5.3 Wall Type E Frame U-Value

The frames have been modeled by means of 2-dimensional FEM analysis, using the THERM program (version 6.3) by the Lawrence Berkeley National Laboratory. Material properties have been assigned as per THERM internal library.

The frame has been modeled including stainless steel glazing spacers.

The projected width of the solid part of the framing (excluding the glazing gaskets) is measured from the inside. For each of the models, the projected width of the frames is stated along with the frame U-value.

5.3.1 Mullion – Metal / Metal

In the following, the THERM model is presented graphically

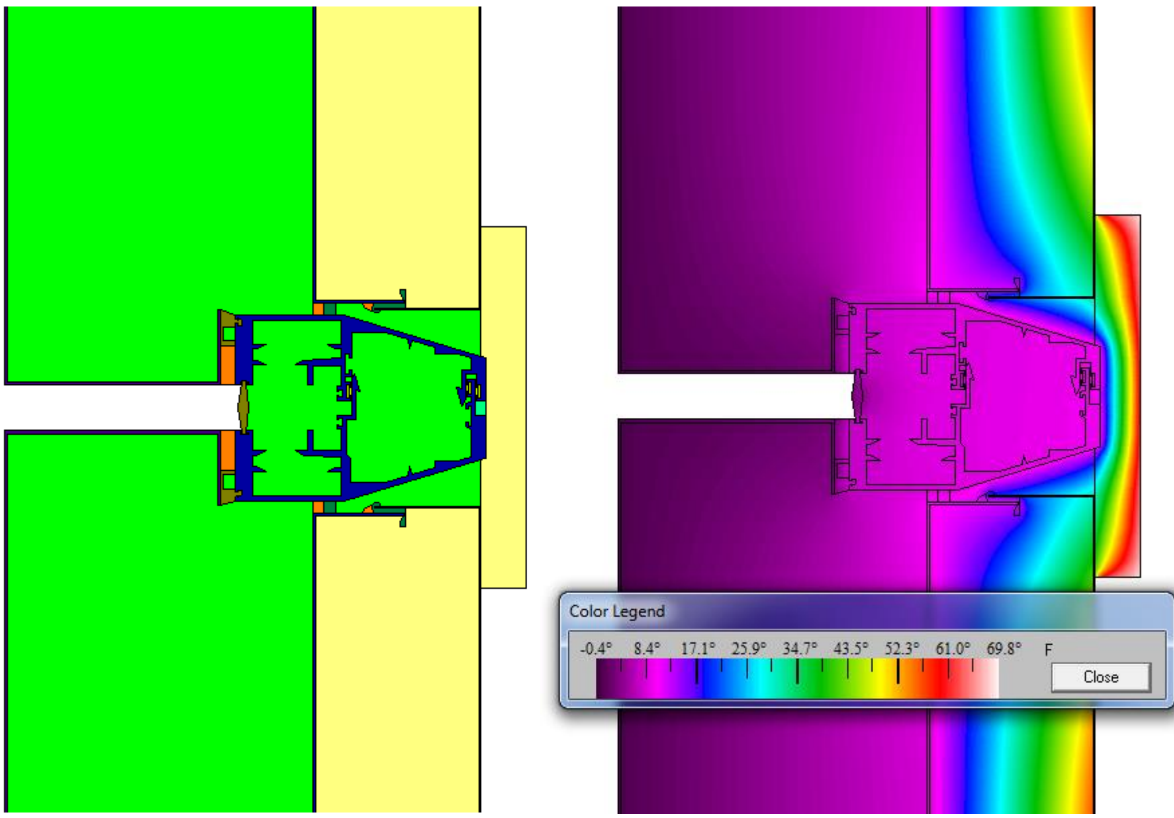

Figure 4: Mullion – Metal / Metal: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.15 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.15 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.15 Btu/h.ft².F

5.3.2 Mullion – Vision / Operable

In the following, the THERM model is presented graphically

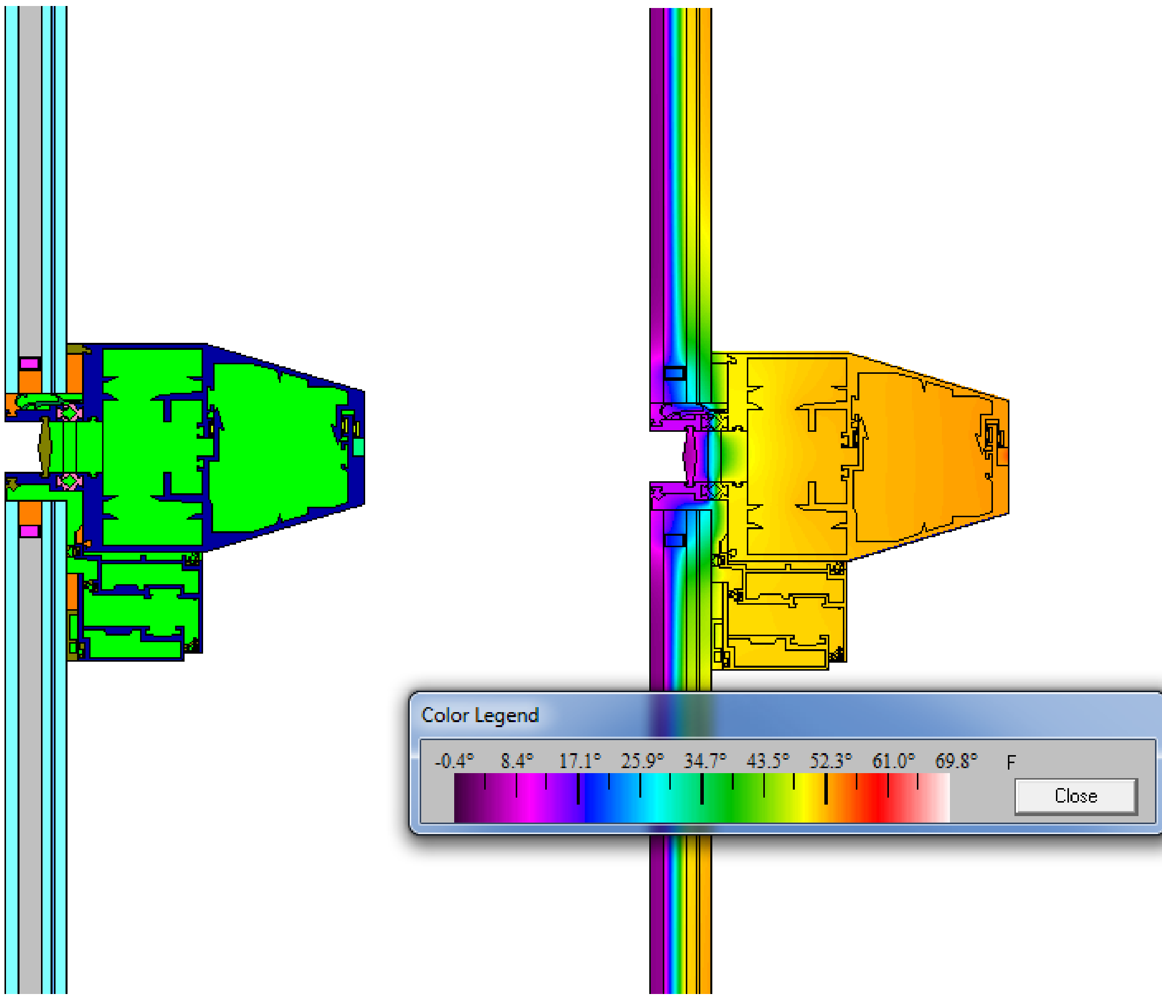

Figure 5: Mullion – Vision / Operable: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.80 Btu/h.ft².F
Frame Projected Width	L_f = 7.00 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.29 Btu/h.ft².F

5.3.3 Mullion – Vision / Vision

In the following, the THERM model is presented graphically

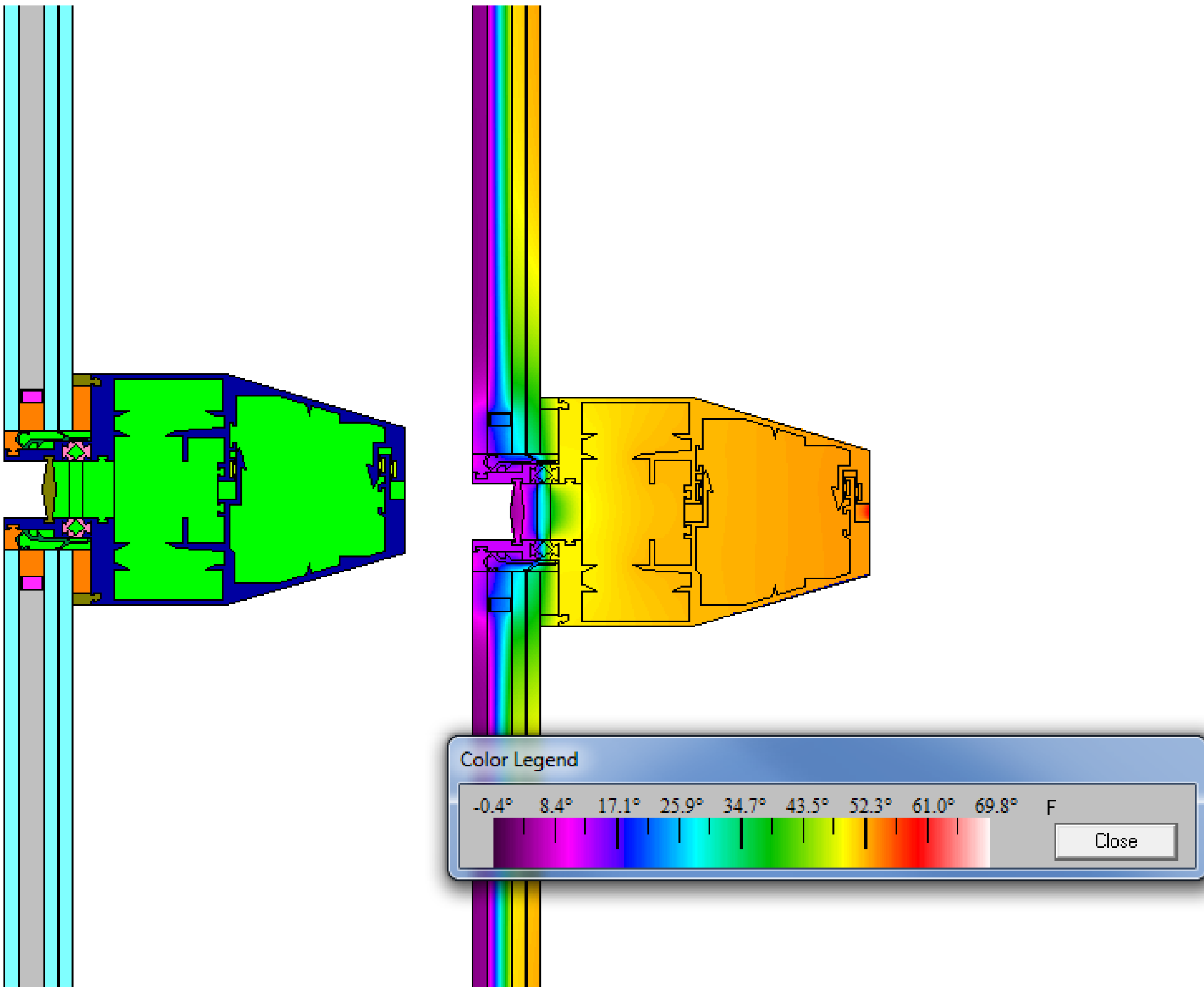

Figure 6: Mullion – Vision/Vision: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.05 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.35 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.35 Btu/h.ft².F

5.3.4 Mullion – Operable / Spandrel

In the following, the THERM model is presented graphically

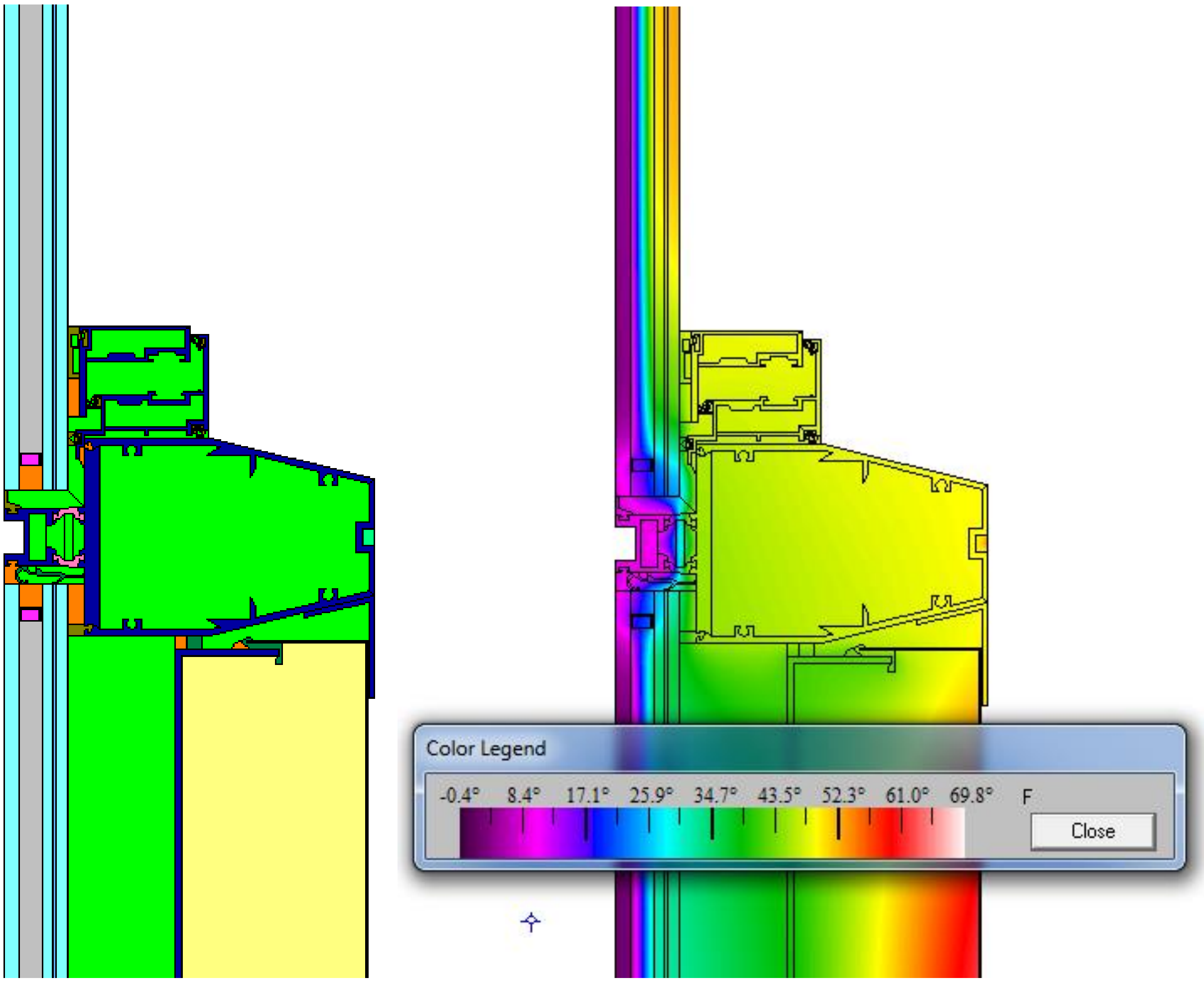

Figure 7: Mullion – Operable / Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.69 Btu/h.ft².F
Frame Projected Width	L_f = 6.70 in
Edge Effect Top Side	U_{e1} = 0.30 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.29 Btu/h.ft².F

5.3.5 Mullion – Vision / Spandrel

In the following, the THERM model is presented graphically

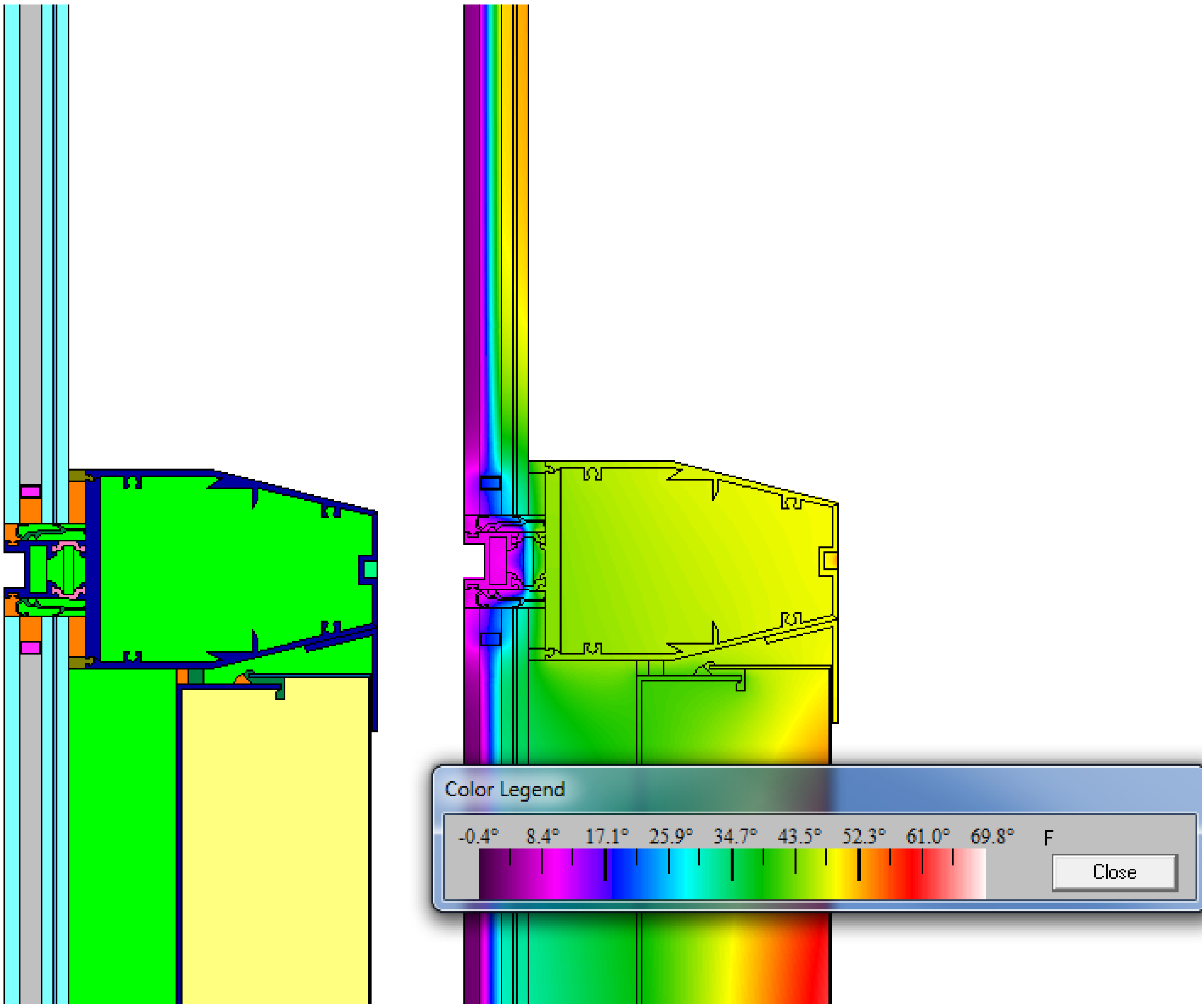

Figure 8: Mullion – Vision / Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.92 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.36 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.32 Btu/h.ft².F

5.3.6 Mullion – Spandrel / Spandrel

In the following, the THERM model is presented graphically

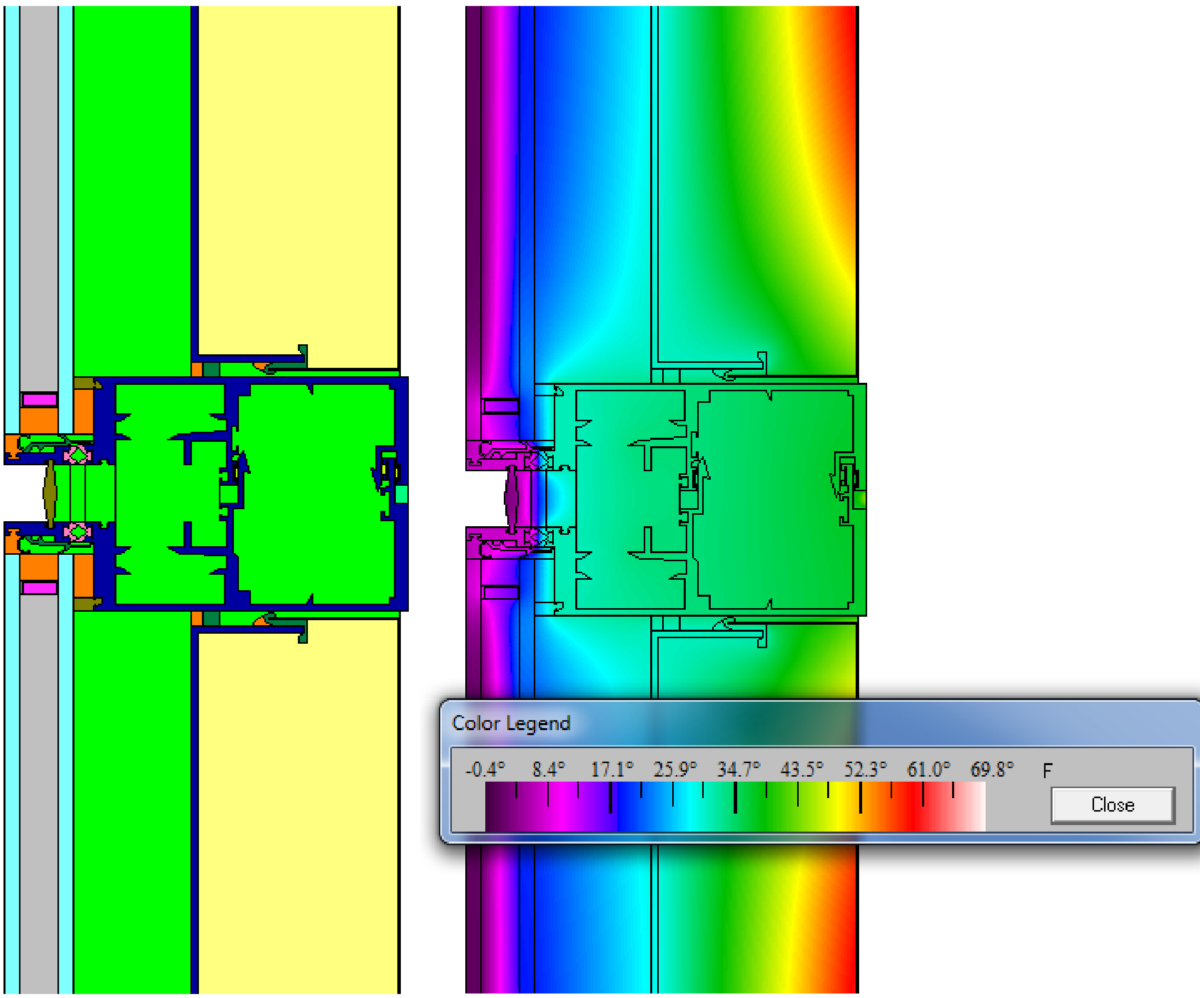

Figure 9: Mullion – Spandrel / Spandrel: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.63 Btu/h.ft².F
Frame Projected Width	L_f = 4.63 in
Edge Effect Top Side	U_{e1} = 0.24 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.24 Btu/h.ft².F

5.3.7 Stack Joint – Vision / Metal

In the following, the THERM model is presented graphically

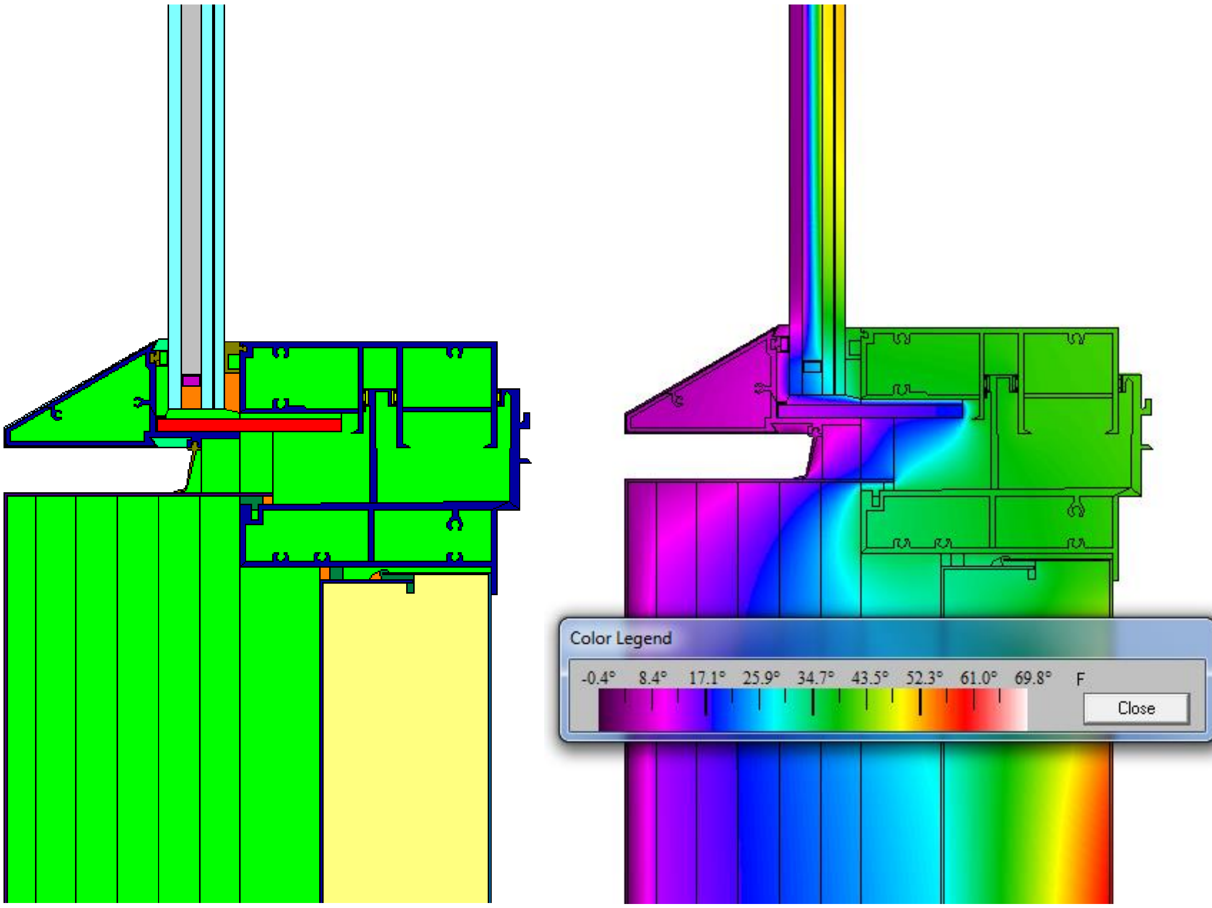

Figure 10: Stack Joint – Vision / Metal: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.28 Btu/h.ft².F
Frame Projected Width	L_f = 5.50 in
Edge Effect Top Side	U_{e1} = 0.33 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.36 Btu/h.ft².F

5.3.8 Stack Joint – Spandrel / Metal

In the following, the THERM model is presented graphically

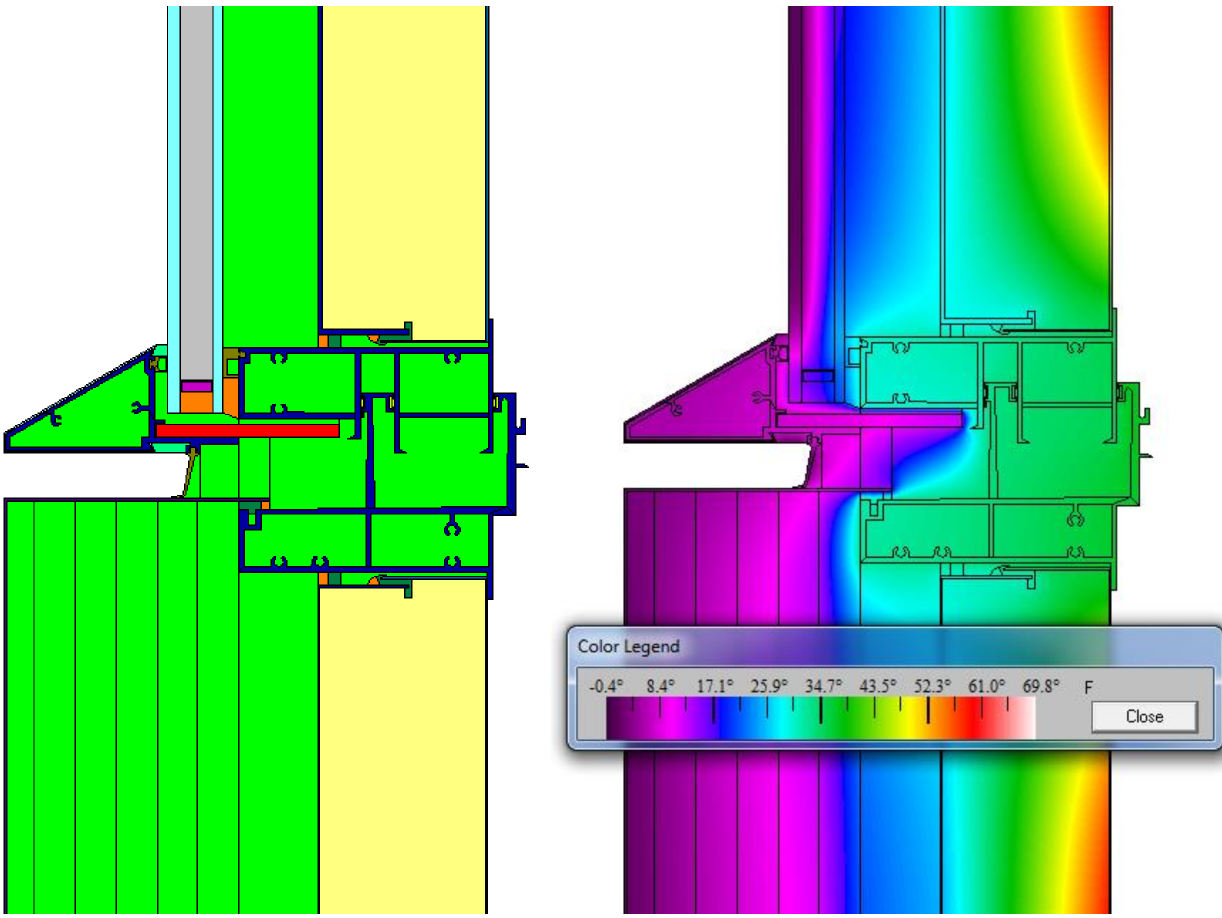

Figure 11: Stack Joint – Spandrel / Metal: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.78 Btu/h.ft².F
Frame Projected Width	L_f = 5.50 in
Edge Effect Top Side	U_{e1} = 0.42 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.41 Btu/h.ft².F

5.3.9 Transom – Metal / Operable

In the following, the THERM model is presented graphically

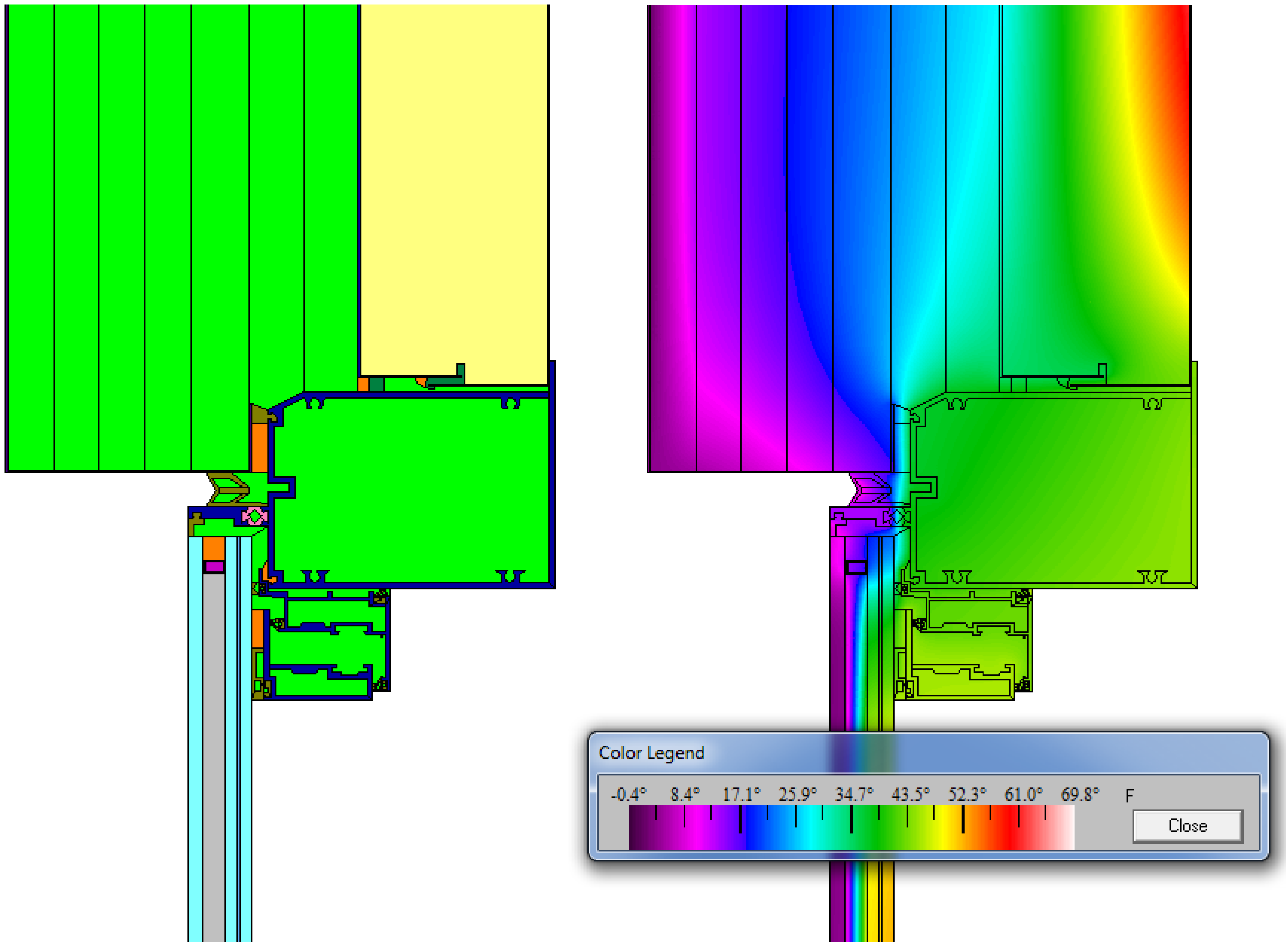

Figure 12: Transom – Metal / Operable: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.87 Btu/h.ft².F
Frame Projected Width	L_f = 6.70 in
Edge Effect Top Side	U_{e1} = 0.33 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.31 Btu/h.ft².F

5.3.10 Transom – Operable / Vision

In the following, the THERM model is presented graphically

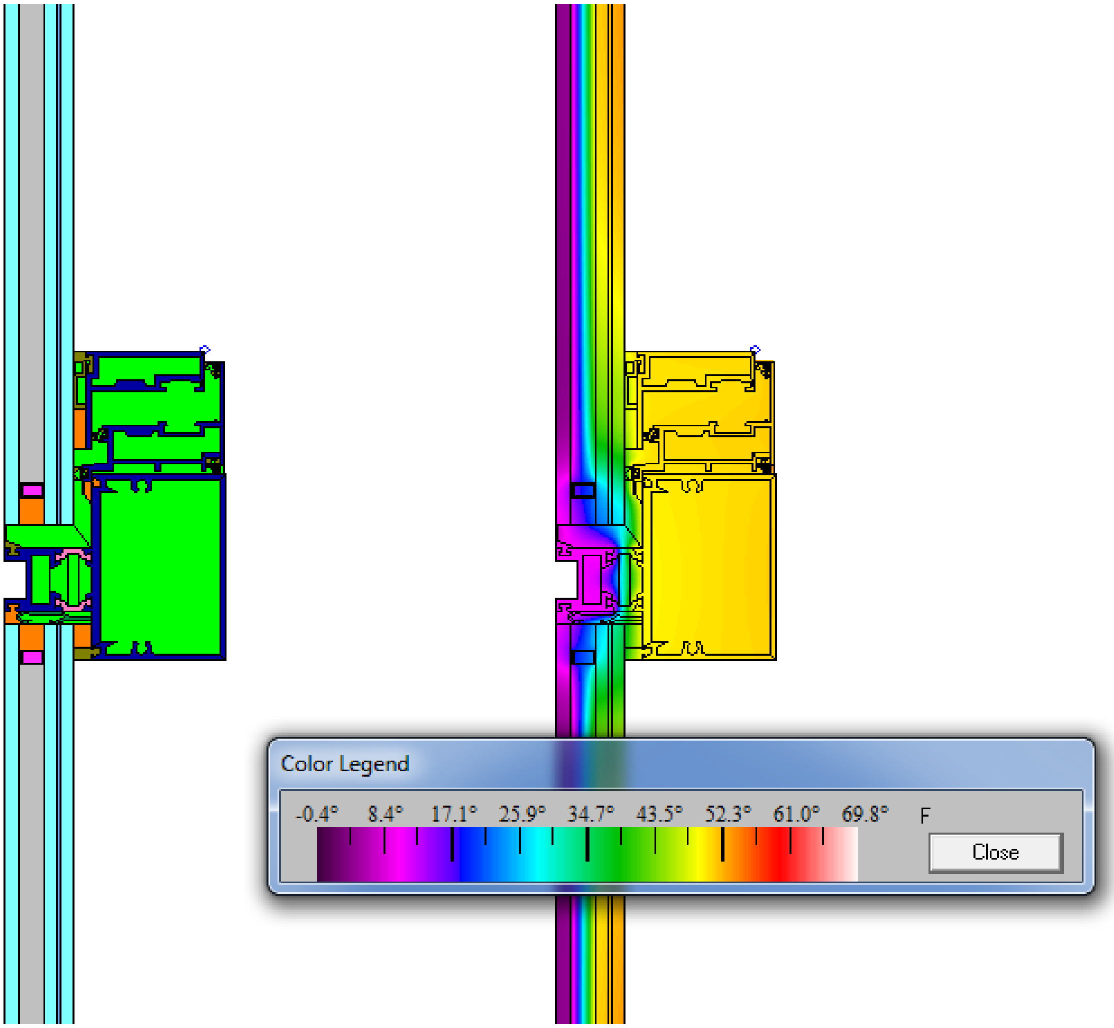

Figure 13: Transom – Operable / Vision: Model Geometry (Left) and Temperature Distribution (Right) (External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.66 Btu/h.ft².F
Frame Projected Width	L_f = 6.19 in
Edge Effect Top Side	U_{e1} = 0.30 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.40 Btu/h.ft².F

5.3.11 Transom – Metal / Spandrel

In the following, the THERM model is presented graphically

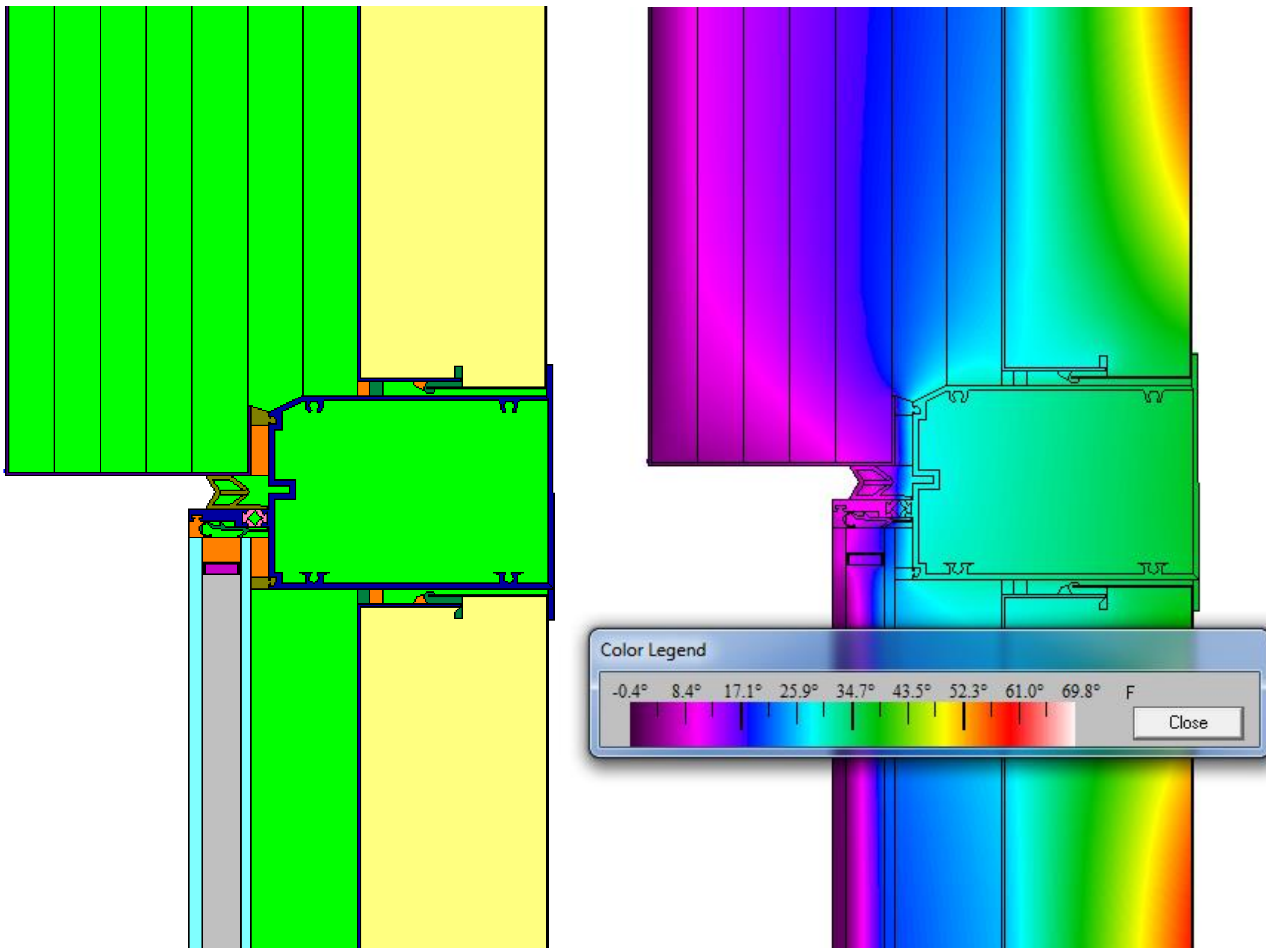

Figure 14: Transom – Metal / Spandrel: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 0.64 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.41 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.40 Btu/h.ft².F

3.3.1 Transom – Metal / Vision

In the following, the THERM model is presented graphically

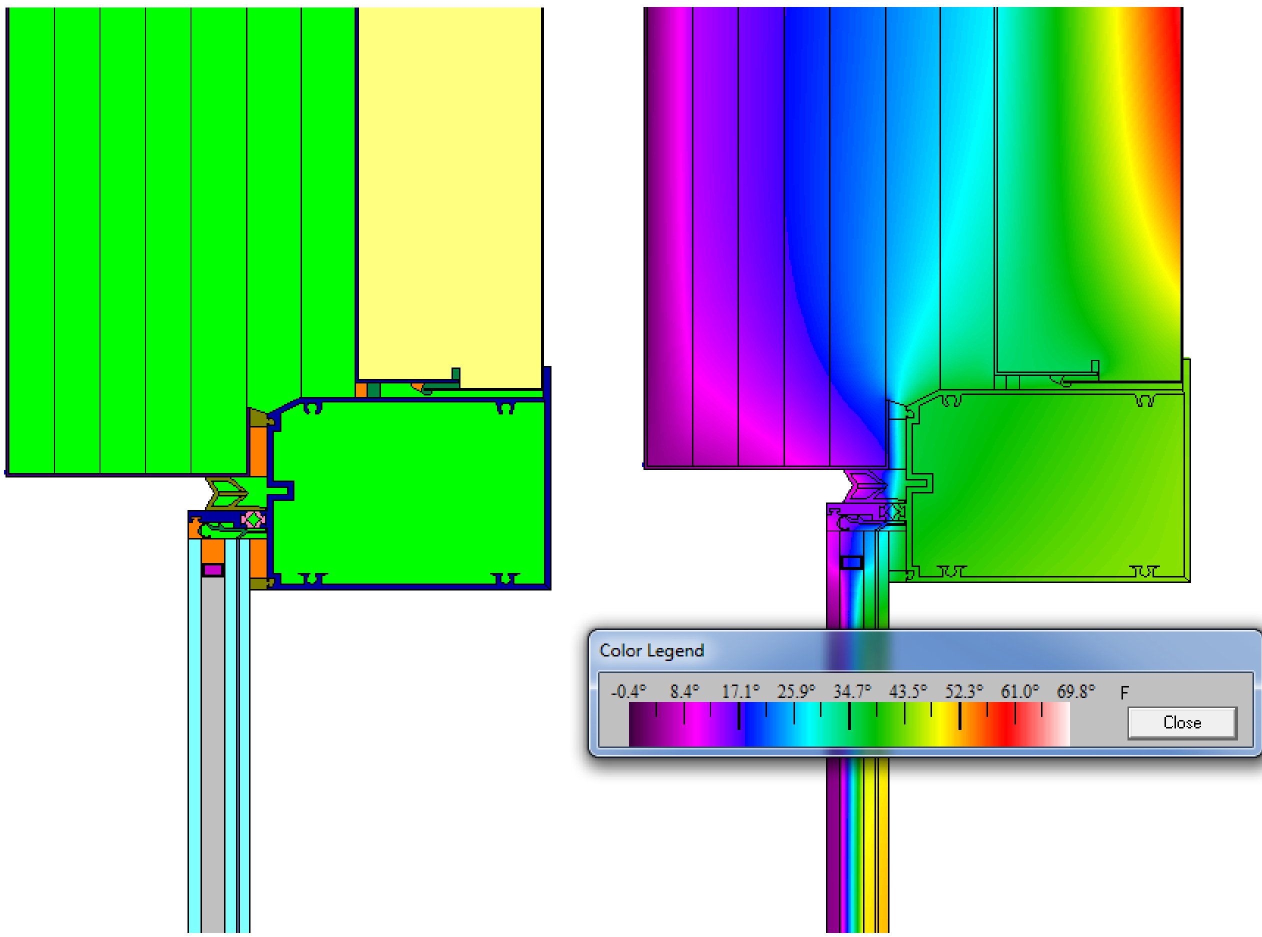

Figure 15: Transom – Metal / Vision: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.21 Btu/h.ft².F
Frame Projected Width	L_f = 4.25 in
Edge Effect Top Side	U_{e1} = 0.33 Btu/h.ft².F
Edge Effect Bottom Side	U_{e2} = 0.36 Btu/h.ft².F

5.4 Overall U-Value

Area weighting of the U-values of all frames, glass and panels is used to calculate the overall U-value for each wall type.

Component	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Metal/Metal	0.15	92.60	0.64	0.10
Left Edge Effect	0.15	23.75	0.16	0.02
Right Edge Effect	0.15	23.75	0.16	0.02
Mullion - Vision/Operable	0.80	714.00	4.96	3.97
Left Edge Effect	0.35	225.75	1.57	0.55
Right Edge Effect	0.29	225.75	1.57	0.45
Mullion - Vision/Vision	1.05	148.16	1.03	1.08
Left Edge Effect	0.35	52.03	0.36	0.13
Right Edge Effect	0.35	52.03	0.36	0.13
Mullion - Operable/Spandrel	0.69	683.40	4.75	3.27
Left Edge Effect	0.30	231.88	1.61	0.48
Right Edge Effect	0.29	231.88	1.61	0.47
Mullion - Vision/Spandrel	0.92	136.00	0.94	0.87
Left Edge Effect	0.36	67.50	0.47	0.17
Right Edge Effect	0.32	67.50	0.47	0.15
Mullion - Metal/Metal	0.15	92.60	0.64	0.10
Left Edge Effect	0.15	23.75	0.16	0.02
Right Edge Effect	0.15	23.75	0.16	0.02
Mullion - Spandrel/Spandrel	0.63	620.42	4.31	2.71
Left Edge Effect	0.24	311.88	2.17	0.52
Right Edge Effect	0.24	311.88	2.17	0.52
Stack Joint - Vision/Metal	1.28	304.54	2.11	2.71
Top Edge Effect	0.33	125.93	0.87	0.29
Bottom Edge Effect	0.36	125.93	0.87	0.31
Transom - Metal/Operable	0.87	154.10	1.07	0.93
Top Edge Effect	0.33	45.00	0.31	0.10
Bottom Edge Effect	0.31	45.00	0.31	0.10
Transom - Operable/Vision	0.66	157.04	1.09	0.72
Top Edge Effect	0.30	50.93	0.35	0.11
Bottom Edge Effect	0.40	50.93	0.35	0.14
Transom - Metal/Spandrel	0.64	99.03	0.69	0.44
Top Edge Effect	0.41	45.75	0.32	0.13
Bottom Edge Effect	0.40	45.75	0.32	0.13

Stack Joint - Spandrel/Metal	0.78	304.54	2.11	1.65
Top Edge Effect	0.42	125.93	0.87	0.37
Bottom Edge Effect	0.41	125.93	0.87	0.36
Transom - Metal/Spandrel	0.64	235.32	1.63	1.05
Top Edge Effect	0.41	125.93	0.87	0.36
Bottom Edge Effect	0.40	125.93	0.87	0.35
Vision Glass	0.28	2049.30	14.23	3.98
Spandrel Region	0.04	9777.01	67.90	2.72
Totals		18480.00	128.33	32.70
Overall U-Value	**0.25**	**[Btu/h.ft².F]**		

Table 5: Thermal Transmittance of Wall Type E

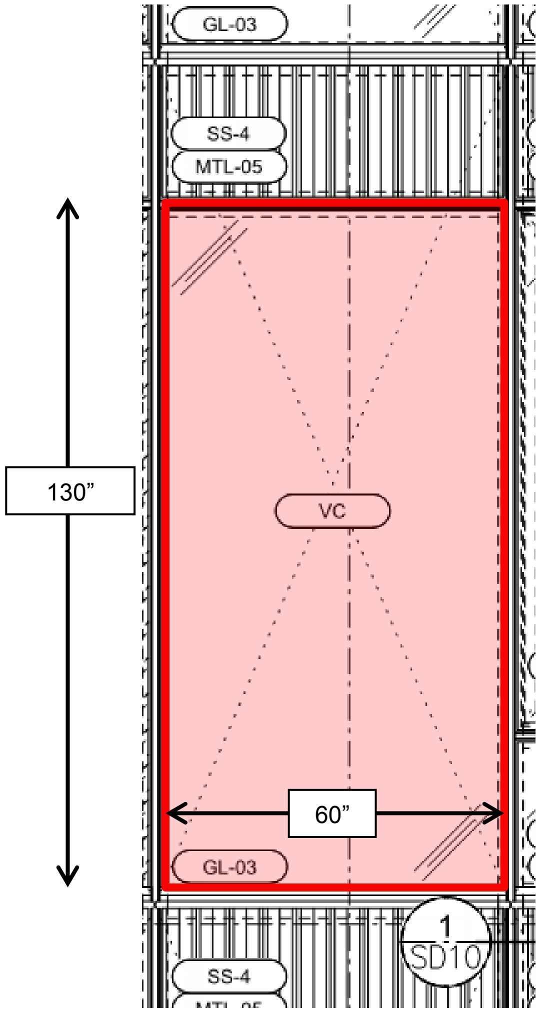

Figure 16: Typical Vision Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Vision	1.05	601.90	4.18	4.39
Left Section	0.35	308.13	2.14	0.75
Right Section	0.35	308.13	2.14	0.75
Transom - Metal / Vision	1.21	235.32	1.63	1.98
Top Section	0.33	132.18	0.92	0.30
Bottom Section	0.36	132.18	0.92	0.33
Glass Vision	0.28	6082.18	42.24	11.83
Totals		7800	54	20.32

Vision U-Value	0.38	[Btu/h.ft².F]

Table 6: Wall Type E Vision U-Value

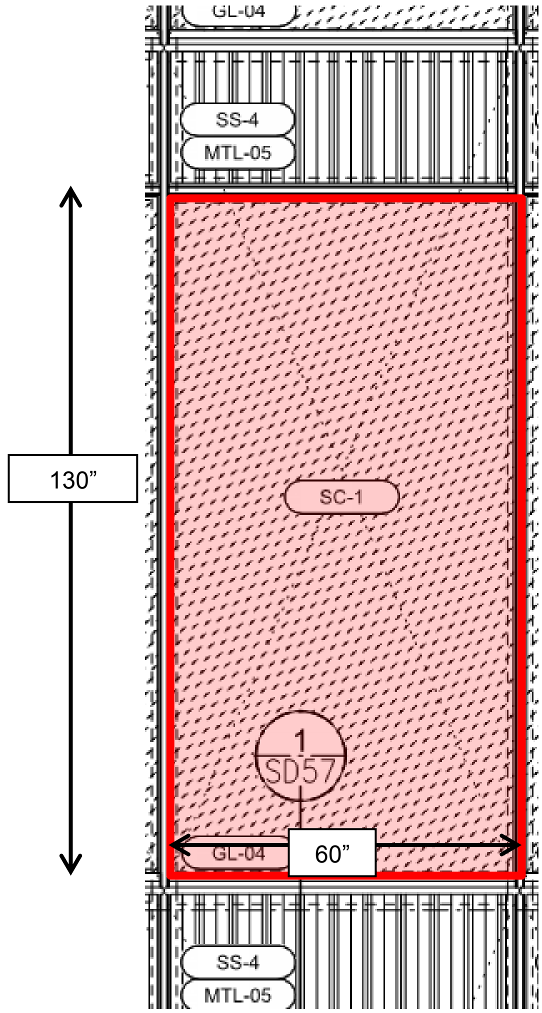

Figure 17: Typical Spandrel Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Spandrel / Spandrel	0.63	601.90	4.18	2.63
Left Section	0.24	308.13	2.14	0.51
Right Section	0.24	308.13	2.14	0.51
Transom - Metal / Spandrel	0.64	235.32	1.63	1.05
Top Section	0.41	132.18	0.92	0.38
Bottom Section	0.40	132.18	0.92	0.37
Glass Vision	0.04	6082.18	42.24	1.69
Totals		7800	54	7.14

Spandrel U-Value	0.13	[Btu/h.ft².F]

Table 7: Wall Type E Spandrel U-Value

6 CONDENSATION ASSESSMENT

The minimum internal surface temperature of the curtain wall has been assessed for each model using THERM 6.3 software using the specified Boundary Conditions. The absolute Minimum Temperature in the surface was found to be $t_{si,min}$=39.3°F on the Transom – Operable/Vision location of the façade (see following table).

Wall Type	Components	Dew Point Temperature (°F)	Minimum Surface Temperature (°F)	Maximum Allowed Relative Humidity (%)
Wall Type E	*Mullion – Metal/Metal*	39.1	49.8	52.1
	Mullion – Vision/Operable		41.5	38.0
	Mullion – Vision/Vision		41.6	38.2
	Mullion – Operable/Spandrel		47.2	47.3
	Mullion – Vision/Spandrel		41.1	37.4
	Mullion – Spandrel/Spandrel		40.1	36.0
	Stack Joint – Vision/Metal		40.1	36.0
	Stack Joint – Spandrel/Metal		39.6	35.3
	Transom – Metal/Operable		43.6	41.2
	Transom – Operable/Vision		39.3	35.1
	Transom – Metal/Spandrel		41.5	38.0
	Transom – Metal/Vision		40.3	36.3

Table 8: Condensation Assessment for Typical Details

With internal temperature of 68°F and Relative Humidity of 35% RH the Dew Point Temperature is 39.1°F. For the given Boundary Conditions, condensation will not occur on the interior surface of the façade and the performance is acceptable. Following THERM models of some critical sections are presented along with the Dew Point Isothermal Line as well as a temperature distribution for the specified Boundary Conditions.

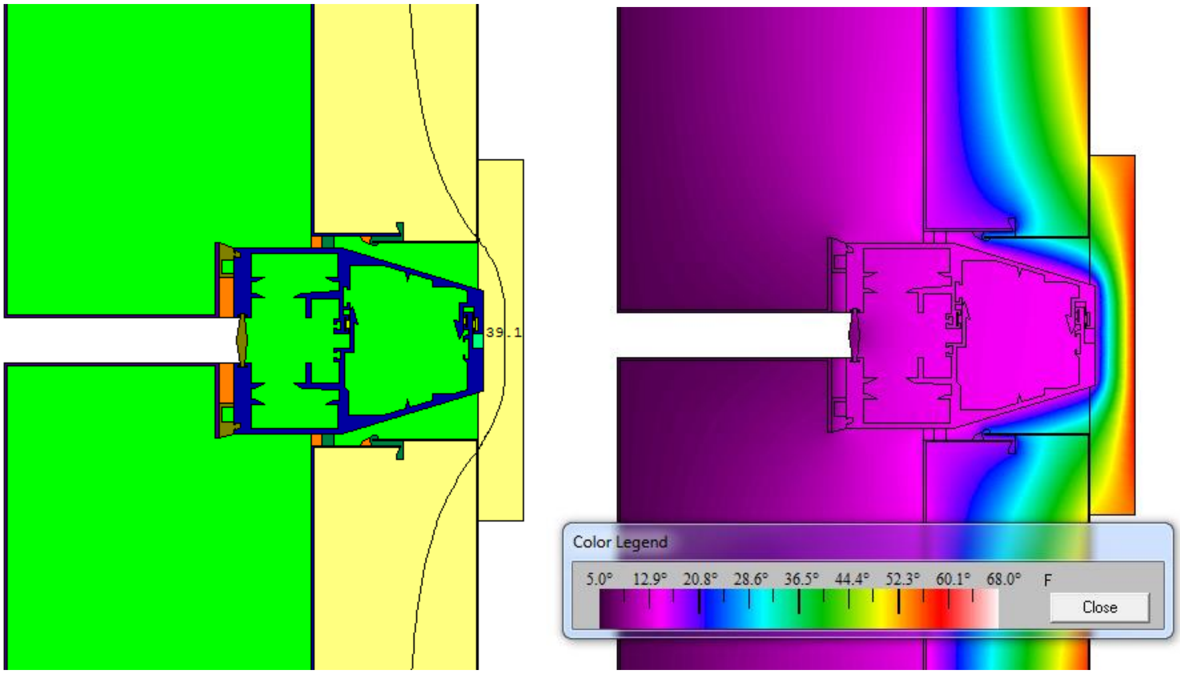

Figure 18: Mullion – Metal/Metal: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right)
(External Temperature 5°F - Internal Temperature 68°F)

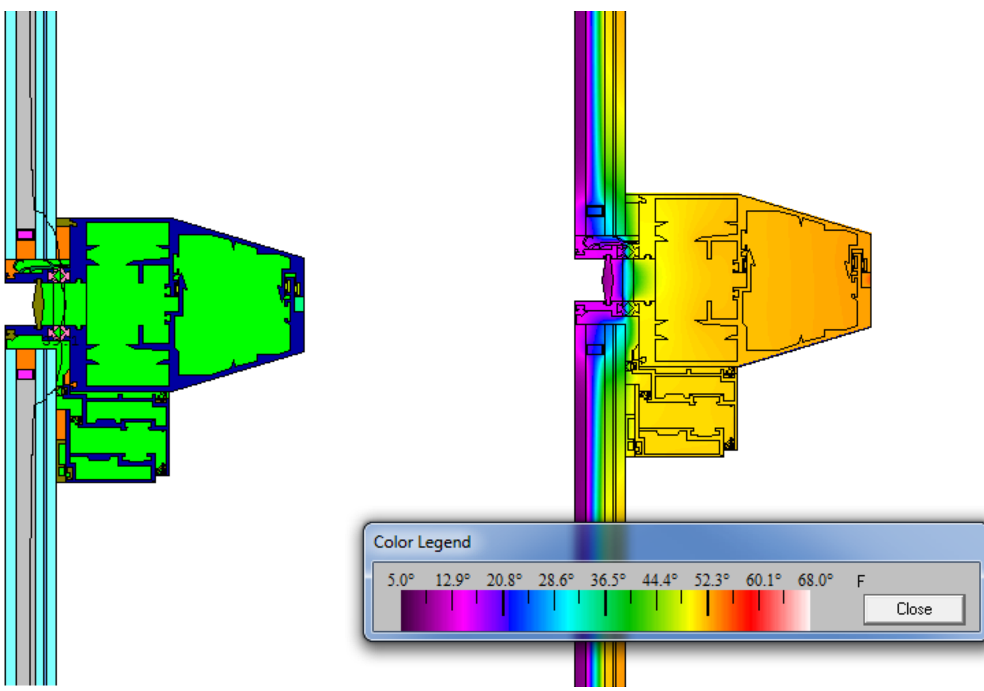

Figure 19: Mullion – Vision/Operable: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right)
(External Temperature 5°F - Internal Temperature 68°F)

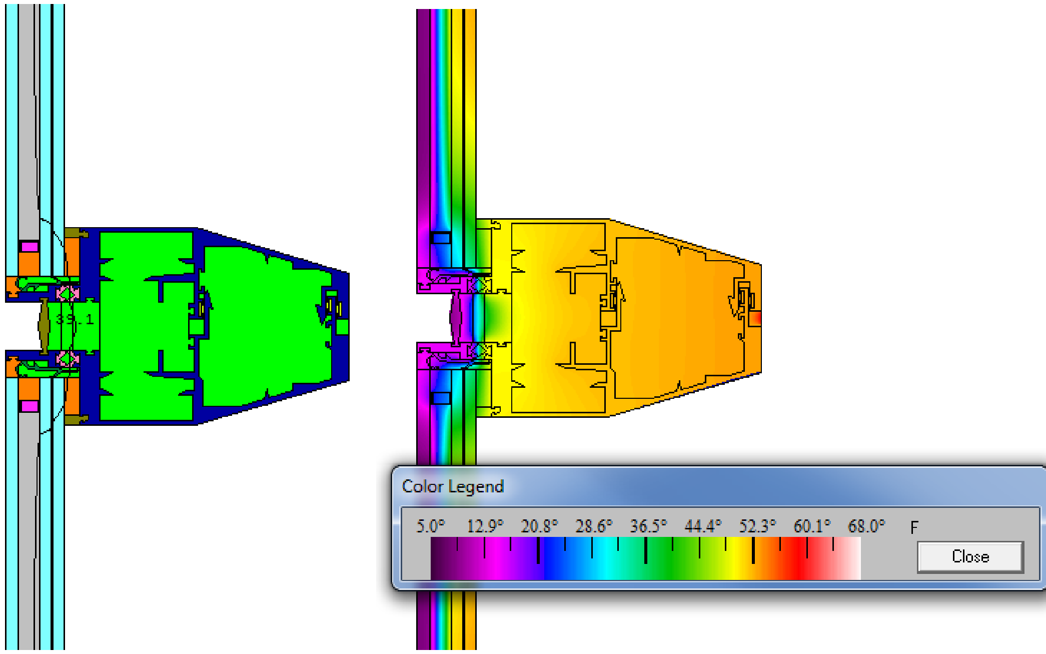

Figure 20: Mullion – Vision/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

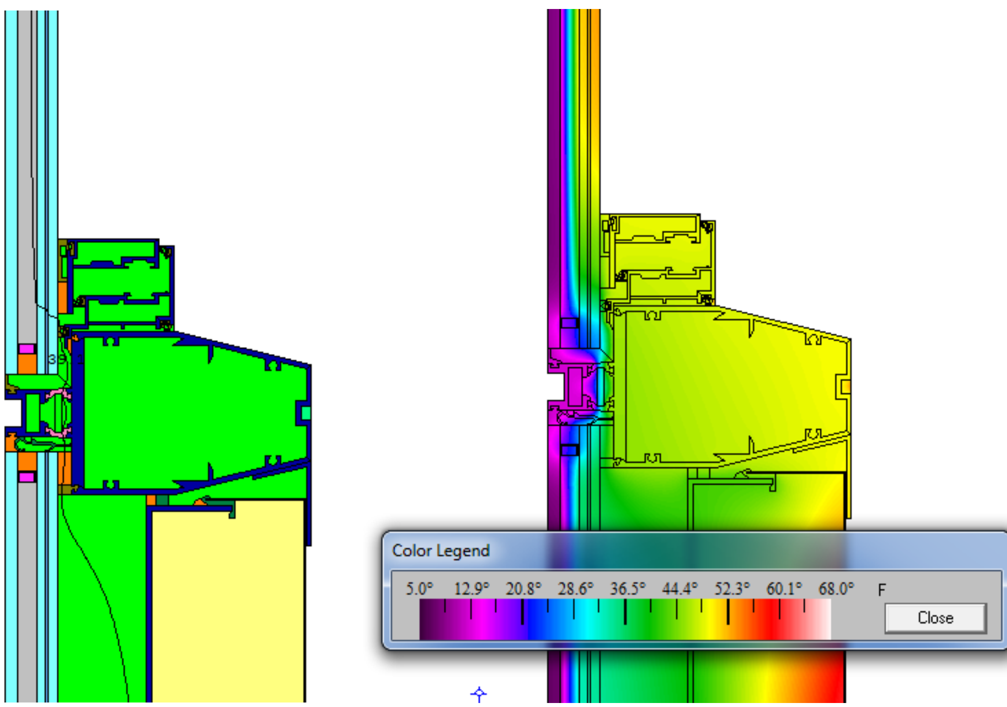

Figure 21: Mullion – Operable/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

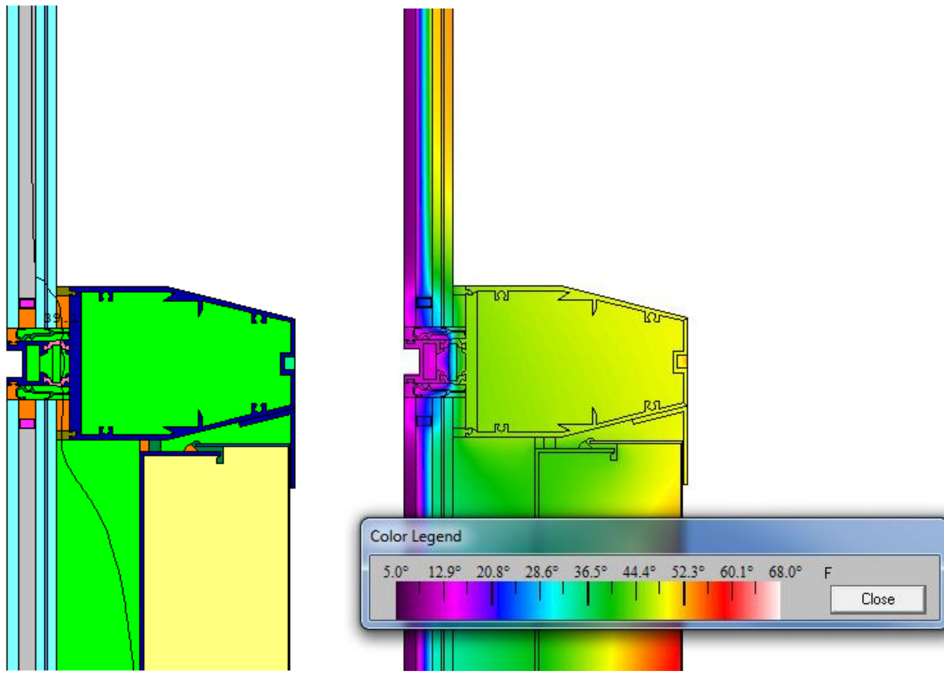

Figure 22: Mullion – Vision/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

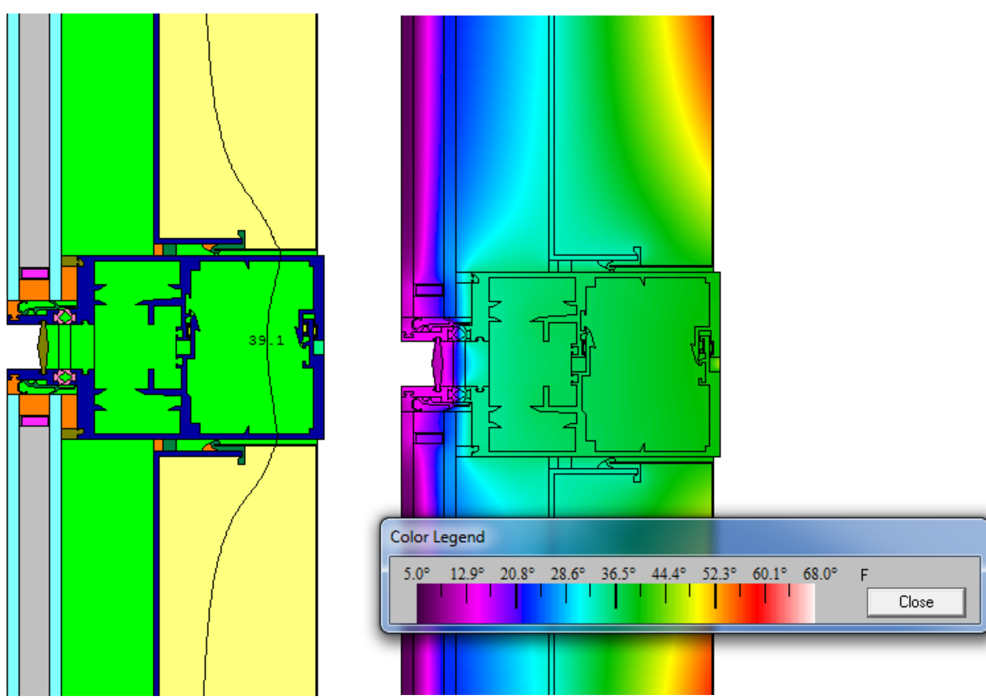

Figure 23: Mullion – Spandrel/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

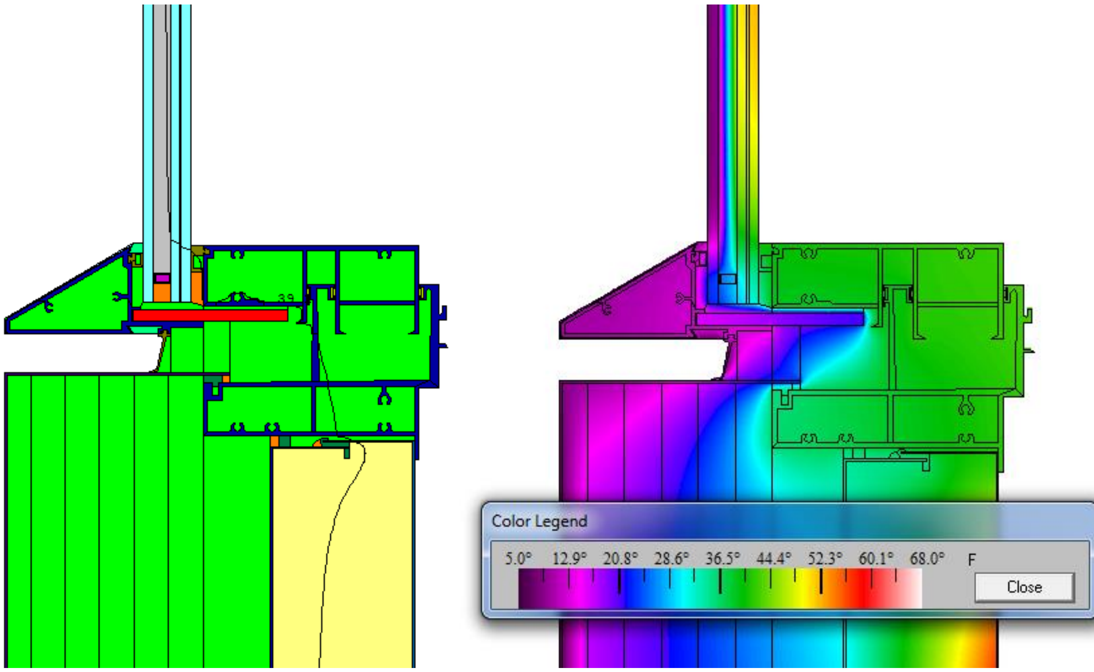

Figure 24: Stack Joint – Vision/Metal: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

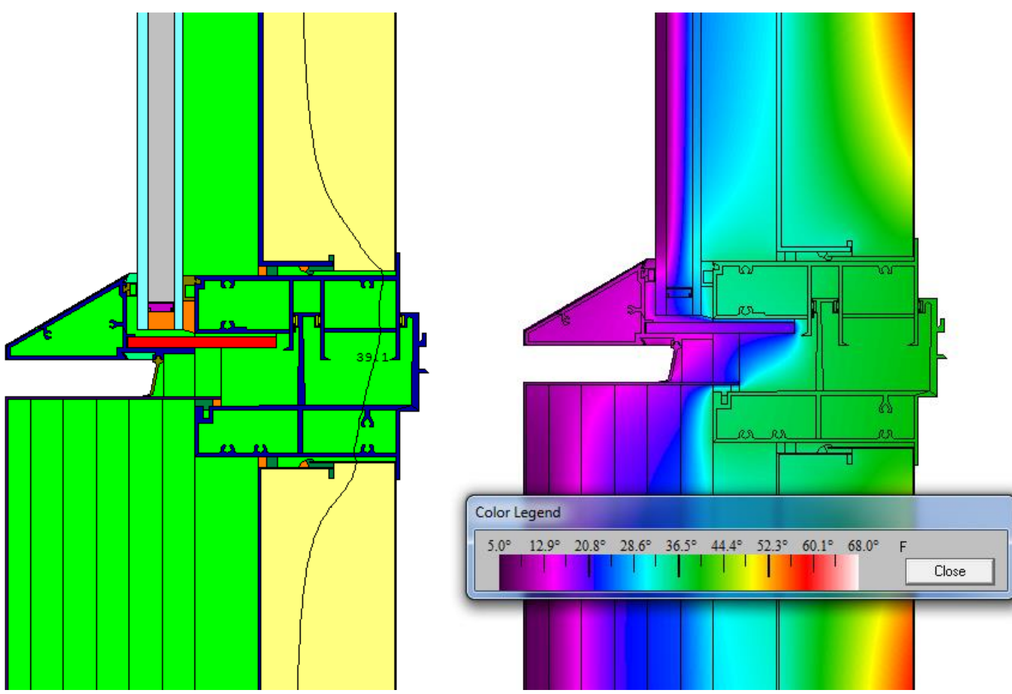

Figure 25: Stack Joint – Spandrel/Metal: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

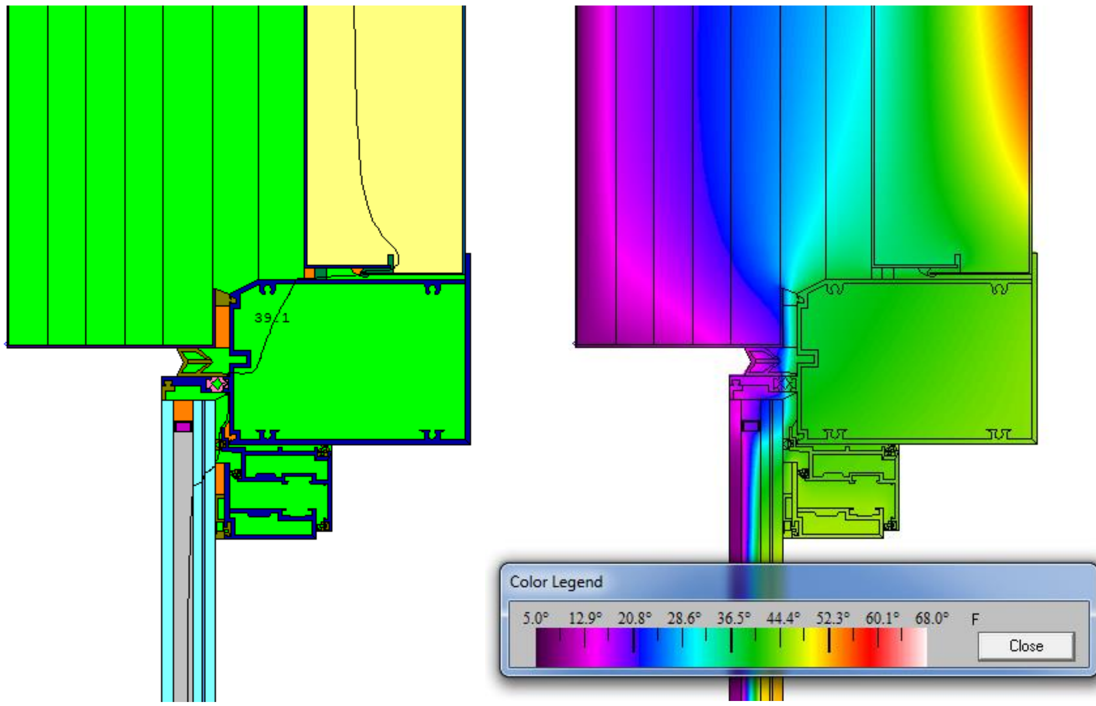

Figure 26: Transom – Metal/Operable: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

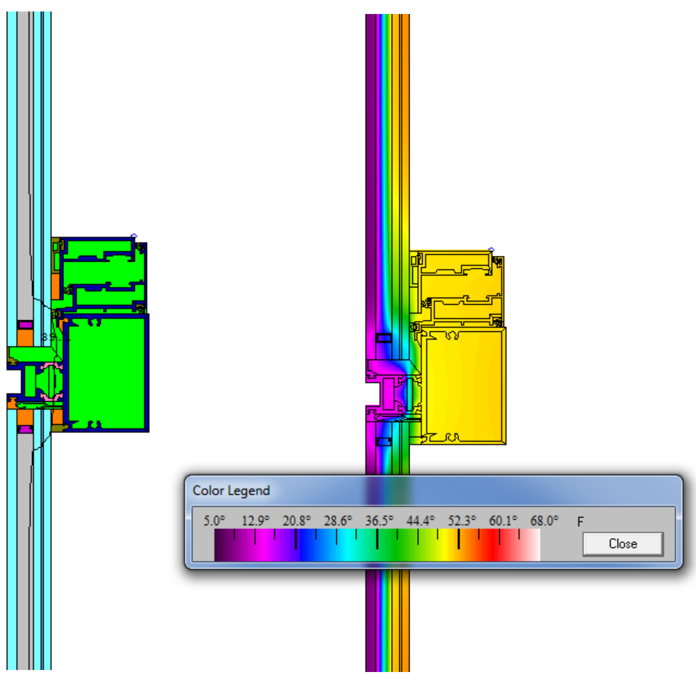

Figure 27: Transom – Operable/Vision: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right) (External Temperature 5°F - Internal Temperature 68°F)

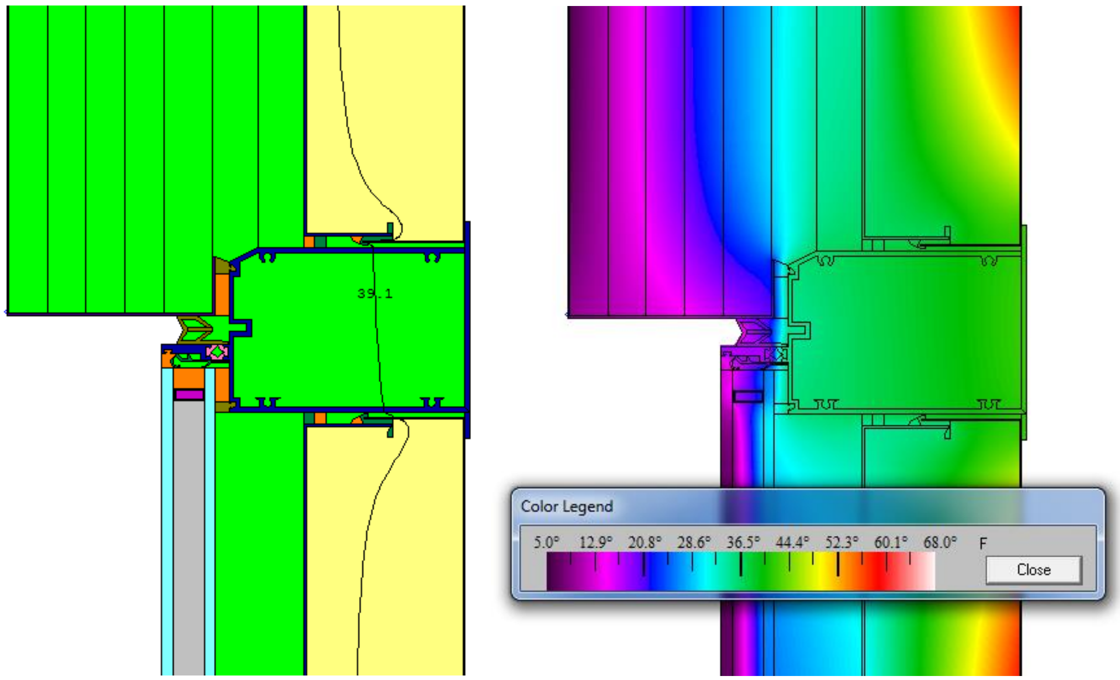

Figure 28: Transom – Metal/Spandrel: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right)

(External Temperature 5°F - Internal Temperature 68°F)

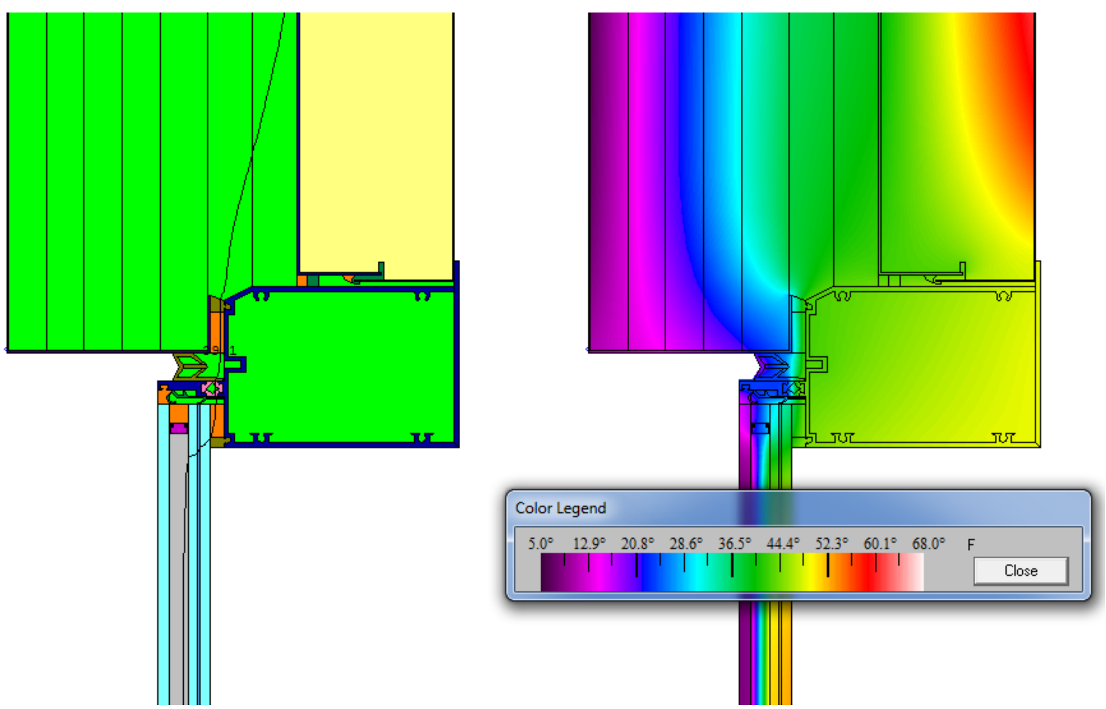

Figure 29: Transom – Metal/Vison: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right)

(External Temperature 5°F - Internal Temperature 68°F)

7 REFERENCES

ASHRAE	ASHRAE Handbook of Fundamentals 1998-2001, American Society of Heating, Refrigerating, and Air-Conditioning Engineering, Atlanta, GA, USA, 2004.
ISO 6946: 2007	Building components and building elements - Thermal resistance and thermal transmittance - Calculation method
ISO 10077-1: 2006	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General
ISO 10077-2: 2003	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames
ISO 10211: 2007	Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations
ISO 13788:2001	Hydrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods
ISO 15099: 2003	Thermal performance of windows, doors and shading devices - Detailed calculations
NFRC 100: 2010	Procedure for Determining Fenestration Product U-Factors.
NFRC 200: 2010	Procedure for Determining Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence
NFRC 300: 2010	Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems
THERM	THERM 6.3 Program description. Windows and Daylighting Group. Lawrence Berkeley National Laboratory, 2002.

Submittal Transmittal

Detailed, Grouped by Each Number

217 West 57th Street | **Project # 11668500** | **Lend Lease (US) Construction LMB Inc.**
200 Park Avenue, 9th Floor | Tel: 212.592.6700 Fax:
New York, NY 10166

Date: 4/23/2015 **Reference Number: 0262**

Transmitted To:	Joe Welker James Carpenter Design 145 Hudson Street New York, NY 10013 Tel: 212-431-4318	**Transmitted By:**	Alexa DiBuono Lend Lease (US) Construction LMB Inc. 200 Park Avenue 9th Floor New York, NY 10166 Tel: 212-592-6700 Fax: 212-592-6988

Qty	Submittal Package No	Description	Due Date	Package Action
26	0024 - 08 44 13 - 0	PNA Retail: Bent Glass Energy Performance Report	5/14/2015	

Transmitted For	Delivered Via	Tracking Number
For Approval	Prolog Converge	

Items	Qty	Description	Notes	Item Action
0001		Podium Radiation and Shading Analysis		

Cc:	Company Name	Contact Name	Copies	Notes

Remarks

Priority: HIGH

JOB NO: 14.04 SUBMISSION NO: 1

CORRECTIONS OR COMMENTS MADE ON THE SHOP DRAWINGS DURING THIS REVIEW DO NOT RELIEVE CONTRACTOR FROM COMPLIANCE WITH REQUIREMENTS OF THE DRAWINGS AND SPECIFICATIONS. THIS CHECK IS ONLY FOR REVIEW OF GENERAL CONFORMANCE WITH THE DESIGN CONCEPT OF THE PROJECT AND GENERAL COMPLIANCE WITH THE INFORMATION GIVEN IN THE CONTRACT DOCUMENTS. THE CONTRACTOR IS RESPONSIBLE FOR CONFIRMING AND CORRELATING ALL QUANTITIES AND DIMENSIONING, SELECTING FABRICATION PROCESSES AND TECHNIQUES OF CONSTRUCTION, COORDINATING HIS WORK WITH THAT OF ALL OTHER TRADES, AND PERFORMING HIS WORK IN A SAFE AND SATISFACTORY MANNER.

	APPROVED
X	APPROVED AS NOTED. ~~RESUBMIT FOR RECORD~~
	REVISE AND RESUBMIT
	REJECTED

CHECKED BY: JRW DATE: Apr 27, 2015

JAMES CARPENTER DESIGN ASSOCIATES
145 HUDSON STREET 4TH FLOOR NEW YORK, NEW YORK 10013
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40 Worth Street
New York, NY 10013
212. 757. 5659

- REVIEWED FOR TECHNICAL MERIT ONLY
- NOT REVIEWED FOR QUANTITIES OR DIMENSIONAL ACCURACY

REVIEWED ☑ NOT REVIEWED ☐

REVIEWED BY: MSF

REVIEW DATE: 5/04/15

Signature **Signed Date**

PERMASTEELISA NORTH AMERICA

217 West 57th Street

Project 865
New York, NY

Podium Radiation and Shading Analysis

DOC NAME: 90918 TC 004-00-150421 JH

Rev.	Date	Description	Prepared by	Checked by
02				
01				
00	04/21/2015	First Submission	JH	AF

TABLE OF CONTENTS

1 SUMMARY

Analysis has been requested for the 217 West 57th Street (Hardrock) podium in New York, New York. The analyzed double glazing unit consists of an external laminated low iron annealed glass with gray frit dots (25% coverage) on surface # 1 and an internal laminated low iron annealed glass. Datasheets containing all thermal performance and optical properties from each vendor can be seen in Figures 1 – 3.

To prove annealed glass will be sufficient, an investigation of the project site's weather data was initially carried out. The exterior air temperature as well as the solar radiation on the vertical plane was analyzed for the north, south, east, and west elevations. The north elevation was mostly ignored due to its low radiation levels. This weather data was applied to an Ecotect model to visualize the potential radiation acting on the podium. Surrounding infrastructure was also taken into consideration to better understand the effects of shadows.

As a result, a substantial portion of the podium will be fully shaded and locations will experience low radiation levels compared to the tower.

2 GLAZING SYSTEM

Refer to below figures from Cricursa and SunGlass showing thermal performance and optical properties. The solar heat gain coefficient (SHGC) is highlighted within datasheet.

JCDA: PROVIDE 25% FRIT, GREY (RAL 7045)

GUARDIAN | PERFORMANCE CALCULATOR

April 22, 2015
By Imaz, Juan
jimaz@guardian.com

NORDSTROM

Make-up Name	Make-up Icon	Outboard Substrate & Coating	Transmittance: Visible (τ_v %)	Transmittance: UV (τ_{uv} %)	Transmittance: Solar (τ_e %)	Reflectance: Visible ρ_v % out	Reflectance: Visible ρ_v % in	Reflectance: Solar ρ_e % out	U-Value Winter Night	Shading Coefficient (sc)	Solar Heat Gain Coefficient (SHGC)	Color Rendering Index (R_a)
C-02		Gray Frit 25% Dots on Float Ultra Clear (Europe)	67	0	59	14	11	13	5.14	0.77	0.67	99
Default Make-up 01	C*	Gray Frit 25% Dots on Float Ultra Clear (Europe)	60	0	50	18	17	16	2.46	0.66	0.58	98

Calculation Standard: NFRC 2010

SUBMIT GL-53, GL-54 PERFORMANCE DATA FOR ENERGY MODEL UPDATE

C-02

Outdoors

LITE	Float Ultra Clear (Europe) Thickness = 10mm	#1 Gray Frit 25% Dots #2 -----
PVB	PVB Clear 1.52mm	
LITE	Float Ultra Clear (Europe) Thickness = 10mm	#3 ----- #4 -----
	Total Unit = 0.847 in / 21.524 mm	Slope = 90°

Indoors

Surface #1: Frits cannot be applied to the outermost surface of a makeup.

JCDA: PNA TO PROVIDE NOTIFICATION IF FRIT ON #1 SURFACE IS NOT FEASIBLE

Default Make-up 01

Outdoors

LITE	Float Ultra Clear (Europe) Thickness = 8mm	#1 Gray Frit 25% Dots #2 -----
PVB	PVB Clear 1.52mm	
LITE	Float Ultra Clear (Europe) Thickness = 8mm	#3 ----- #4 -----
GAP	100% Air, 12mm (.472")	
LITE	Float Ultra Clear (Europe) Thickness = 8mm	#5 ----- #6 -----
PVB	PVB Clear 1.52mm	
LITE	Float Ultra Clear (Europe) Thickness = 8mm	#7 ----- #8 -----
	Total Unit = 1.852 in / 47.048 mm	Slope = 90°

Indoors

Surface #1: Frits cannot be applied to the outermost surface of a makeup.

AJLP
Confirm this is for the purposes of modeling only; not fabrication issue, typ.

Figure 1: Performance Datasheet with Grey Frit (Cricursa)

GUARDIAN | PERFORMANCE CALCULATOR

April 14, 2015 Prepared for Michela Marangon
By Tran, Tuan
ttran@guardian.com 315-787-7110

Hard Rock Podium Glazing - Gray Frit

Make-up Name	Outboard Substrate & Coating	Inboard Substrate & Coating	Transmittance			Reflectance			U-Value		Relative Heat Gain (RHG)	Shading Coefficient (sc)	Solar Heat Gain Coefficient (SHGC)	Light To Solar Gain (LSG)
			Visible ($τ_v$ %)	UV ($τ_{uv}$ %)	Solar ($τ_s$ %)	Visible $ρ_v$ % out	Visible $ρ_v$ % in	Solar $ρ_s$ % out	Winter Night	Summer Day				
GL-51	Gray Frit 30% Dots on Float Ultra Clear (Europe)	Float Ultra Clear (Europe)	56	0	46	19	17	17	0.43	0.45	132	0.63	0.55	1.02
GL-52	Gray Frit 20% Dots on Float Ultra Clear (Europe)	Float Ultra Clear (Europe)	70	0	62	13	11	12	0.90	0.83	171	0.80	0.69	1.02

Calculation Standard: NFRC 2010

GL-51

Outdoors

LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#1 Gray Frit 30% Dots #2 -----
PVB	0.060" (1.52mm) Saflex® RB71 Clear PVB	
LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#3 ----- #4 -----
GAP	100% Air, 1/2" = 12.7 mm	
LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#5 ----- #6 -----
PVB	0.060" (1.52mm) Saflex® RB71 Clear PVB	
LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#7 ----- #8 -----
	Total Unit = 1.88 in / 47.748 mm	Slope = 90°

Indoors

Surface #1: Frits cannot be applied to the outermost surface of a makeup.

GL-52

Outdoors

LITE	Float Ultra Clear (Europe) Thickness = 3/8" = 10mm	#1 Gray Frit 20% Dots #2 -----
PVB	0.060" (1.52mm) Saflex® RB71 Clear PVB	
LITE	Float Ultra Clear (Europe) Thickness = 3/8" = 10mm	#3 ----- #4 -----
	Total Unit = 0.847 in / 21.524 mm	Slope = 90°

Indoors

Surface #1: Frits cannot be applied to the outermost surface of a makeup.

Figure 2: Performance Datasheet with Grey Frit (SunGlass)

GUARDIAN | PERFORMANCE CALCULATOR

April 20, 2015 Prepared for Michela Marangon
By Tran, Tuan
ttran@guardian.com 315-787-7110

Hard Rock Podium Glazing - Warm Gray Frit

Make-up Name	Outboard Substrate & Coating	Inboard Substrate & Coating	Transmittance			Reflectance			U-Value		Relative Heat Gain (RHG)	Shading Coefficient (sc)	Solar Heat Gain Coefficient (SHGC)	Light To Solar Gain (LSG)
			Visible (τ_v %)	UV (τ_{uv} %)	Solar (τ_s %)	Visible ρ_v % out	Visible ρ_v % in	Solar ρ_s % out	Winter Night	Summer Day				
GL-51	Warm Gray Frit 30% Dots on Float Ultra Clear (Europe)	Float Ultra Clear (Europe)	55	0	45	18	17	17	0.43	0.45	130	0.62	0.54	1.01
GL-52	Warm Gray Frit 20% Dots on Float Ultra Clear (Europe)	Float Ultra Clear (Europe)	70	0	61	13	10	12	0.90	0.83	170	0.79	0.69	1.02

Calculation Standard: NFRC 2010

GL-51

Outdoors

LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#1 Warm Gray Frit 30% Dots #2 -----
PVB	0.060" (1.52mm) Saflex® RB71 Clear PVB	
LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#3 ----- #4 -----
GAP	100% Air, 1/2" = 12.7 mm	
LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#5 ----- #6 -----
PVB	0.060" (1.52mm) Saflex® RB71 Clear PVB	
LITE	Float Ultra Clear (Europe) Thickness = 5/16" = 8mm	#7 ----- #8 -----
	Total Unit = 1.88 in / 47.748 mm	Slope = 90°

Indoors

Surface #1: Frits cannot be applied to the outermost surface of a makeup.

GL-52

Outdoors

LITE	Float Ultra Clear (Europe) Thickness = 3/8" = 10mm	#1 Warm Gray Frit 20% Dots #2 -----
PVB	0.060" (1.52mm) Saflex® RB71 Clear PVB	
LITE	Float Ultra Clear (Europe) Thickness = 3/8" = 10mm	#3 ----- #4 -----
	Total Unit = 0.847 in / 21.524 mm	Slope = 90°

Indoors

Surface #1: Frits cannot be applied to the outermost surface of a makeup.

Figure 3: Performance Datasheet with Warm Grey Frit (SunGlass)

3 WEATHER DATA

The Global Meteorological Database Meteonorm v4.0 software provides hourly external temperatures and global radiation. Peak values for solar radiation were found during each season. Temperature data was derived for New York City, New York. Results are shown below:

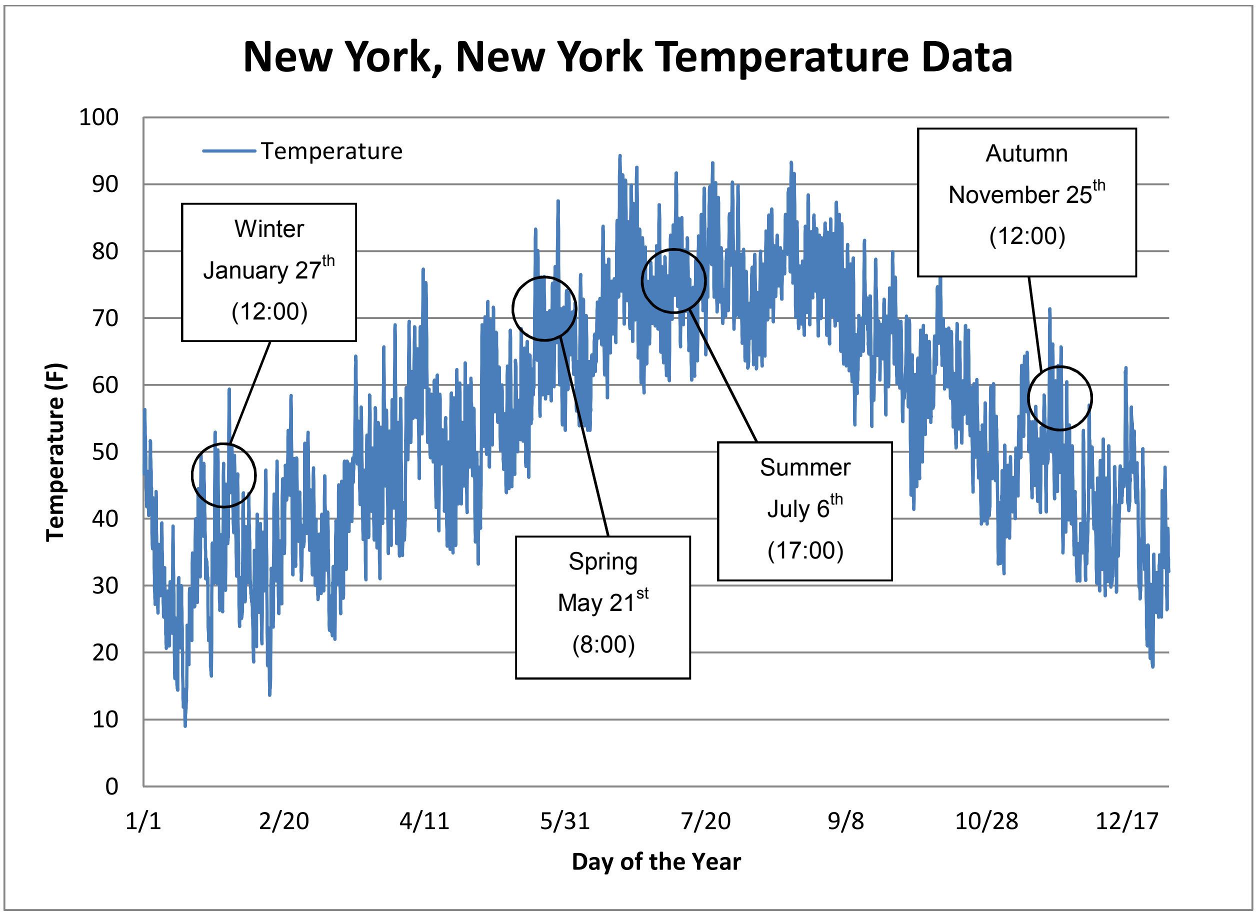

Figure 4: New York, New York Temperature Data

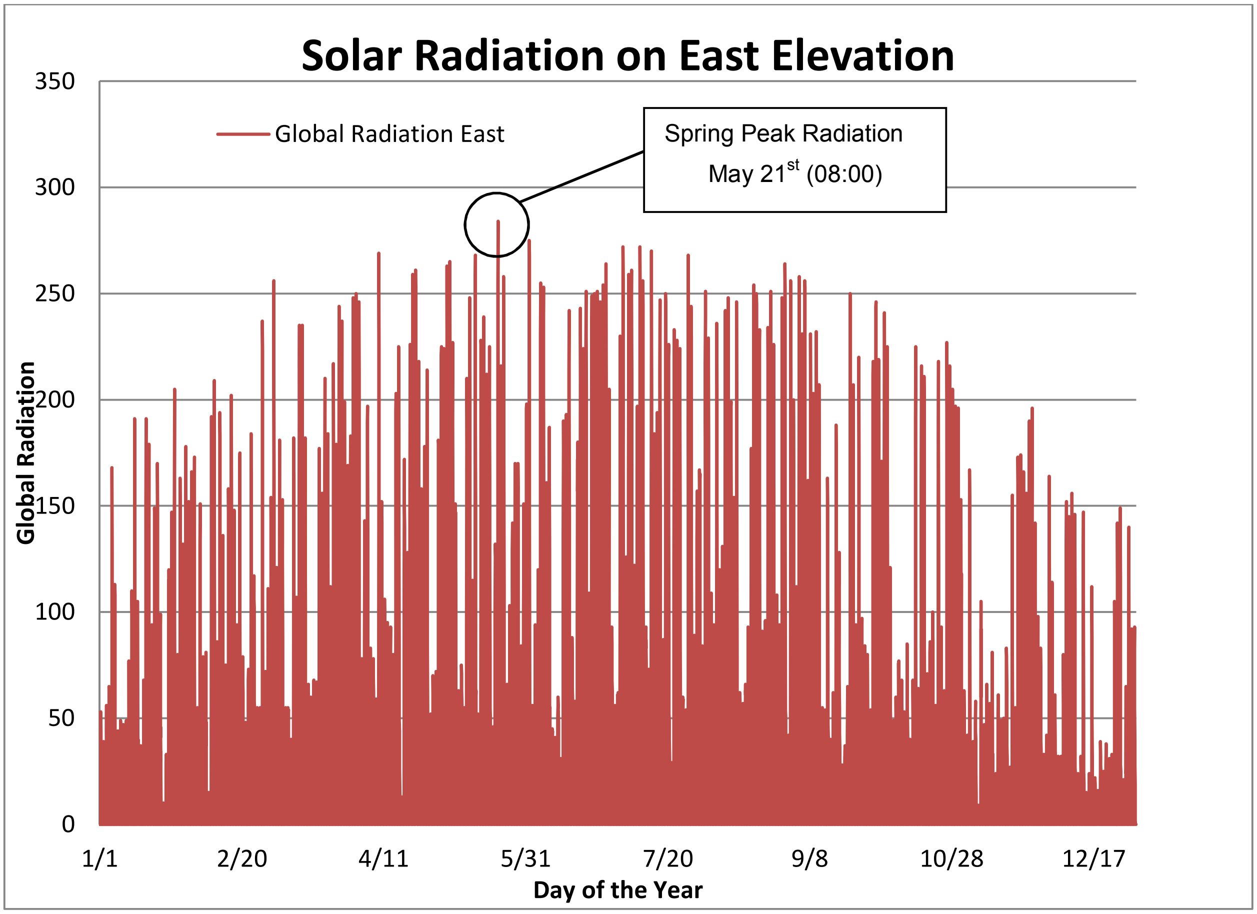

Figure 5: Solar Radiation on East Elevation

Spring Maximum Global Radiation:

Date	May 21st (08:00)
External Temperature	71.2 F (21.78 C)
Maximum Global Radiation	284 Btu/h/ft^2 (895 W/m^2.K)

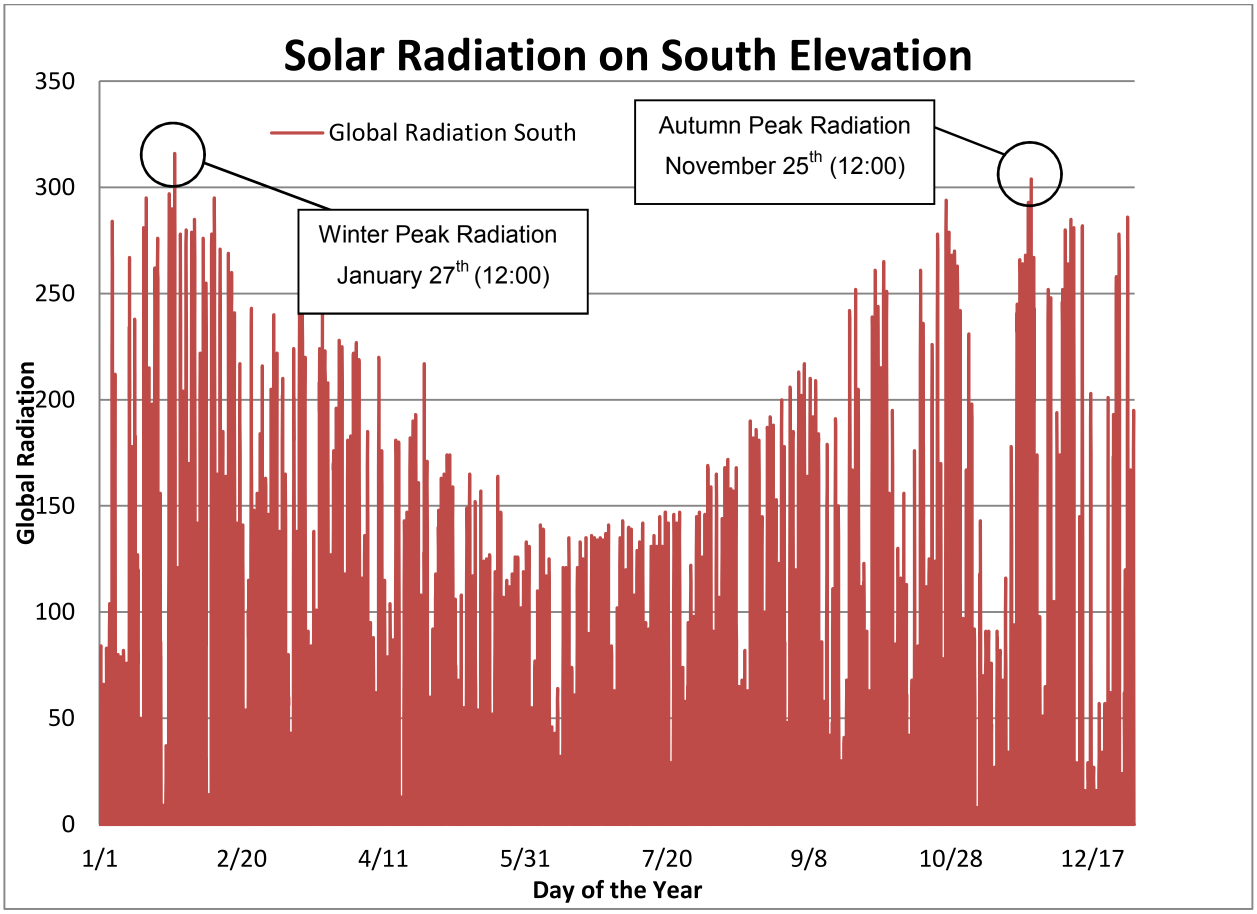

Figure 6: Solar Radiation on South Elevation

Winter Maximum Global Radiation:

Date	January 27th (12:00)
External Temperature	47.3 F (8.50 C)
Maximum Global Radiation	316 Btu/h/ft^2 (995 W/m^2.K)

Autumn Maximum Global Radiation:

Date	November 25th (12:00)
External Temperature	57.2 F (14.0 C)
Maximum Global Radiation	304 Btu/h/ft^2 (959 W/m^2.K)

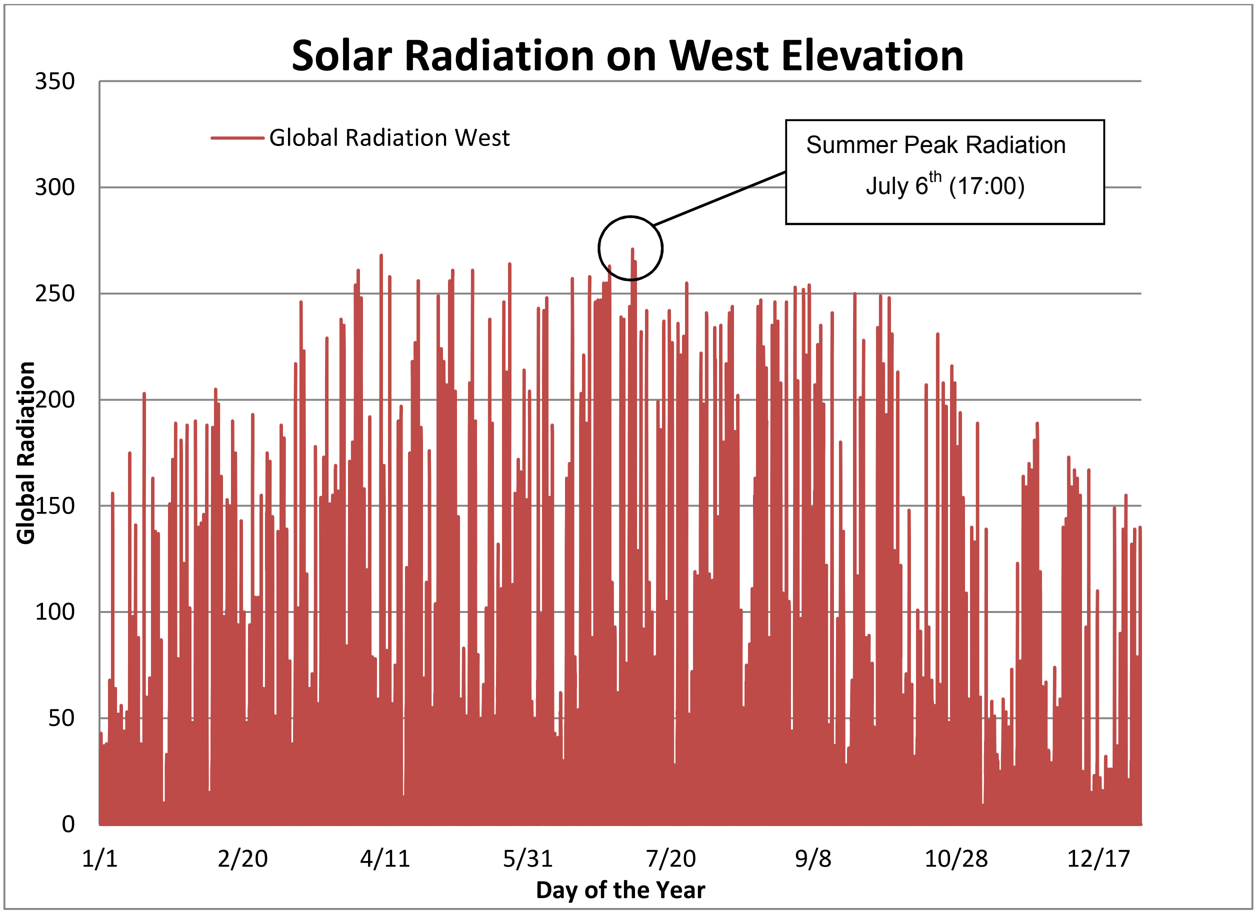

Figure 7: Solar Radiation on West Elevation

Summer Maximum Global Radiation:

Date	July 6th (17:00)
External Temperature	75.4 F (24.11 C)
Maximum Global Radiation	271 Btu/h/ft^2 (854 W/m^2.K)

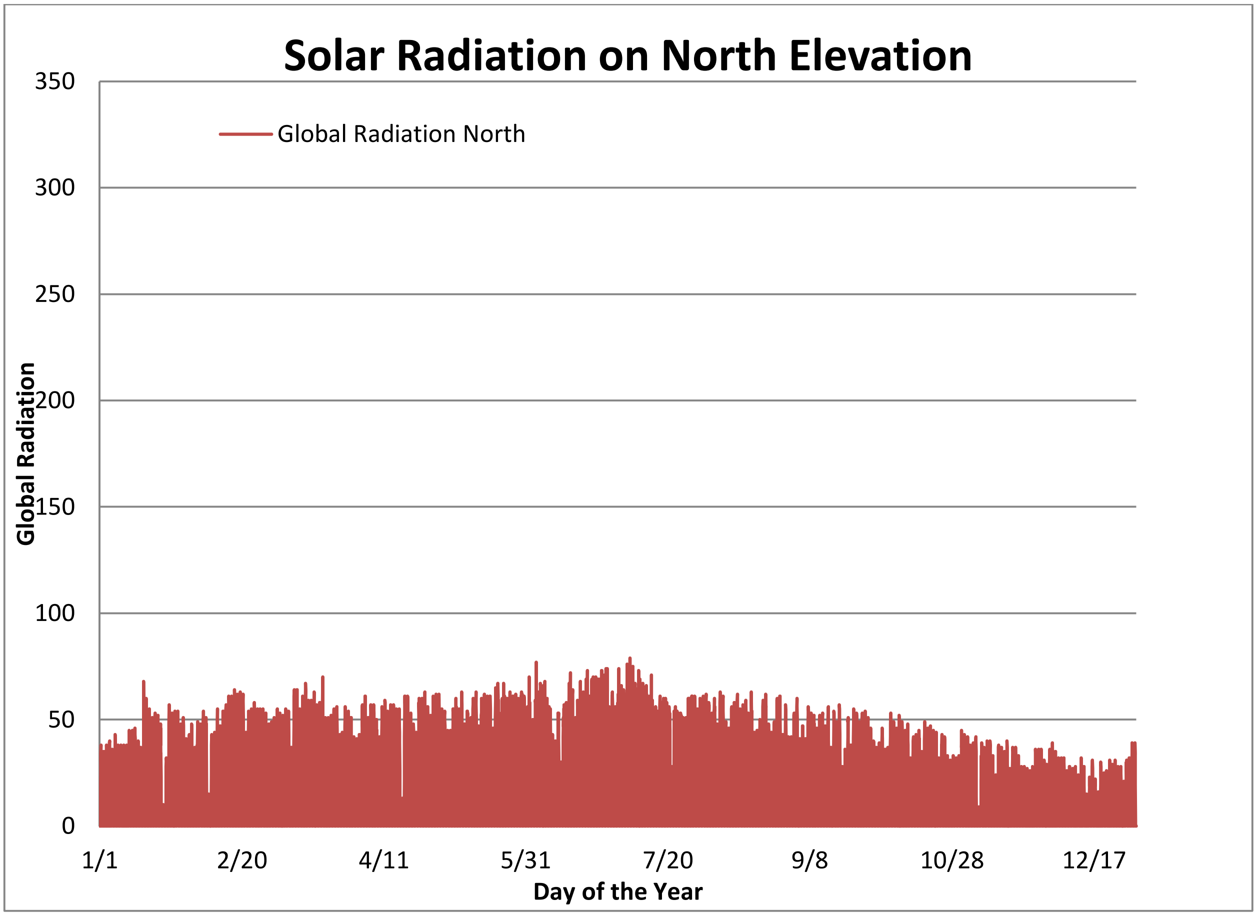

Figure 8: Solar Radiation on North Elevation

4 ECOTECT ANALYSIS

4.1 Annual Average Radiation

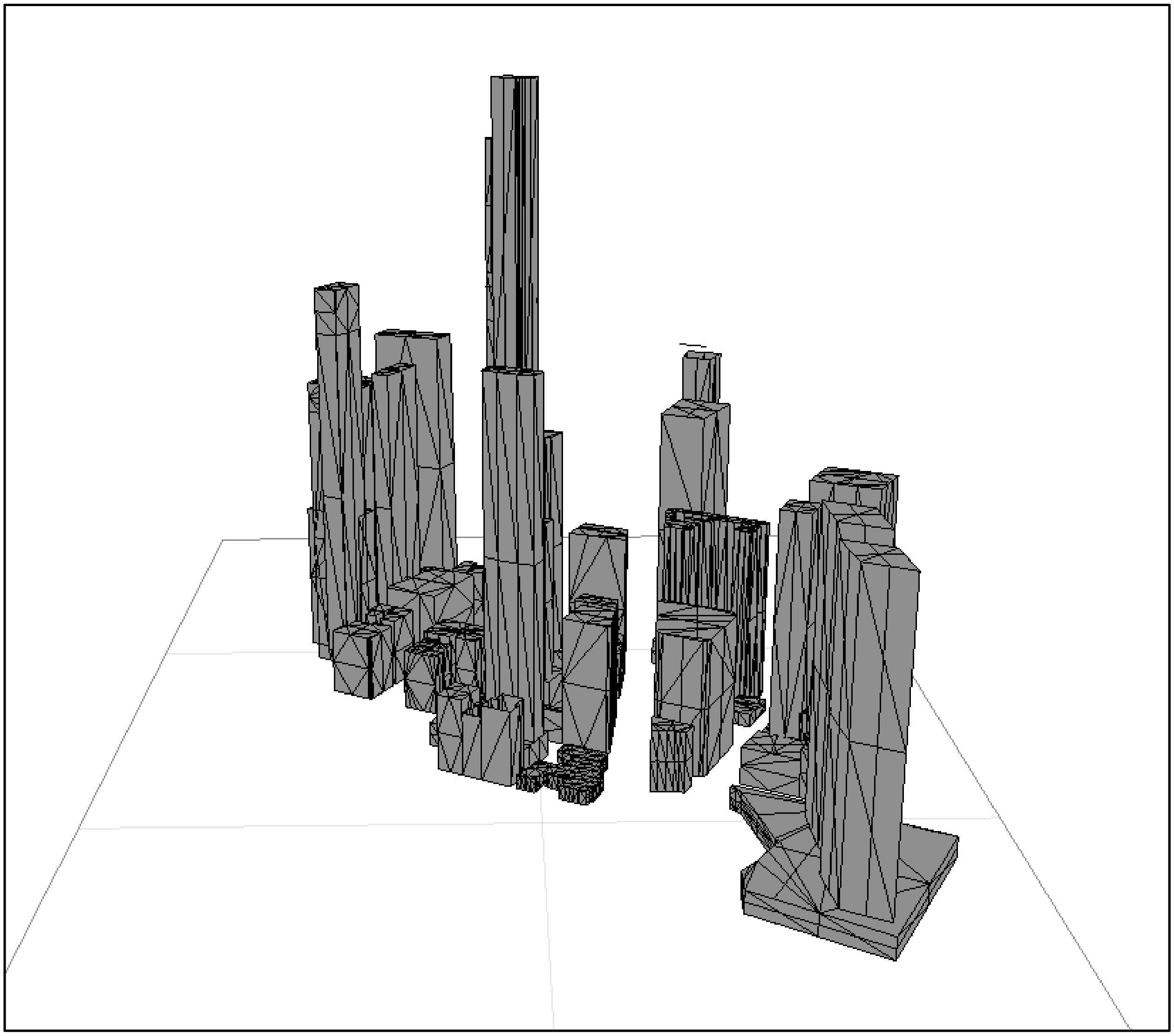

Figure 9: Ecotect Model Geometry (North Elevation)

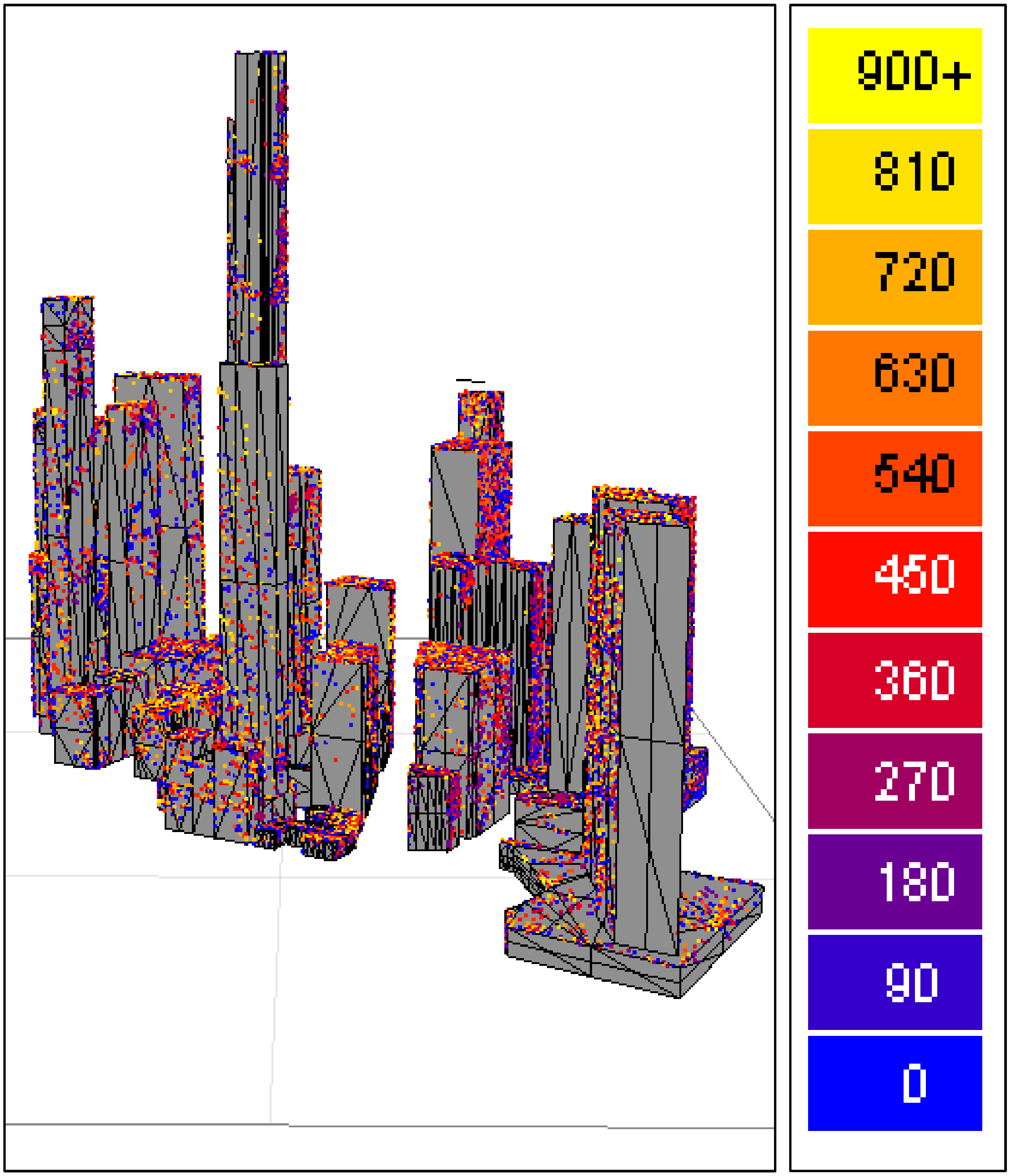

Figure 10: Annual Radiation Overall Model (North Elevation)

Units (W/m2-K)

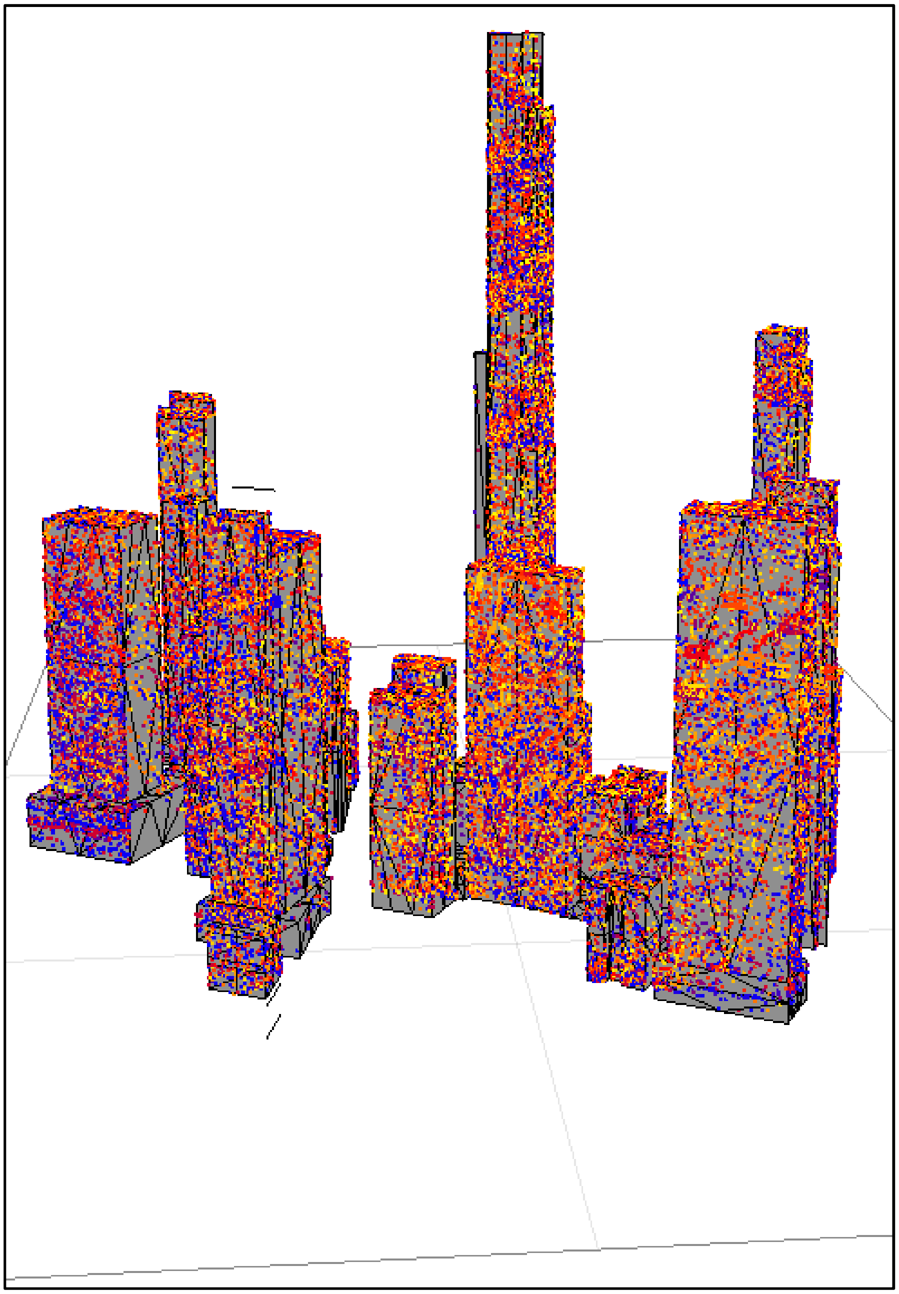

Figure 11: Annual Radiation Overall Model (South Elevation)

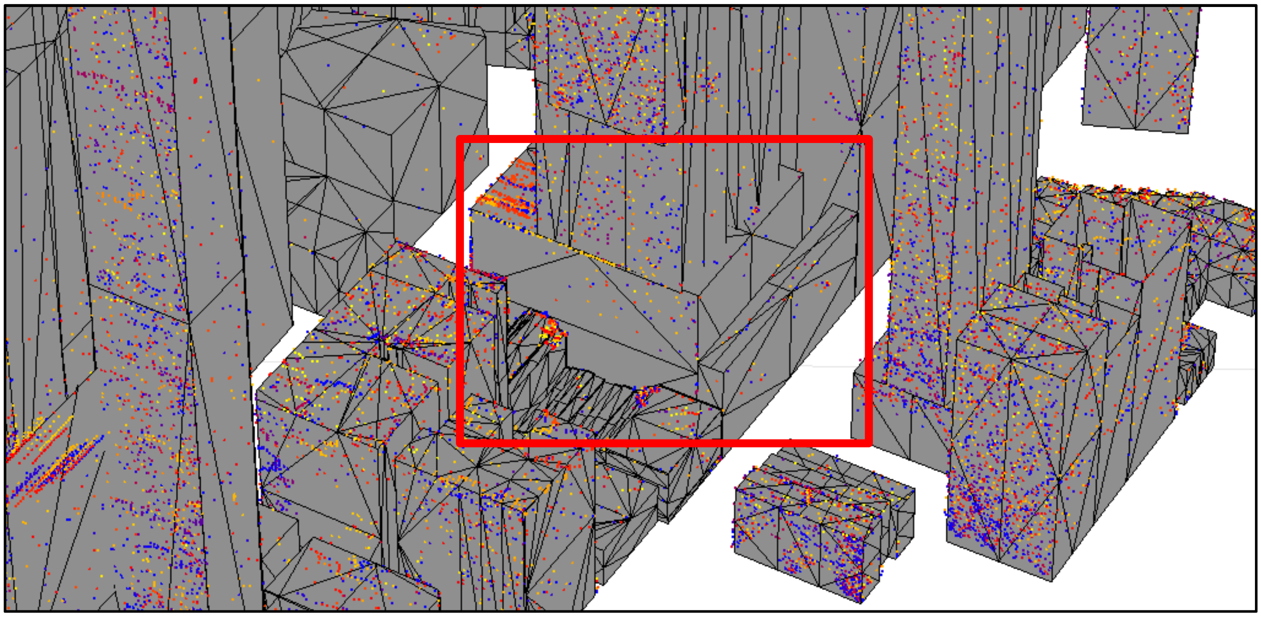

Figure 12: Annual Radiation Zoomed Model (North-East Elevation)

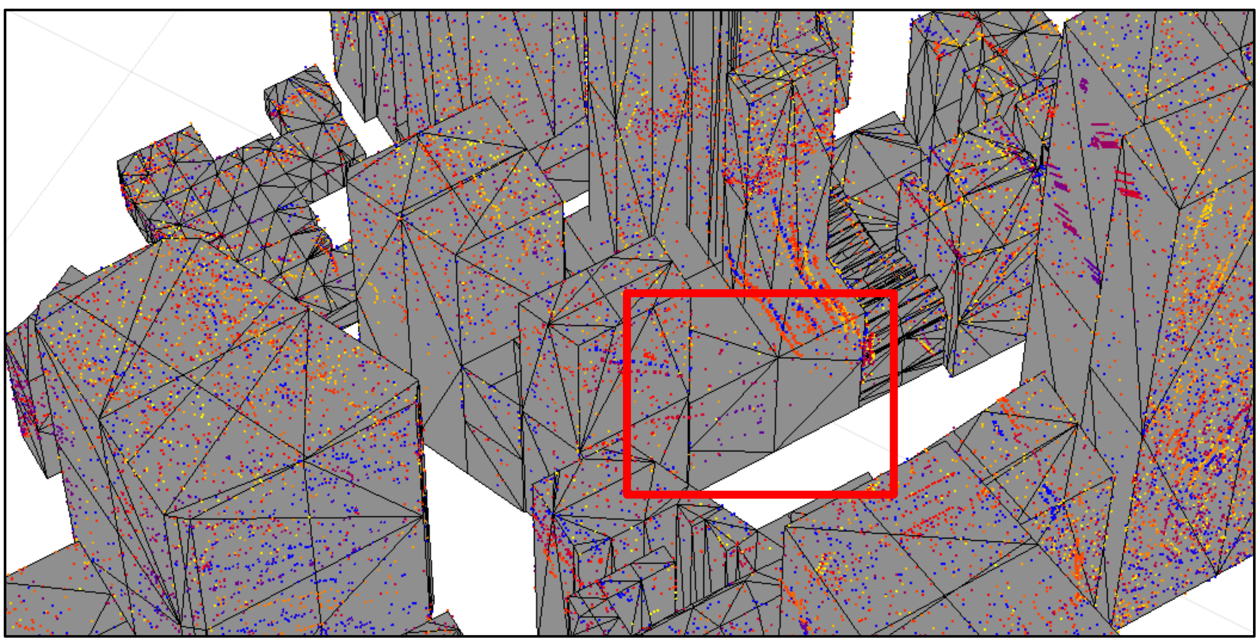

Figure 13: Annual Radiation Zoomed Model (South-West Elevation)

4.2 Annual Average Sunlight

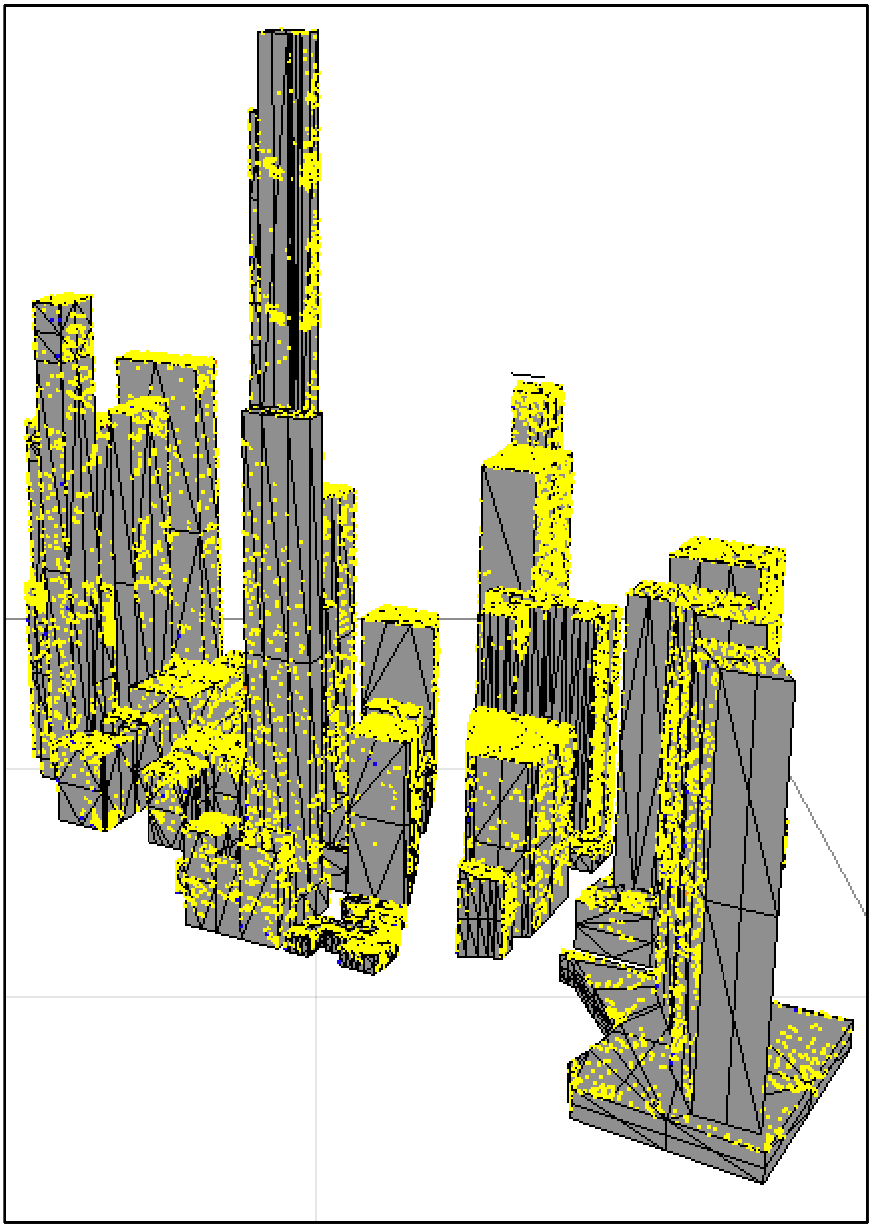

Figure 14: Annual Sunlight Overall Model (North Elevation)

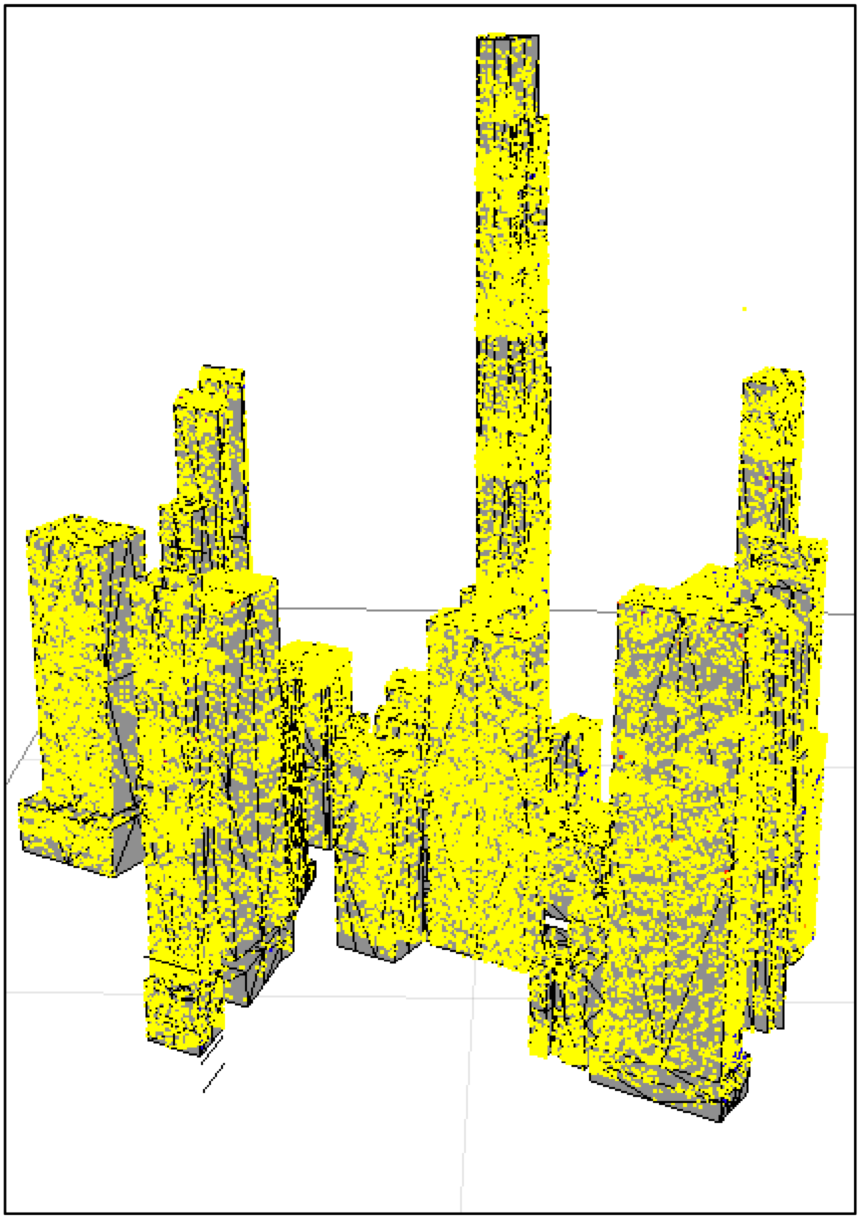

Figure 15: Annual Sunlight Overall Model (South Elevation)

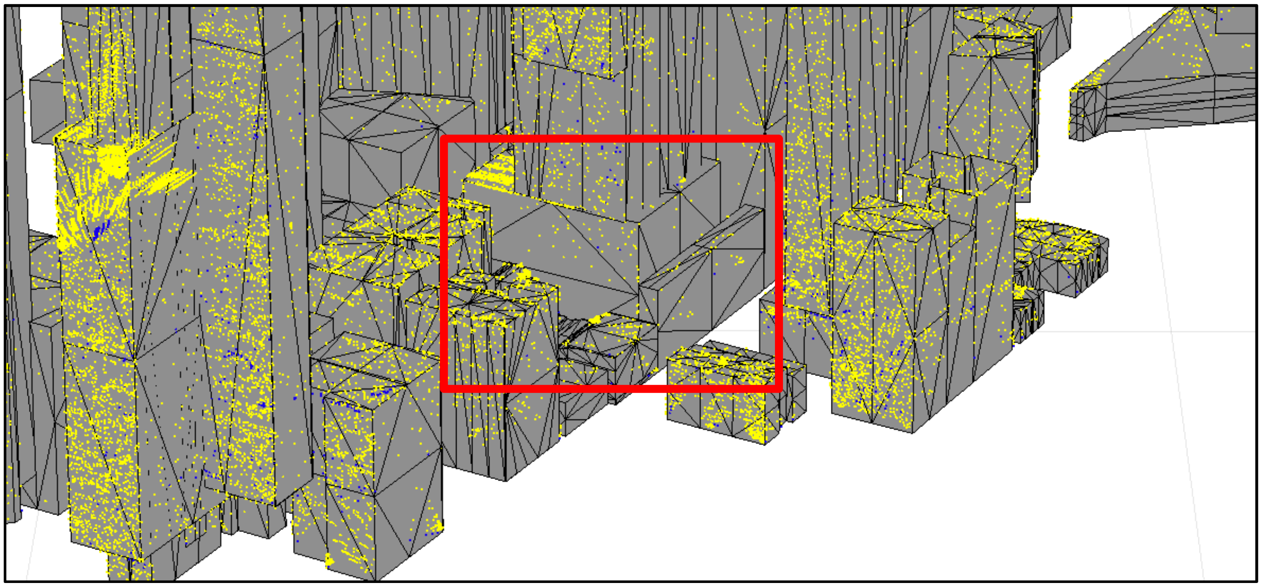

Figure 16: Annual Sunlight Zoomed Model (North-East Elevation)

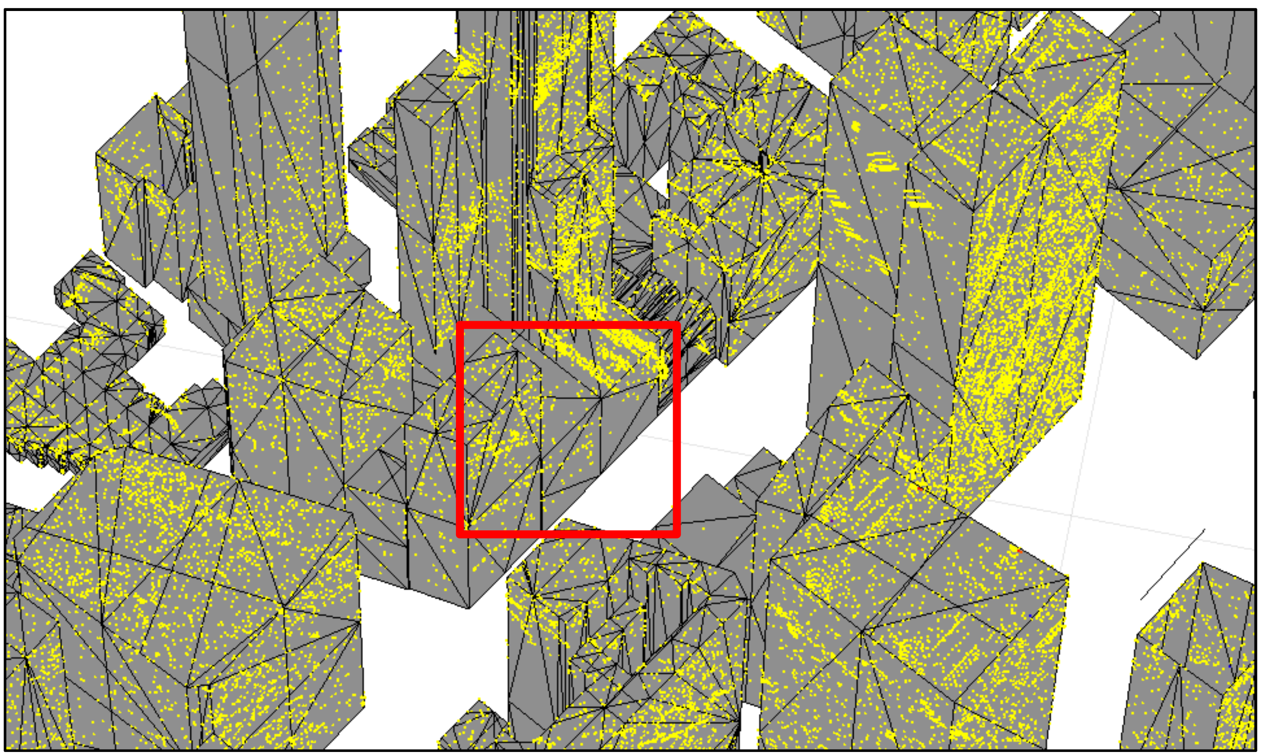

Figure 17: Annual Sunlight Zoomed Model (South-West Elevation)

4.3 Seasonal Shadow Analysis

	Winter	Spring	Summer	Autumn
Elevation	South	East	West	South
Date (Time)	January 27 (12:00)	May 21 (08.00)	July 6 (17:00)	August 19 (15:00)
External Temperature	47.3F (8.5C)	71.2F (21.8C)	75.4F (24.1C)	93.3F (34.1C)
Maximum Radiation (W/m2)	995	895	854	959

Table 1: Summary of Seasons

4.3.1 Winter Peak Radiation Shadow Distribution (January 27th 12:00)

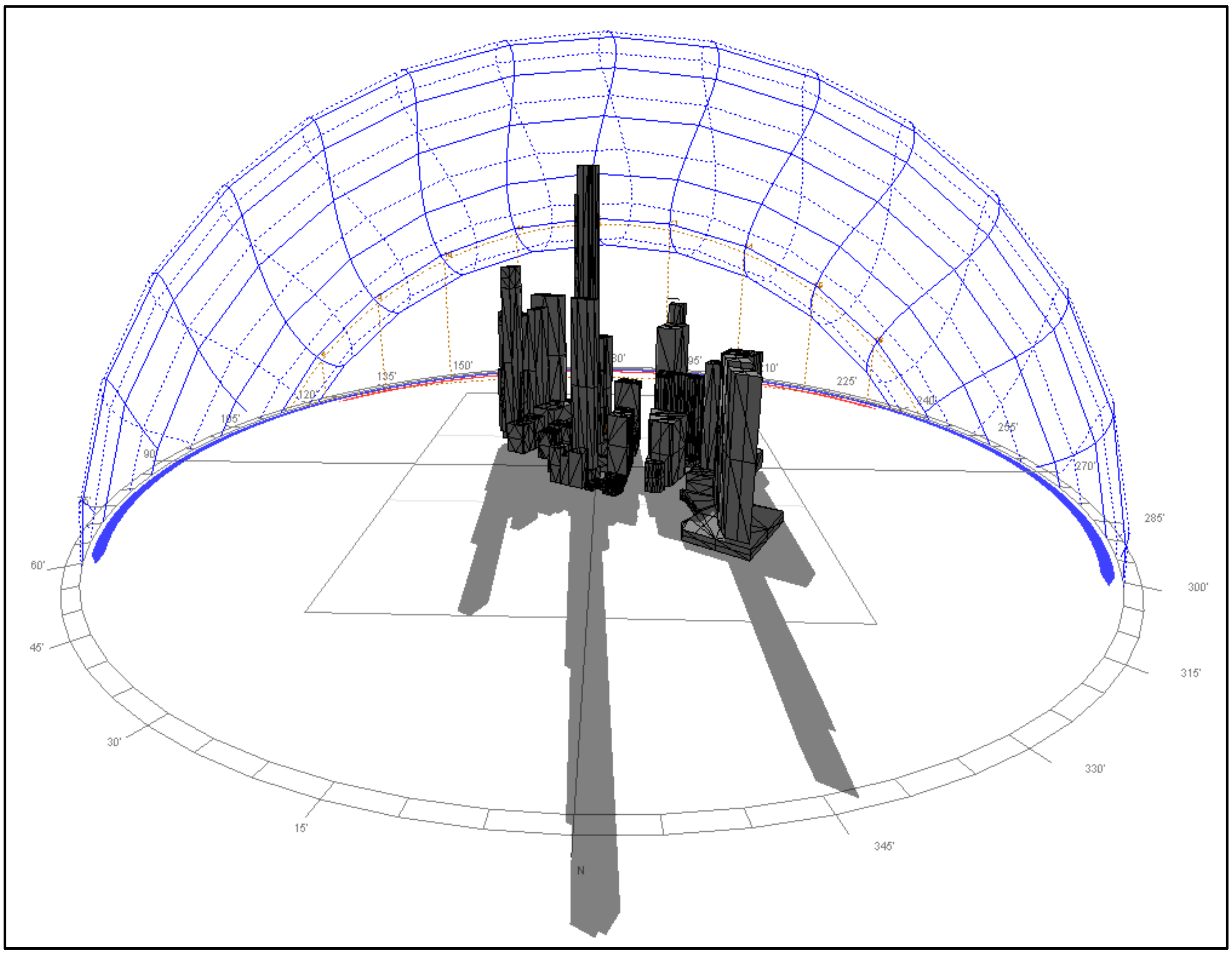

Figure 18: Overall Ecotect Winter Model

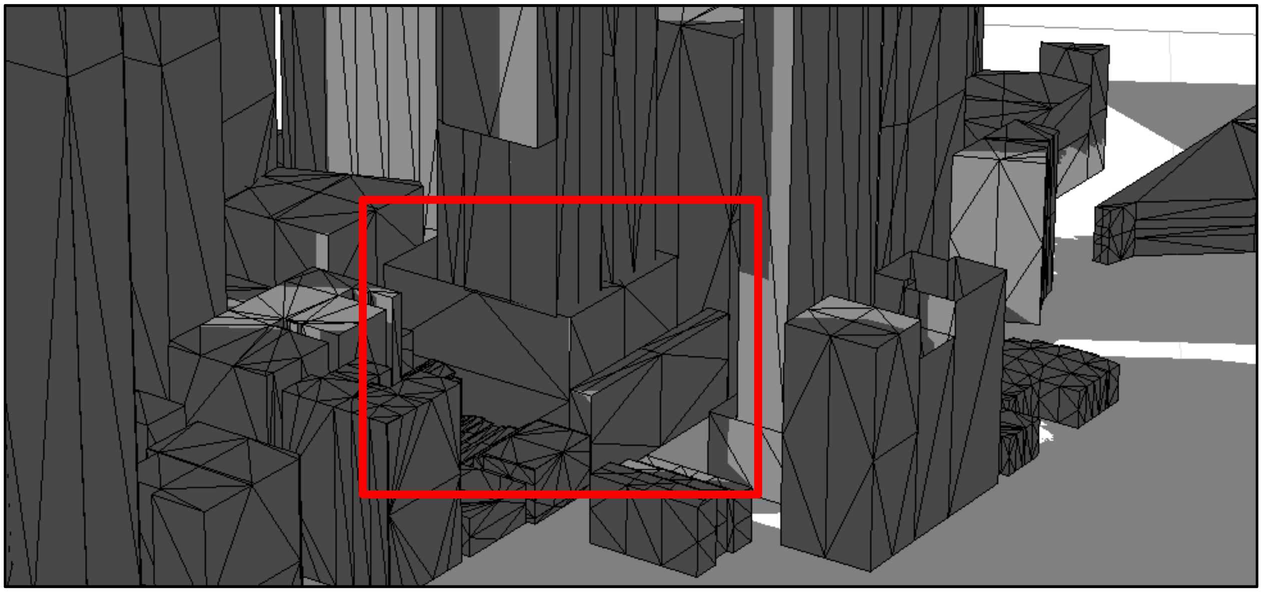

Figure 19: Shadow Distribution Winter (North-East Elevation)

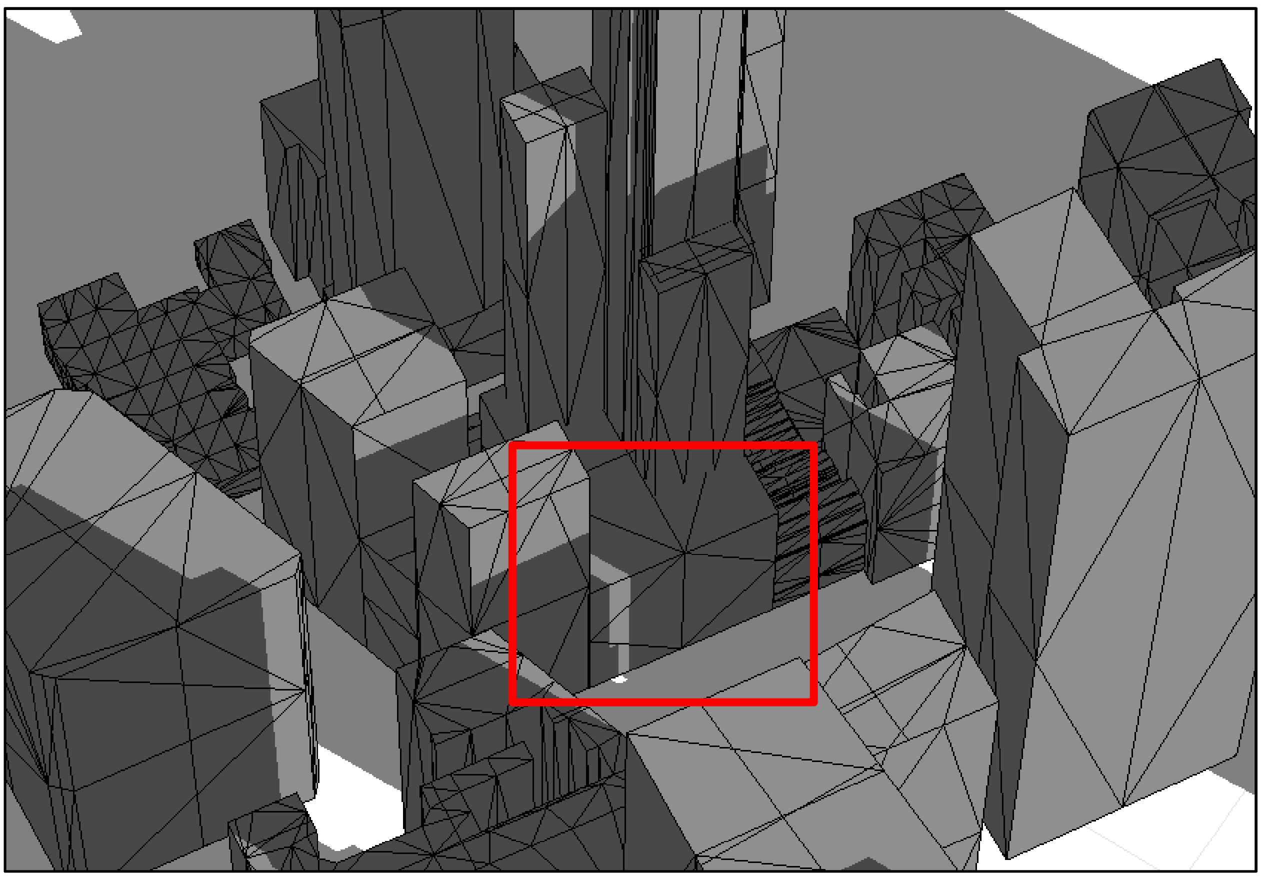

Figure 20: Shadow Distribution Winter (South-West Elevation)

4.3.2 Spring Peak Radiation Shadow Distribution (May 21st 8:00)

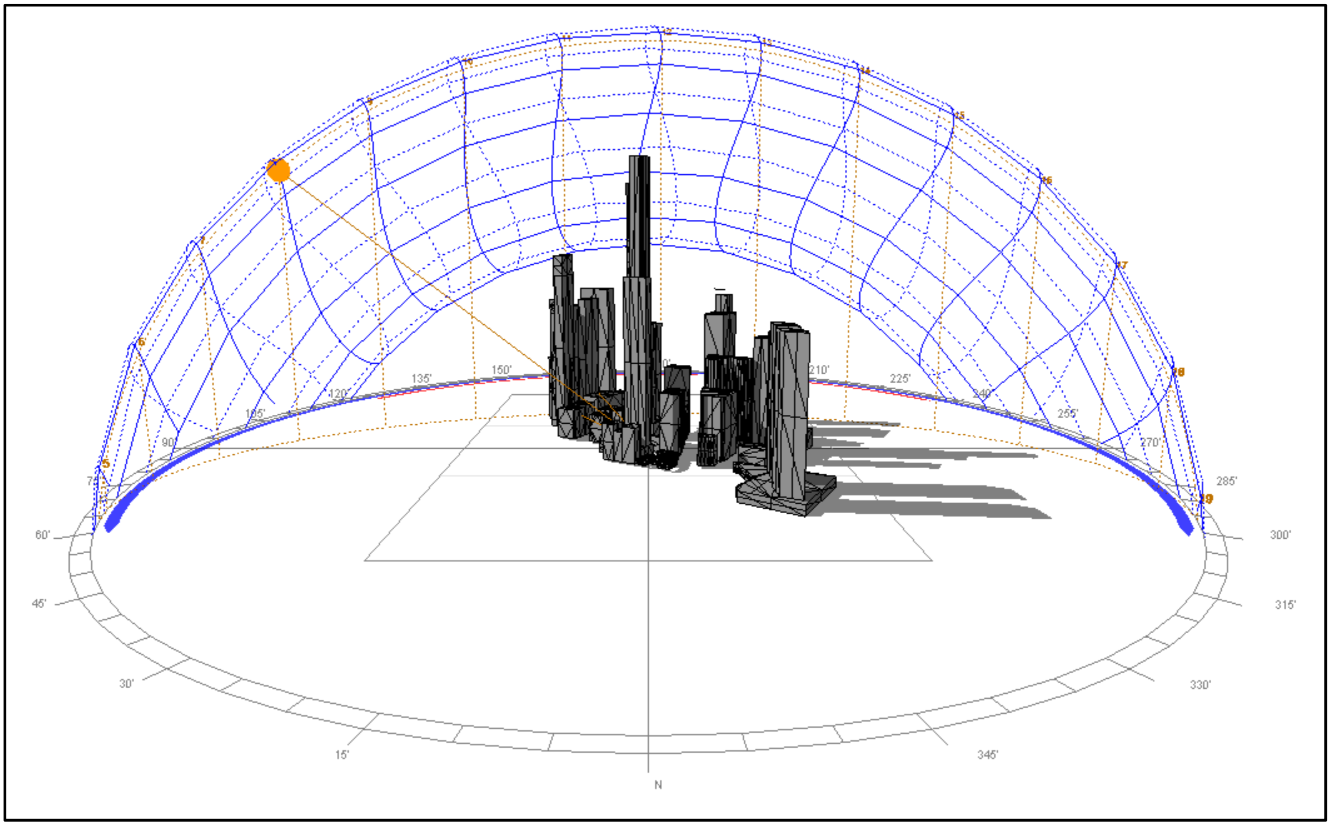

Figure 21: Overall Ecotect Spring Model

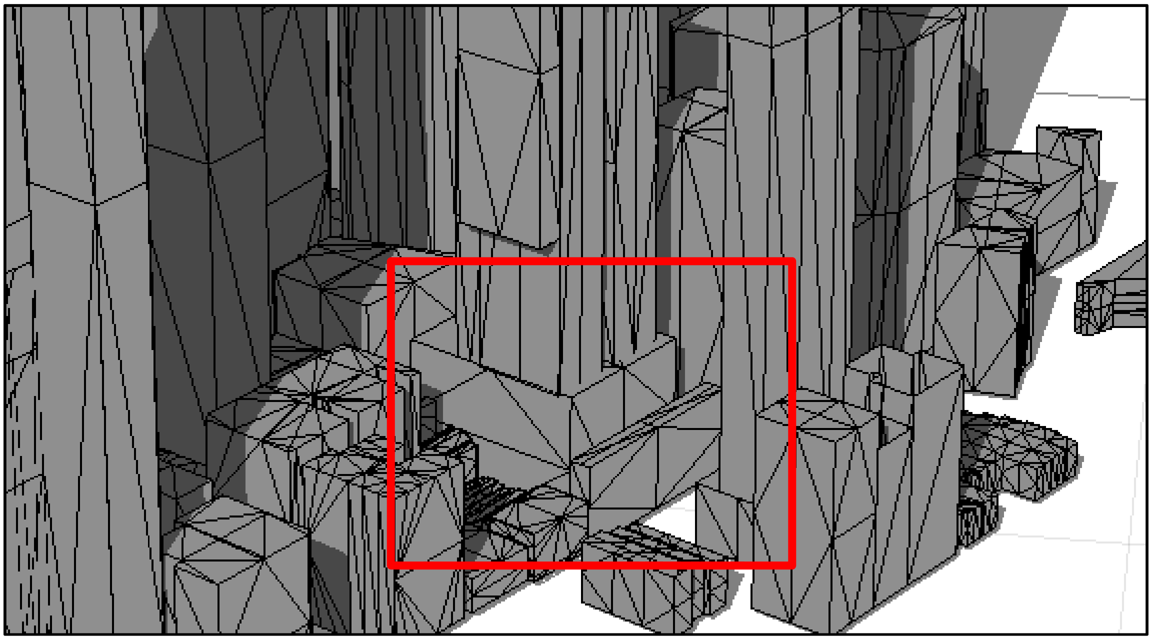

Figure 22: Shadow Distribution Spring (North-East Elevation)

Note that some buildings were not included in the northeastern region of this model because it's low radiation levels (refer to Figures 8, 10 and 12). The skyline of surrounding buildings would block much of this direct sunlight.

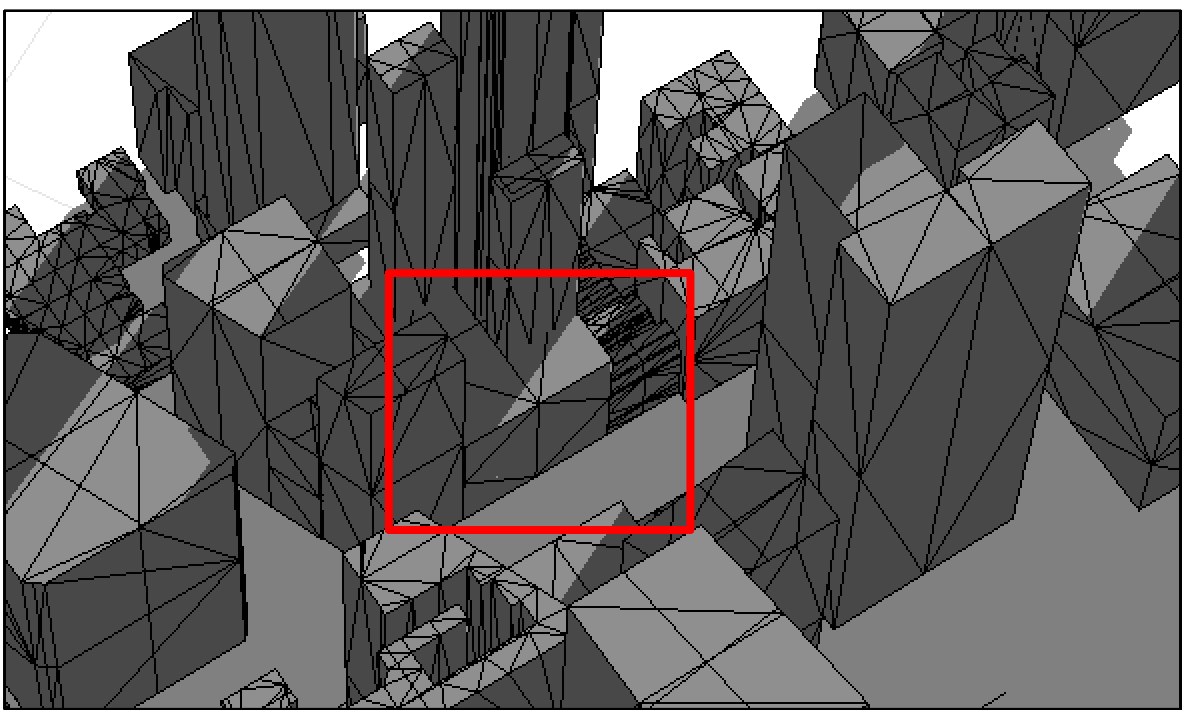

Figure 23: Shadow Distribution Spring (South-West Elevation)

4.3.3 Summer Peak Radiation Shadow Distribution (July 6th 17:00)

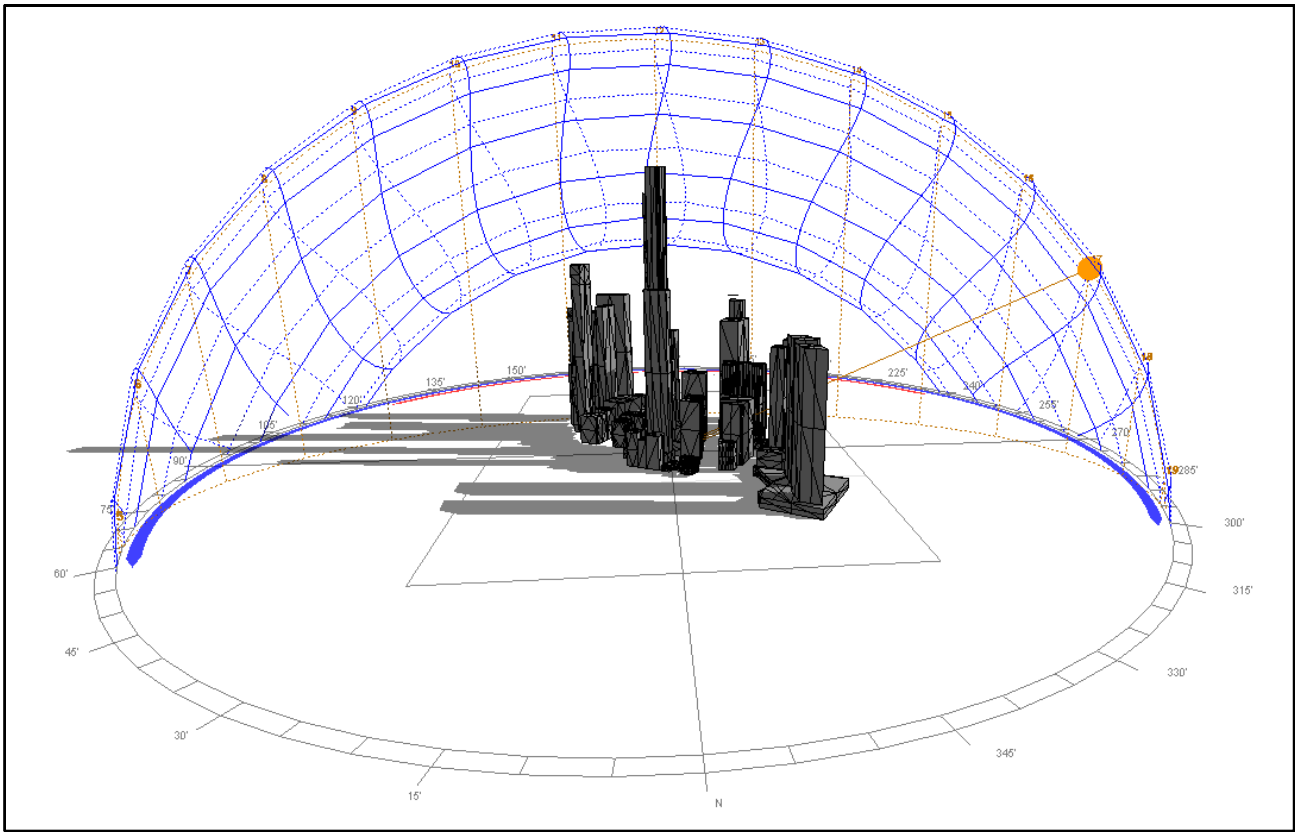

Figure 24: Overall Ecotect Summer Model

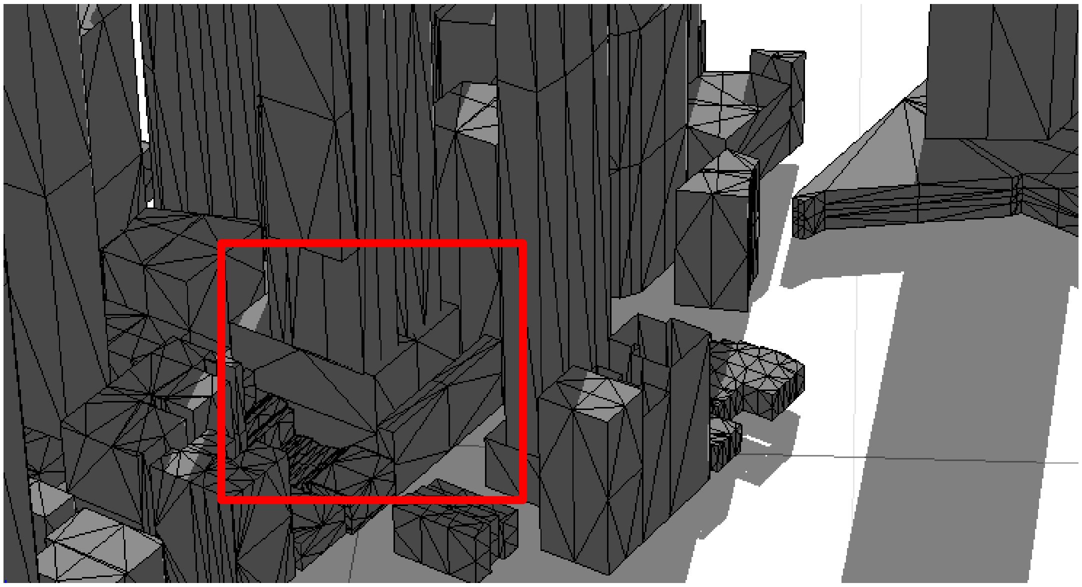

Figure 25: Shadow Distribution Summer (North-East Elevation)

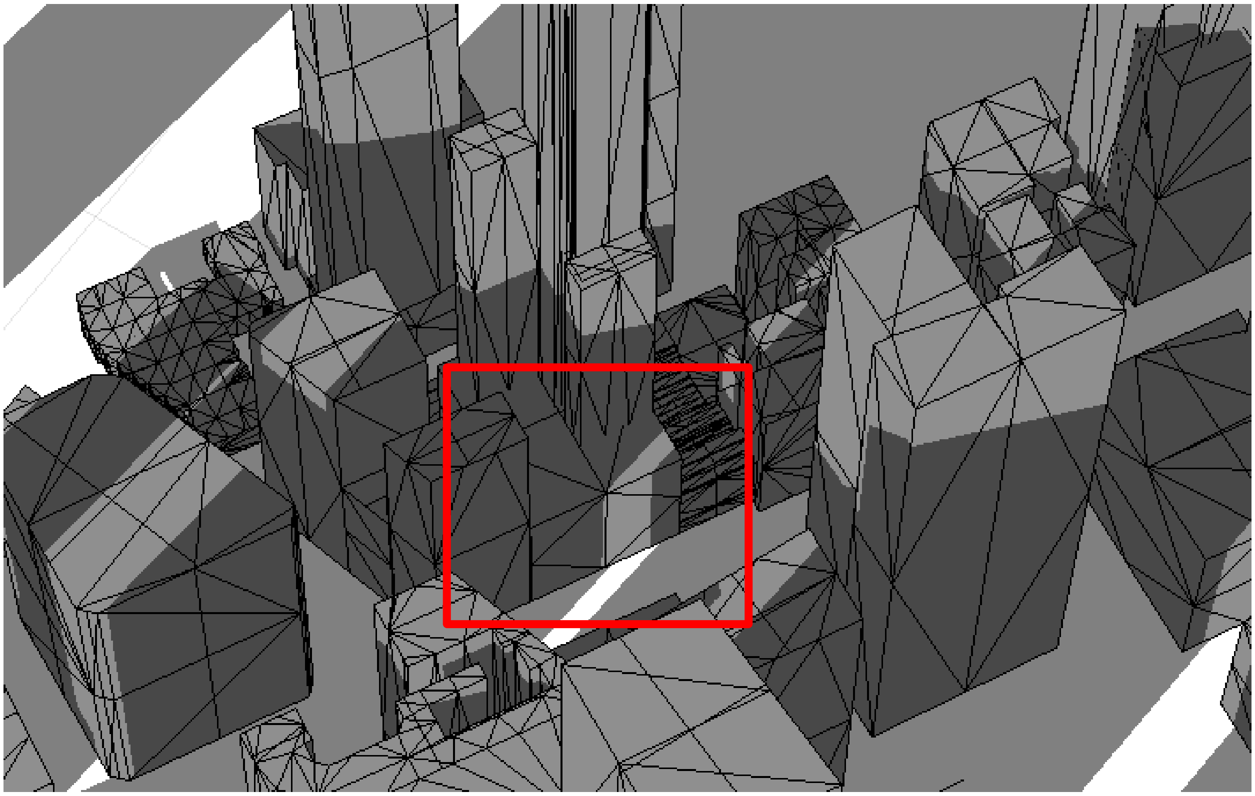

Figure 26: Shadow Distribution Summer (South-West Elevation)

4.3.4 Autumn Peak Radiation Shadow Distribution (November 25th 12:00)

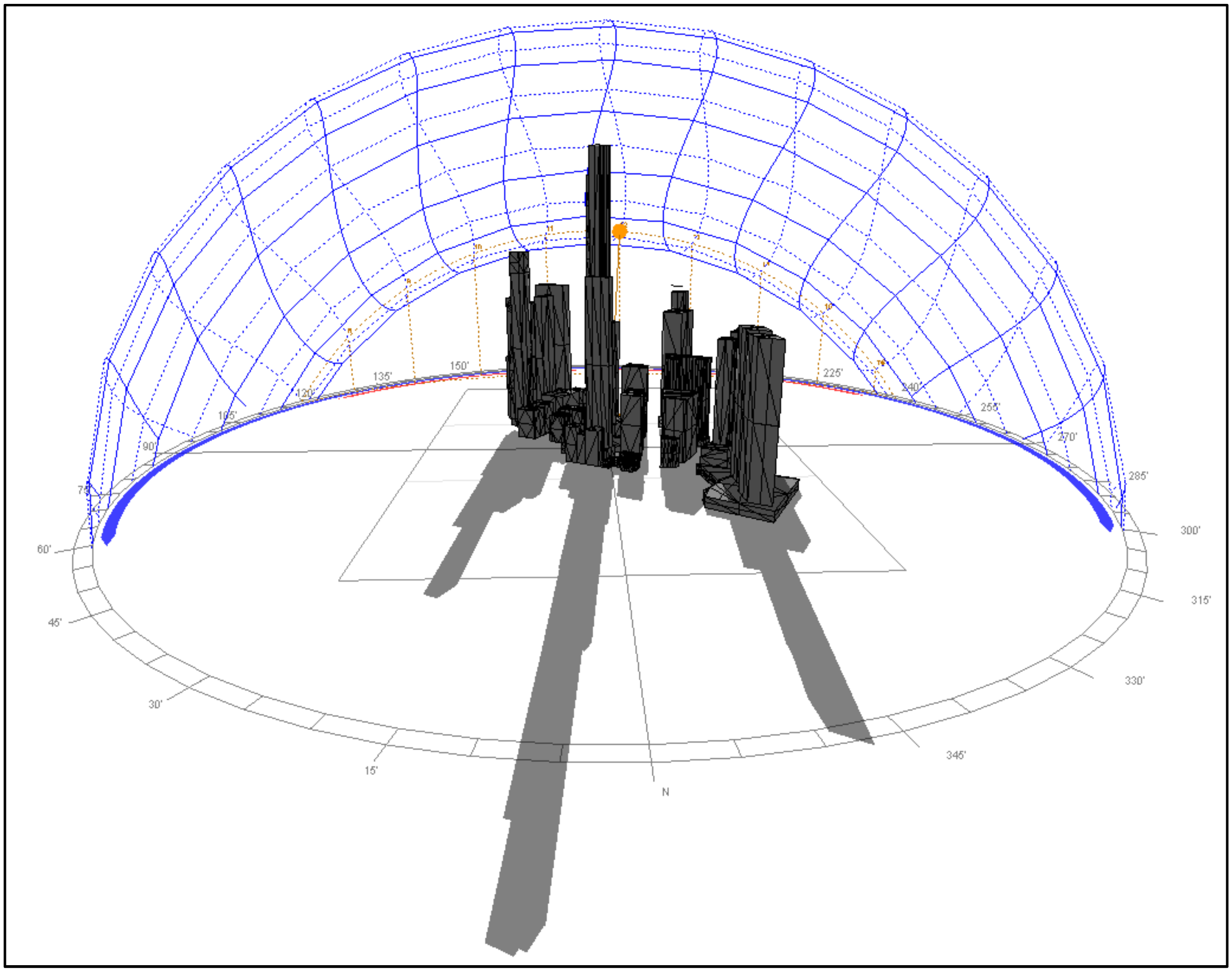

Figure 27: Overall Ecotect Autumn Model

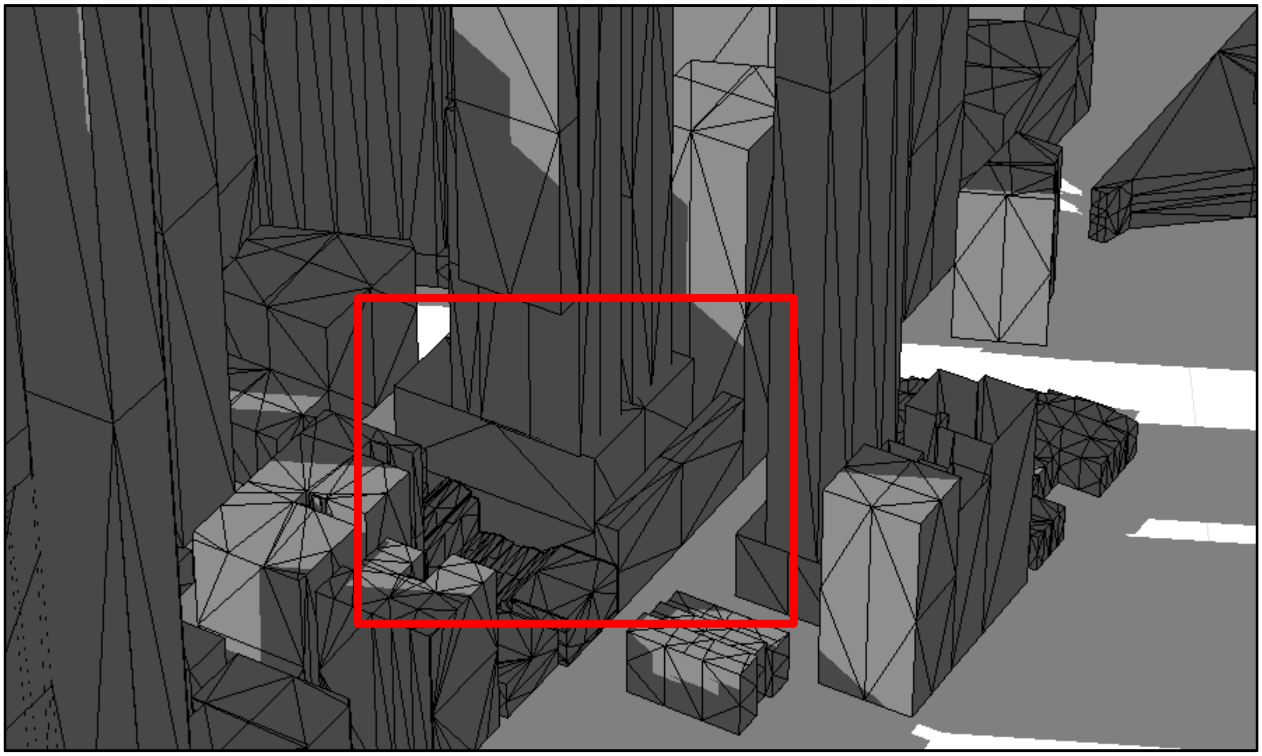

Figure 28: Shadow Distribution Autumn (North-East Elevation)

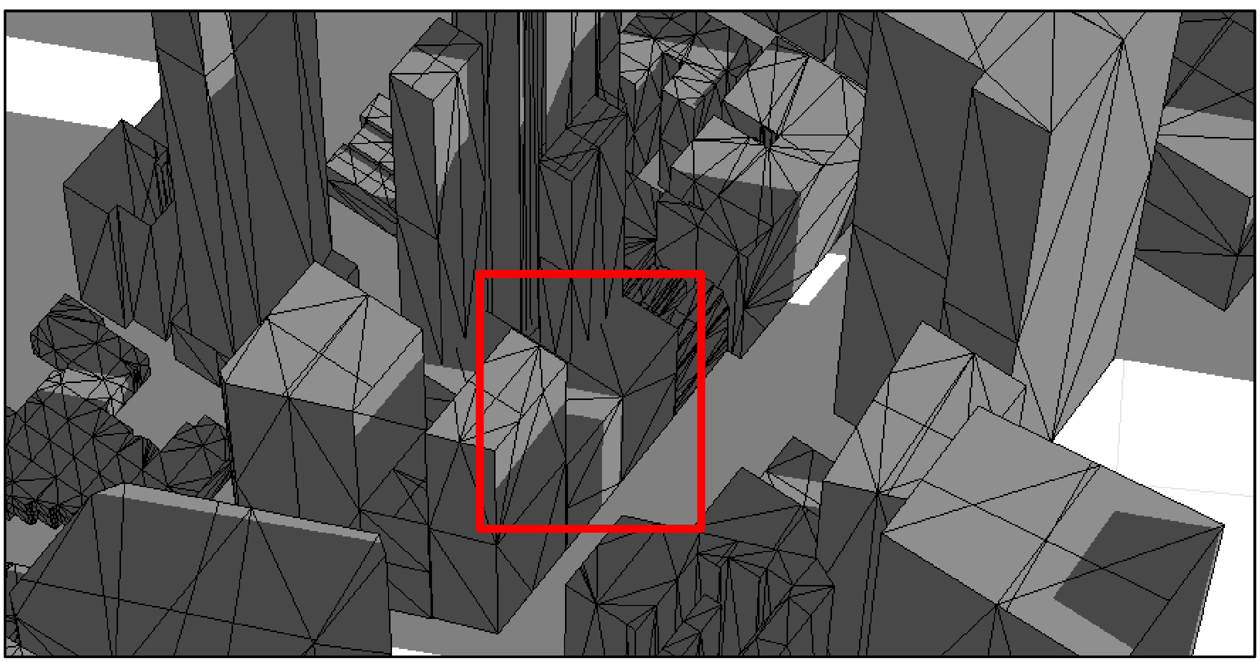

Figure 29: Shadow Distribution Autumn (South-West Elevation)

Lend Lease

Submittal Transmittal

Detailed, Grouped by Each Number

217 West 57th Street
200 Park Avenue, 9th Floor
New York, NY 10166

Project # 11668500
Tel: 212.592.6700 Fax:

Lend Lease (US) Construction LMB Inc.

Date: 8/5/2015 **Reference Number: 0528**

Transmitted To:
Joe Welker
James Carpenter Design

145 Hudson Street
New York, NY 10013
Tel: 212-431-4318
Fax:

Transmitted By:
Alexa DiBuono
Lend Lease (US) Construction LMB Inc.
200 Park Avenue
9th Floor
New York, NY 10166
Tel: 212-592-6700
Fax: 212-592-6988

Qty	Submittal Package No	Description	Due Date	Package Action
16	0035 - 08 44 13 - 0	PNA Retail – Thermal Calculations W37	8/24/2015	

Transmitted For	Delivered Via	Tracking Number
For Approval	Prolog Converge	

Items	Qty	Description	Notes	Item Action
00735		System Design - Thermal Calculations - W37 Wall		

Cc:	Company Name	Contact Name	Copies	Notes

Remarks

Routing:
Day 0 - LL to JCDA
Day 3 - JCDA to SBP
Day 5 - SBP to CAL
Day 6 - CAL to AKF
Day 8 – AKF to AJLP (Molly)
Day 10 - AJLP to AAI
Day 13 – AAI return to LL

Signature **Signed Date**

Bleu Tech Montréal, Inc.
Membre du groupe / Member of the group PERMASTEELISA

4150 Autoroute Chomedey (A13), Laval, Quebec, Canada H7R 6E9
Tel: (450) 767-2890 Fax: (450) 767-2891

TRANSMITTAL 90941-TR022

Attention Sadaf J. Khanttak
Company LEND LEASE (US)
200 PARK AVE, 9TH FLOOR
NEW YORK, NY 10166

Project: Hardrock
PNA Project No: 90941
Project area: Thermal Calculations Rev 00
From: Audrey-Anne Harvey
Date: August 4, 2015

We transmit:
- [x] Herewith
- [ ] Under Separate Cover
- [ ] Per your request

The following:
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- [ ] Original(s)
- [ ] Spécifications
- [ ] Color(s) to match
- [ ] Literature
- [ ] Sample(s)
- [x] Electronic file(s)

For:
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- [ ] Information
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- [ ] Records
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Message:

*** If enclosures are not as noted, please inform us immediately**

Qty	Date	Document #	Rev	Description
1	7/24/2015	TC002	0	Thermal Calculations W37
1				

Signature:

PERMASTEELISA NORTH AMERICA

217 WEST 57TH STREET

HARDROCK

NEW YORK CITY, NY

PODIUM WALL PACKAGE - W37 WALL

SYSTEM DESIGN - THERMAL CALCULATIONS

DOC NAME: 90941TC002-00-150804PMG

Lend Lease
LEND LEASE (US) CONSTRUCTION LMB, INC.
RECEIVED
8/5/15
0035-08 44 13-0
SUBMITTAL NUMBER

JOB NO: 14.04 SUBMISSION NO: 1

CORRECTIONS OR COMMENTS MADE ON THE SHOP DRAWINGS DURING THIS REVIEW DO NOT RELIEVE CONTRACTOR FROM COMPLIANCE WITH REQUIREMENTS OF THE DRAWINGS AND SPECIFICATIONS. THIS CHECK IS ONLY FOR REVIEW OF GENERAL CONFORMANCE WITH THE DESIGN CONCEPT OF THE PROJECT AND GENERAL COMPLIANCE WITH THE INFORMATION GIVEN IN THE CONTRACT DOCUMENTS. THE CONTRACTOR IS RESPONSIBLE FOR CONFIRMING AND CORRELATING ALL QUANTITIES AND DIMENSIONING, SELECTING FABRICATION PROCESSES AND TECHNIQUES OF CONSTRUCTION, COORDINATING HIS WORK WITH THAT OF ALL OTHER TRADES, AND PERFORMING HIS WORK IN A SAFE AND SATISFACTORY MANNER.

- [ ] APPROVED
- [x] APPROVED AS NOTED. RESUBMIT FOR RECORD
- [ ] REVISE AND RESUBMIT
- [ ] REJECTED

CHECKED BY: JRW DATE: Aug 7, 2015

JAMES CARPENTER DESIGN ASSOCIATES
145 HUDSON STREET 4TH FLOOR NEW YORK, NEW YORK 10013
TEL: (212) 431-4318 FAX: (212) 431-4425
EMAIL: INFO@JCDAINC.COM

NOT REVIEWED
CAL-jmf

ADAMSON ASSOCIATES ARCHITECTS

ADRIAN SMITH + GORDON GILL ARCHITECTURE

EXTELL DEVELOPMENT COMPANY

JAMES CARPENTER DESIGN ASSOCIATES

LEND LEASE

Rev.	Date	Description	Prepared by	Checked by
00	08/04/2015	First Submission	P.M. Gamache	P.Collin

TABLE OF CONTENTS

1 SUMMARY

THERM 6.3 software was used to analyze the two-dimensional heat transfer through the frame and frame edge areas. The frame U-values have been derived using THERM 6.3 according to NFRC standard.
Main results are reported in the following:

Wall Type	Overall U - Factor BTU/(h·ft^2·°F)	Condensation Resistance (%)
WT-37	0.22	35.8

Table 1: Summary of Results

2 THERM KEY

Material	Thermal Conductivity (Btu/h.ft².F)	Model Color
Aluminum Alloy (Painted)	92.5	
Aluminum Alloy (Painted) 6%*	5.56	
Aluminum Alloy (Painted) 10%*	9.25	
Ethylene Propylene Diene Monomer (EPDM)	0.14	
Foam Weather Stripping	0.017	
Frame Cavity NFRC	Calculated by THERM	
Frame Cavity Slightly Ventilated	Calculated by THERM	
Insulation	0.02	
Polyethylene / Polythene HD (High Density)	0.29	
Polyvinylchloride (PVC) /Vinyl – Rigid 12.5%*	0.024	
Polyvinylchloride (PVC) /Vinyl – Rigid 12.5% / Foam Weather Stripping*	0.027	
Silicone Gasket	0.20	
Silicone Sealant	0.20	
Steel – Galvanized Sheet (0.14%C)	35.9	

Table 2: THERM Material Color Key

*Example of calculation for PVC 12.5%/ Air 87.5%: Given a thermal conductivity of 0.024 W/m.K for air and 0.170 W/m.K for PVC, an average thermal conductivity can be calculated based on an area weighted method. The calculation can be seen below.

$$\left(12.5\% * 0.170\frac{W}{m.K}\right) + \left(87.5\% * 0.024\frac{W}{m.K}\right) = 0.04255\frac{W}{m.K} = 0.024\frac{Btu}{h.ft2.F}$$

3 BOUNDARY CONDITIONS

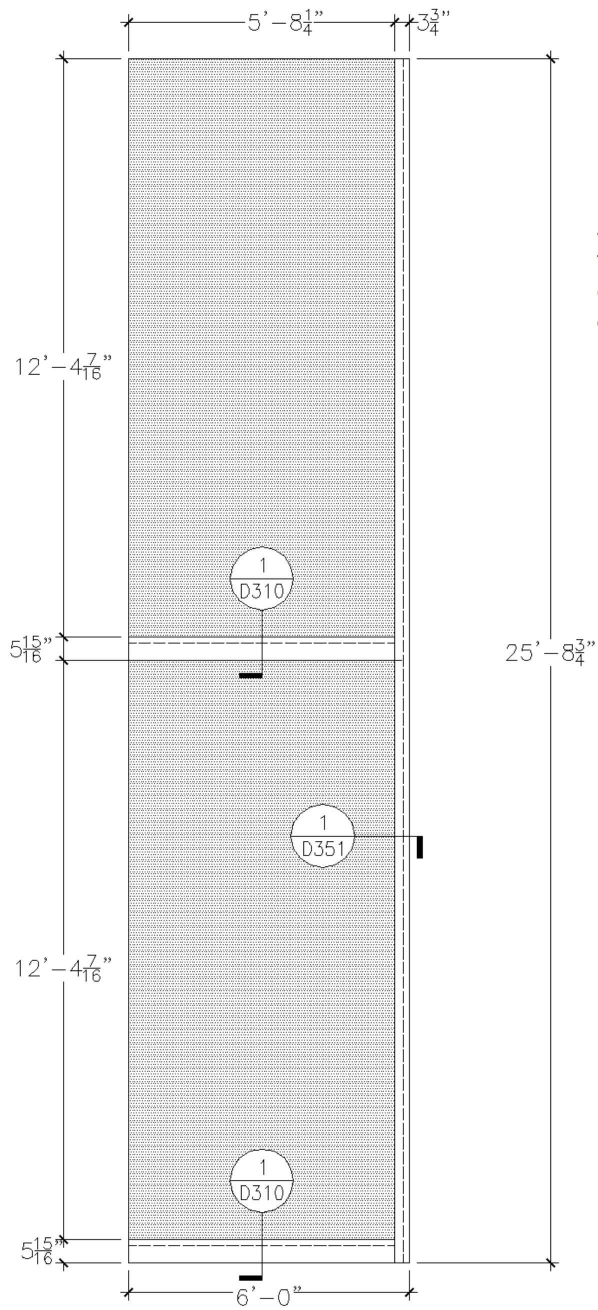
Calculation	Standard	Cold-Side Environmental Temperature	Warm-Side Environmental Temperature	External Wind Speed	External Heat Transfer Coefficient	Internal Relative Humidity	Internal Heat Transfer Coefficient
Thermal Transmittance	NFRC (100-2010)	-0.4°F	69.8°F	12.3mph	4.58 Btu/h-ft²-F	----	0.53 Btu/h-ft²-F
Condensation Assessment	Project Specification (12/18/14)	13.0°F	72.0°F	15mph	5.43 Btu/hft²-F	35%	0.40 Btu/h-ft²-F

Table 3: Boundary Conditions

4 GENERAL DESCRIPTION

This report must be read in conjunction with Permasteelisa's drawings dated on August 4th, 2015. The thermal performance of the typical façade type is stated in the following report. The overall U-value, as well as Condensation Assessment of the curtain wall panels have been performed according to the (NFRC), (ASHRAE) and (ISO) Standards.

Typical unit elevation is shown in the following figure.



JCDA: this condition occurs largely at the mechanical floors. WSP and AKF to confirm boundary parameters for environmental conditions.

Figure 1: Wall Type 37 Elevation (E008)

5 THERMAL TRANSMITTANCE

5.1 Thermal Transmittance Calculation Method

The heat transfer through the frame and glazing is assessed as described in the thermal guide (NFRC and ISO15099).

There are then the following thermal transmittances (U-values):

- Centre-panel U-value U_{sp}, which is assumed to apply to the whole of the spandrel panel (defined in section 5.2.1);
- Frame U-value U_f (defined in section 5.3);
- Edge U-value U_{edge1}, U_{edge2}, to take into account the heat transfer due to the interaction (edge effect) between the framing and spandrel panel (defined in section 5.3).

The overall U-value of the curtain wall is then calculated by using the principle of the area weighting of U-values of the frames and spandrel (as shown in section 5.4).

5.2 Center U-Value

One-dimensional center U-value calculation has been performed for the spandrel.

5.2.1 Spandrel

In the following, the THERM model and results are presented graphically

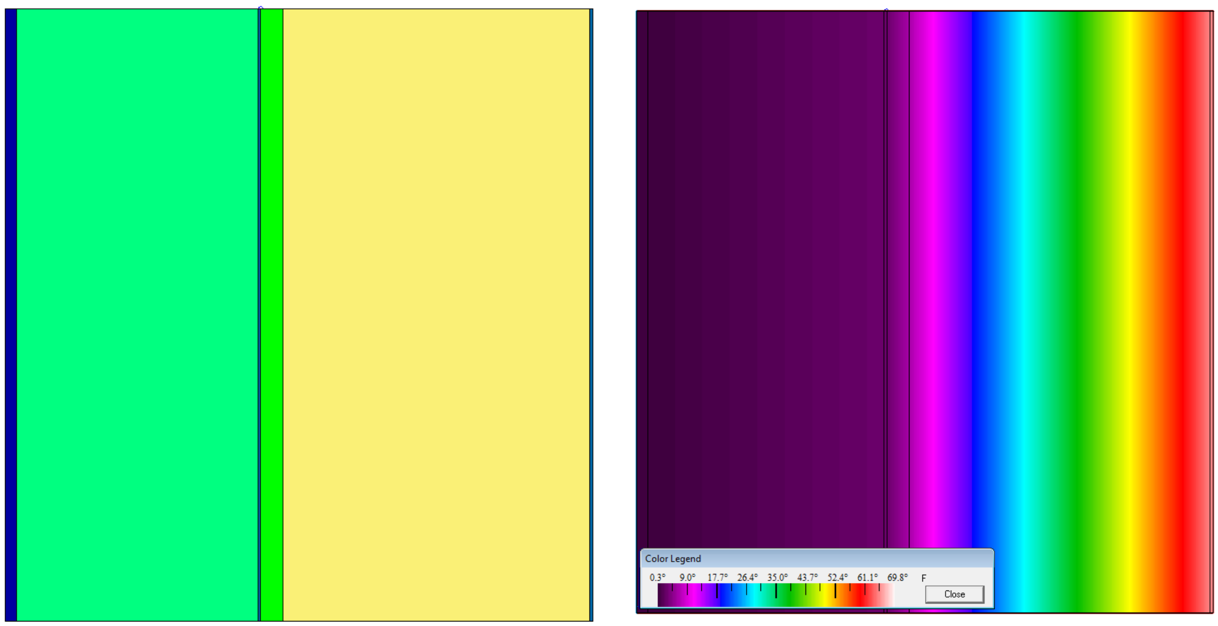


Figure 2: Spandrel section: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Standard	Spandrel Characteristics	Value
NFRC 100 - 2010	Thermal Transmittance (Btu/h.ft².F)	0.050

Table 4: 1 Dimensional Analysis Summary

NOTE: Above information for was provided in specifications dated April 24th, 2015.

5.3 Frame U-Value

The frames have been modeled by means of 2-dimensional FEM analysis, using the THERM program (version 6.3) by the Lawrence Berkeley National Laboratory. Material properties have been assigned as per THERM internal library.

The projected width of the solid part of the framing (excluding the glazing gaskets) is measured from the inside. For each of the models, the projected width of the frames is stated along with the frame U-value.

5.3.1 Mullion (1/D351)

In the following, the THERM model and results are presented graphically

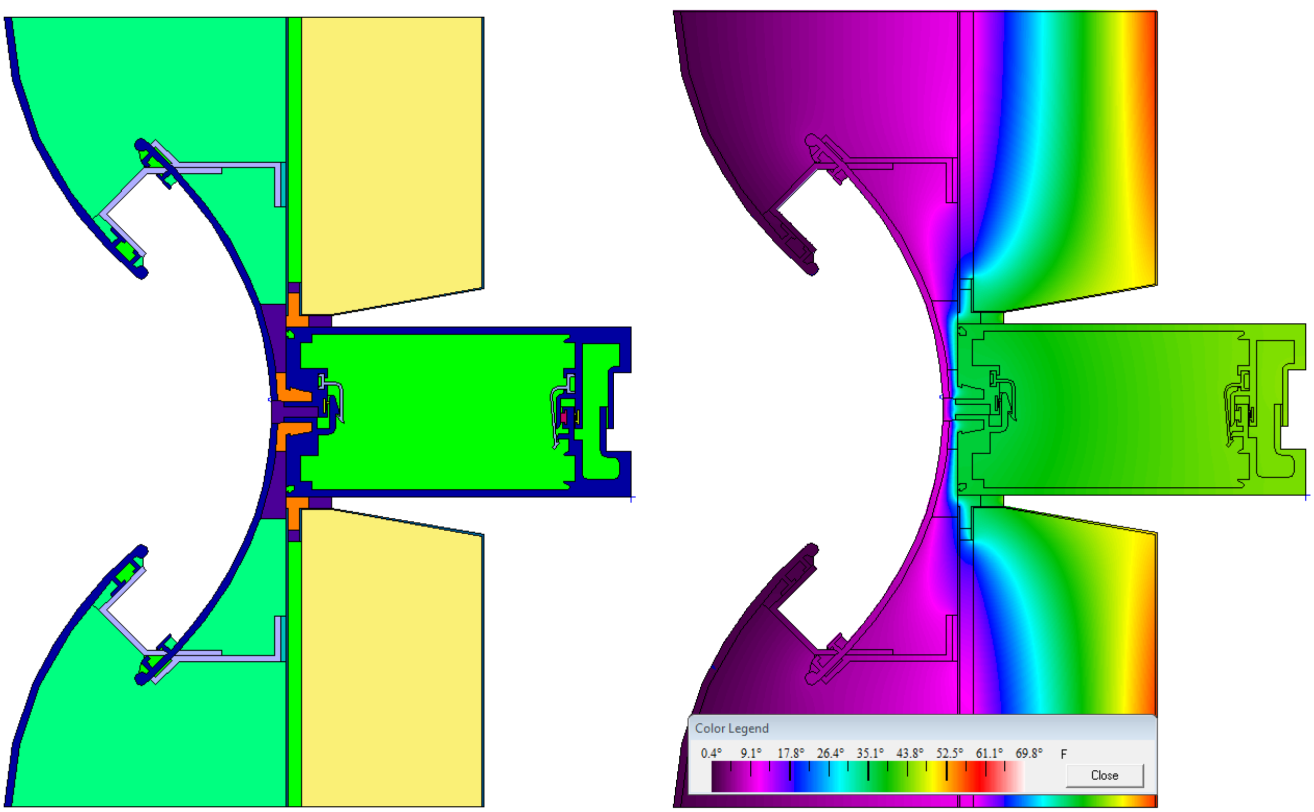


Figure 3: Mullion 1/D351: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

Two Dimensional Frame Thermal Transmittances	U_f = 1.87 Btu/h.ft².F	U_{male} = 2.21 Btu/h.ft².F
		U_{female} = 1.64 Btu/h.ft².F
Frame Projected Width	L_f = 3.75 in	L_{male} = 1.51 in
		L_{female} = 2.24 in
Edge Effect Male Side	U_{e1} = 0.37 Btu/h.ft².F	
Edge Effect Female Side	U_{e2} = 0.37 Btu/h.ft².F	

5.3.2 Stack Joint (1/D310)

In the following, the THERM model and results are presented graphically

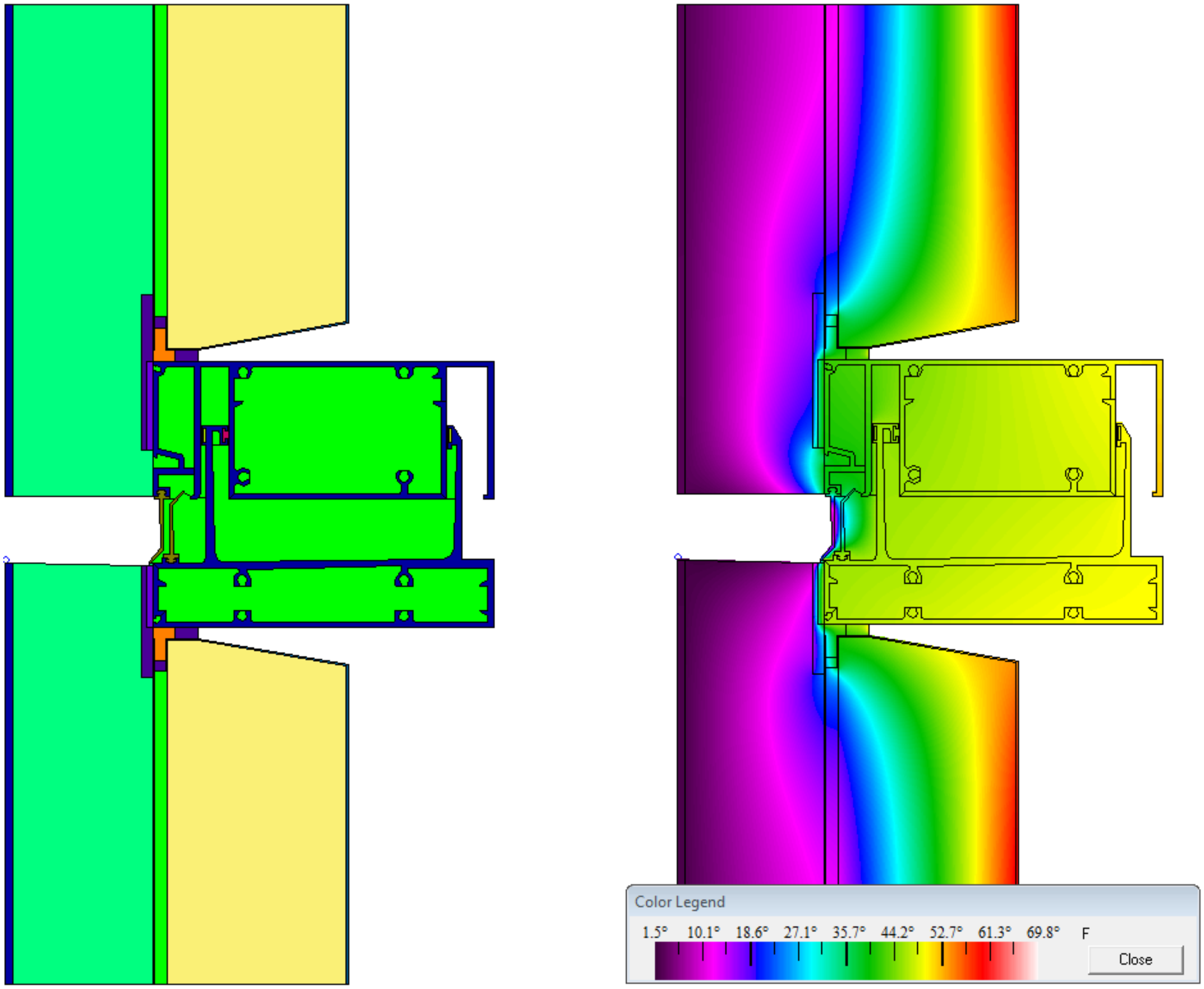


Figure 4: Stack Joint 1/D310: Model Geometry (Left) and Temperature Distribution (Right)
(External Temperature -0.4°F - Internal Temperature 69.8°F)

Results of Calculation:

<table>
<tr><td rowspan="2">Two Dimensional Frame Thermal Transmittances</td><td rowspan="2">U_f = 1.23 Btu/h.ft².F</td><td>U_{gutter} = 0.75 Btu/h.ft².F</td></tr>
<tr><td>U_{sill} = 0.1.26 Btu/h.ft².F</td></tr>
<tr><td rowspan="2">Frame Projected Width</td><td rowspan="2">L_f = 5.96 in</td><td>L_{gutter} = 4.53 in</td></tr>
<tr><td>L_{sill} = 3.09 in</td></tr>
<tr><td>Edge Effect Gutter Side</td><td colspan="2">U_{e1} = 0.32 Btu/h.ft².F</td></tr>
<tr><td>Edge Effect Sill Side</td><td colspan="2">U_{e2} = 0.32 Btu/h.ft².F</td></tr>
</table>

5.4 Overall U-Value

Area weighting of the U-values of frame sections and center-of-spandrel is used to calculate the overall frame U-value for WT-37 calculation.

Components	U-Value (Btu/h.ft².F)	Area (in²)	Area (ft²)	U * A
Mullion Spandrel Area	1.87	1157.81	8.04	15.06
Left/Male Edge	0.37	729.58	5.07	1.88
Right/Female Edge	0.37	729.58	5.07	1.88
Stack	1.23	813.54	5.65	6.94
Sill Edge	0.32	328.75	2.28	0.74
Gutter Edge	0.32	328.75	2.28	0.72
Spandrel	0.05	18142.00	125.99	6.35
Totals	0.00	22230.00	154.38	33.57

Overall U-Value	0.22	(Btu/h.ft².F)

Table 5: Overall Thermal Transmittance of Wall Type 37

6 CONDENSATION ASSESSMENT

The minimum internal surface temperature of the curtain wall has been assessed for each model using THERM 6.3 software using the specified Boundary Conditions. The absolute Minimum Temperature in the surface was found to be $t_{si,min}$=43.5°F on the frame mullion (see following table).

Components	Dew Point Temperature (°F)	Minimum Surface Temperature (°F)	Maximum Allowed Relative Humidity (%)
1/D351 Mullion	42.7	43.5	**35.8**
1/D310 Stack Joint		47.9	42.4

Table 6: Condensation Assessment for Typical Details

With internal temperature of 72°F and Relative Humidity of 35% RH the Dew Point Temperature is 42.7°F. For the given Boundary Conditions, condensation will not occur on the interior surface of the façade and the performance is acceptable. Following THERM models of some critical sections are presented along with the Dew Point Isothermal Line as well as a temperature distribution for the specified Boundary Conditions.

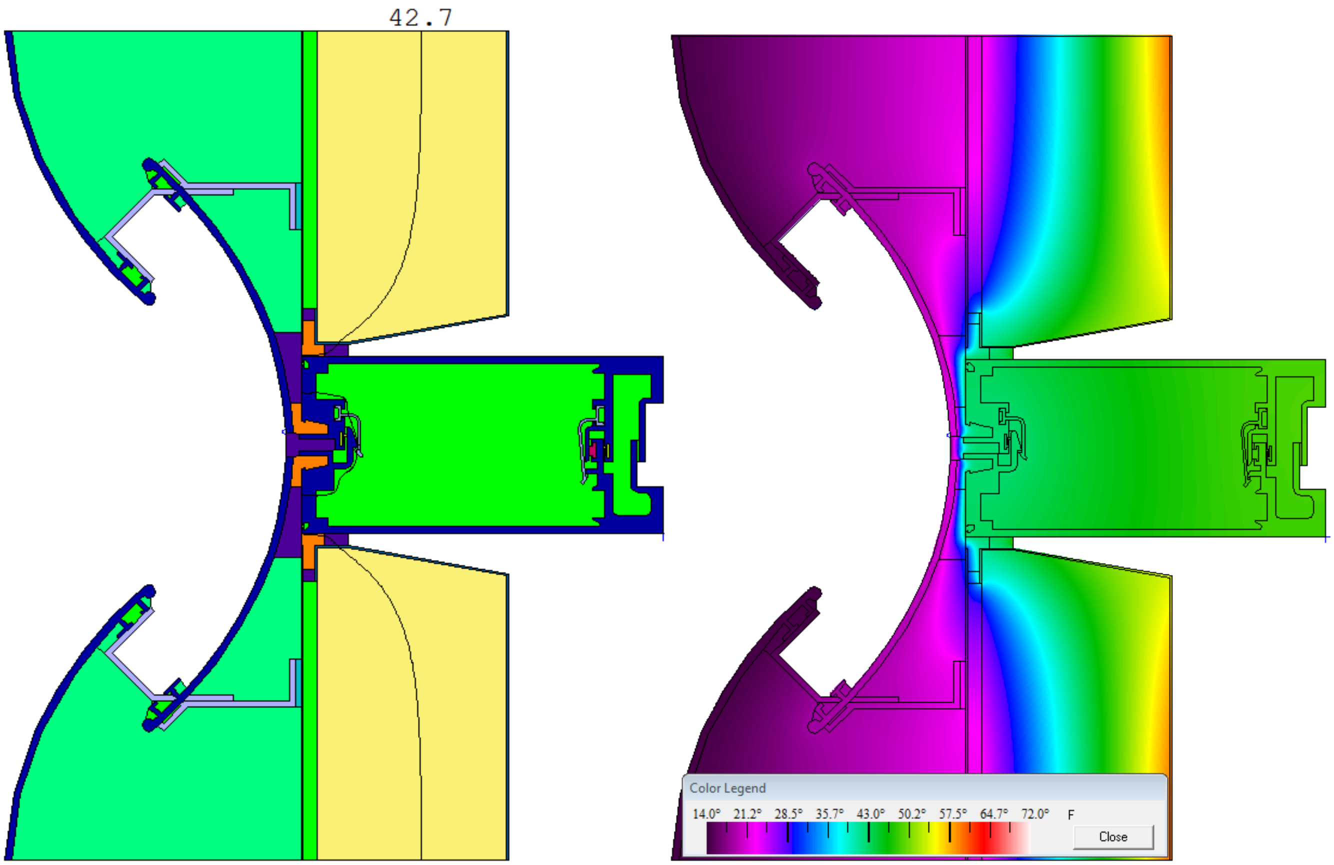


Figure 5: 1/D351 Mullion: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right)
(External Temperature 13°F - Internal Temperature 72°F)

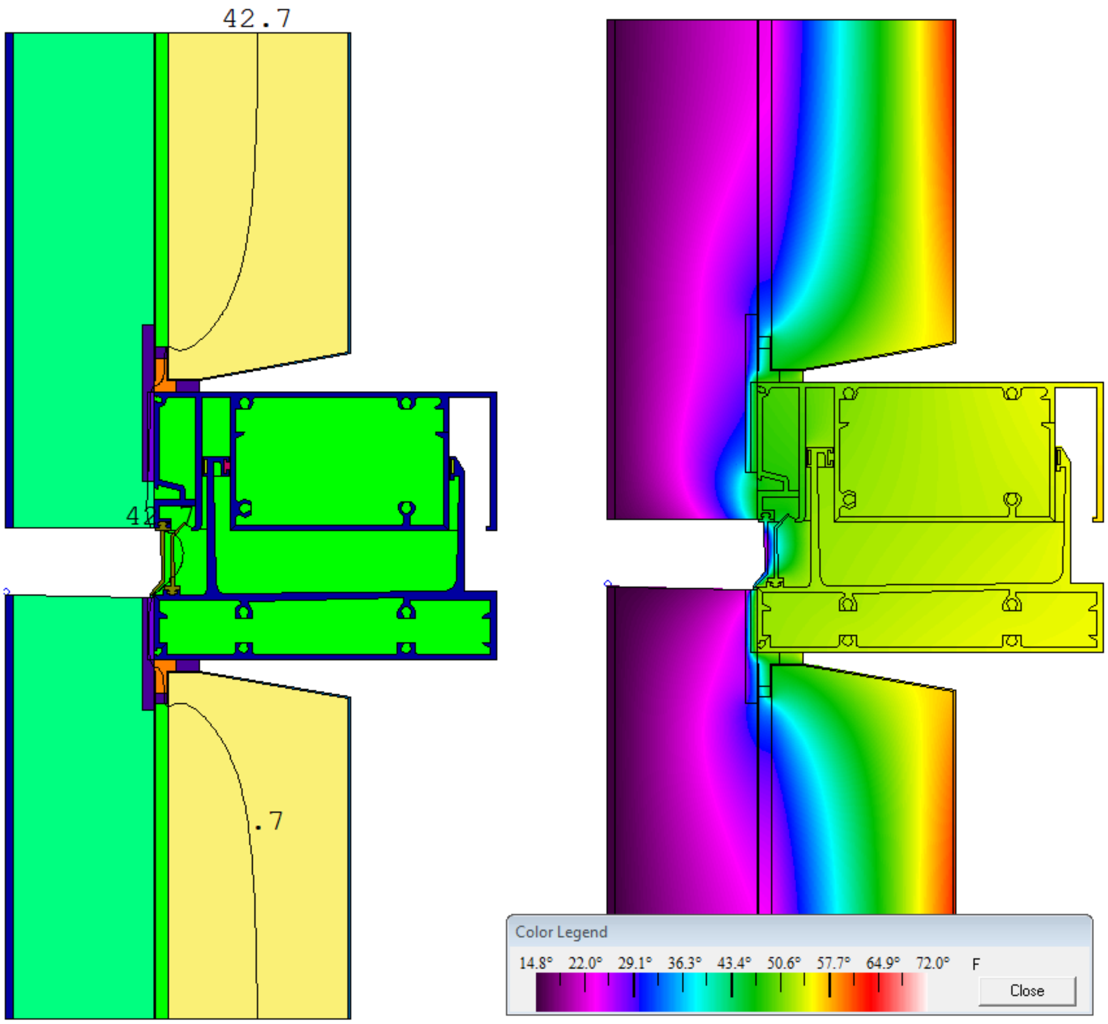


Figure 6: 1/D310 Stack Joint: Model Geometry with Dew Point Line (Left) and Temperature Distribution (Right)
(External Temperature 13°F - Internal Temperature 72°F)

REFERENCES

ASHRAE	ASHRAE Handbook of Fundamentals 1998-2001, American Society of Heating, Refrigerating, and Air-Conditioning Engineering, Atlanta, GA, USA, 2004.
ISO 6946: 2007	Building components and building elements - Thermal resistance and thermal transmittance - Calculation method
ISO 10077-1: 2006	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 1: General
ISO 10077-2: 2003	Thermal performance of windows, doors and shutters - Calculation of thermal transmittance - Part 2: Numerical method for frames
ISO 10211: 2007	Thermal bridges in building construction - Heat flows and surface temperatures - Detailed calculations
ISO 13788:2001	Hydrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods
ISO 15099: 2003	Thermal performance of windows, doors and shading devices - Detailed calculations
NFRC 100: 2010	Procedure for Determining Fenestration Product U-Factors.
THERM	THERM 6.3 Program description. Windows and Daylighting Group. Lawrence Berkeley National Laboratory, 2002.

5.4 Overall U-Value

Area weighting of the U-values of frame sections and center-of-spandrel is used to calculate the overall frame U-value for WT-37 calculation.

Components	U-Value (Btu/h.ft².F)	Area (in²)	Area (ft²)	U * A
Mullion Spandrel Area	1.87	1157.81	8.04	15.06
Left/Male Edge	0.37	729.58	5.07	1.88
Right/Female Edge	0.37	729.58	5.07	1.88
Stack	1.23	813.54	5.65	6.94
Sill Edge	0.32	328.75	2.28	0.74
Gutter Edge	0.32	328.75	2.28	0.72
Spandrel	0.05	18142.00	125.99	6.35
Totals	0.00	22230.00	154.38	33.57

Overall U-Value	**0.22**	(Btu/h.ft².F)

Table 5: Overall Thermal Transmittance of Wall Type 37

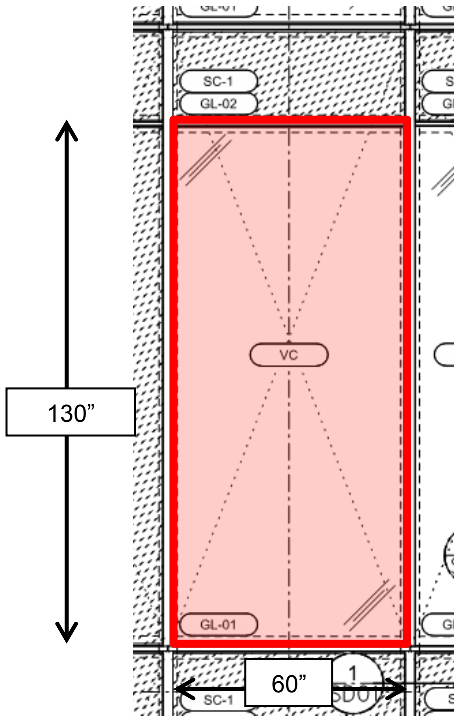


Figure 18: Typical Vision Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Spandrel	1.25	601.90	4.18	5.22
Left Section	0.23	308.13	2.14	0.49
Right Section	0.37	308.13	2.14	0.79
Transom - Spandrel / Vision	0.98	235.32	1.63	1.60
Top Section	0.27	132.18	0.92	0.25
Bottom Section	0.35	132.18	0.92	0.32
Vision Glass	0.28	6082.18	42.24	11.83
Totals		7800	54	20.51

Vision U-Value	0.38	[Btu/h.ft².F]

Table 6: Wall Type A Vision U-Value

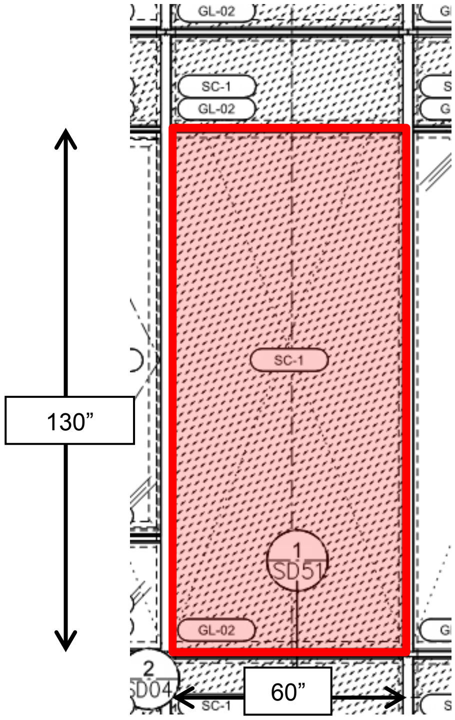


Figure 19: Typical Spandrel Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Dart Mullion - Spandrel / Spandrel	0.14	601.90	4.18	0.59
Left Section	0.14	308.13	2.14	0.30
Right Section	0.14	308.13	2.14	0.30
Transom - Spandrel / Spandrel	0.55	235.32	1.63	0.90
Top Section	0.35	132.18	0.92	0.32
Bottom Section	0.35	132.18	0.92	0.32
Spandrel Region	0.05	6082.18	42.24	2.11
Totals		7800	54	4.84

Spandrel U-Value	0.09	[Btu/h.ft².F]

Table 7: Wall Type A Spandrel U-Value

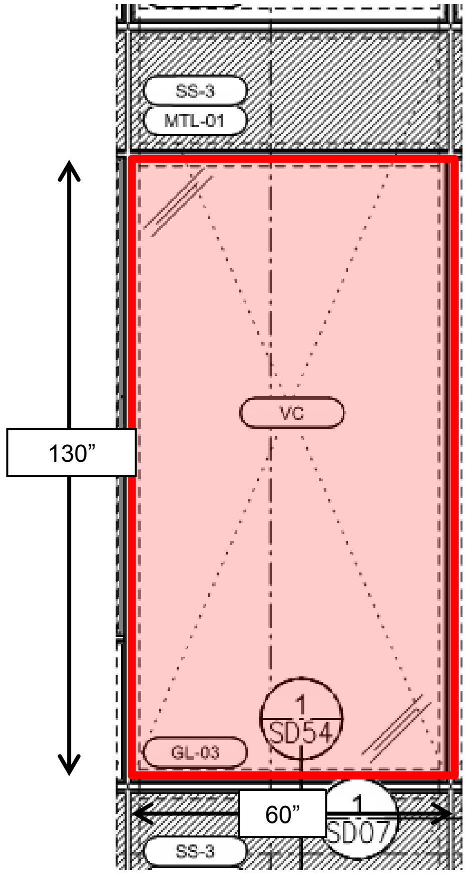


Figure 16: Typical Vision Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Vision	1.05	601.90	4.18	4.39
Left Section	0.35	308.13	2.14	0.75
Right Section	0.35	308.13	2.14	0.75
Transom - Metal / Vision	1.17	235.32	1.63	1.91
Top Section	0.32	132.18	0.92	0.29
Bottom Section	0.36	132.18	0.92	0.33
Glass Vision	0.28	6082.18	42.24	11.83
Totals		7800	54	20.25

Vision U-Value	0.37	[Btu/h.ft².F]

Table 6: Wall Type B Vision U-Value

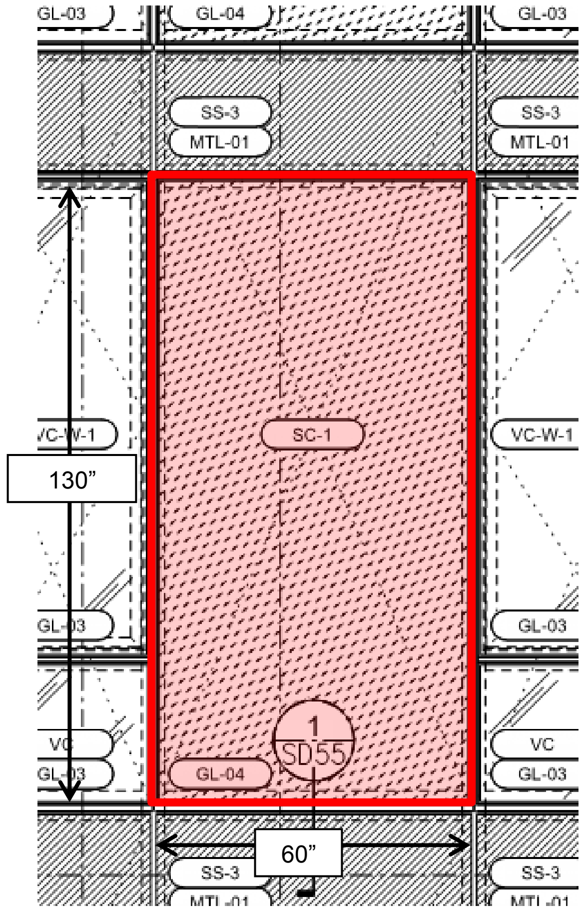


Figure 17: Typical Spandrel Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Spandrel	0.98	601.90	4.18	4.10
Left Section	0.37	308.13	2.14	0.79
Right Section	0.19	308.13	2.14	0.41
Transom - Metal / Spandrel	0.60	235.32	1.63	0.98
Top Section	0.39	132.18	0.92	0.36
Bottom Section	0.38	132.18	0.92	0.35
Spandrel Region	0.05	6082.18	42.24	2.11
Totals		7800	54	9.09

Overall U-Value	0.17	[Btu/h.ft².F]

Table 7: Wall Type B Spandrel U-Value

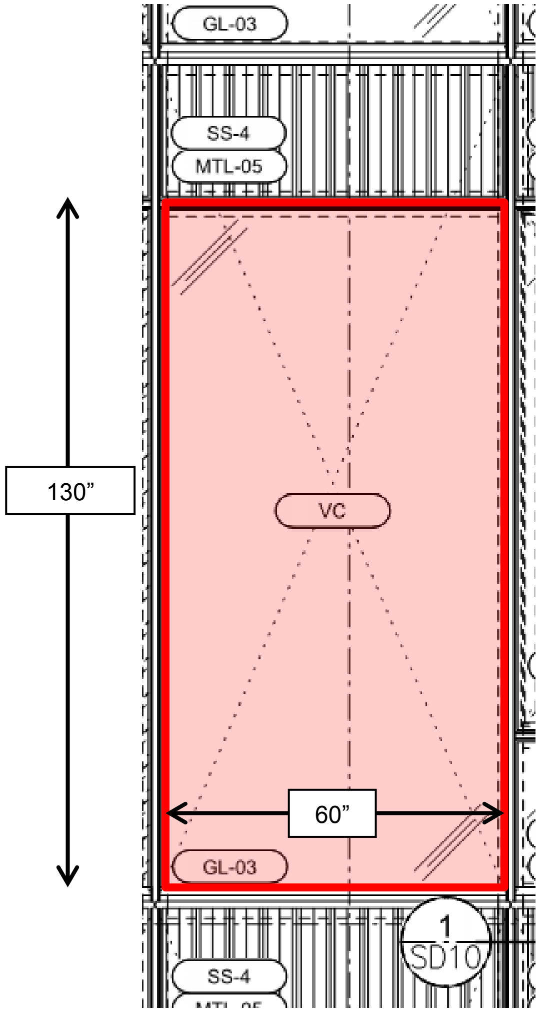


Figure 16: Typical Vision Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Vision / Vision	1.05	601.90	4.18	4.39
Left Section	0.35	308.13	2.14	0.75
Right Section	0.35	308.13	2.14	0.75
Transom - Metal / Vision	1.21	235.32	1.63	1.98
Top Section	0.33	132.18	0.92	0.30
Bottom Section	0.36	132.18	0.92	0.33
Glass Vision	0.28	6082.18	42.24	11.83
Totals		7800	54	20.32

Vision U-Value	0.38	[Btu/h.ft².F]

Table 6: Wall Type E Vision U-Value

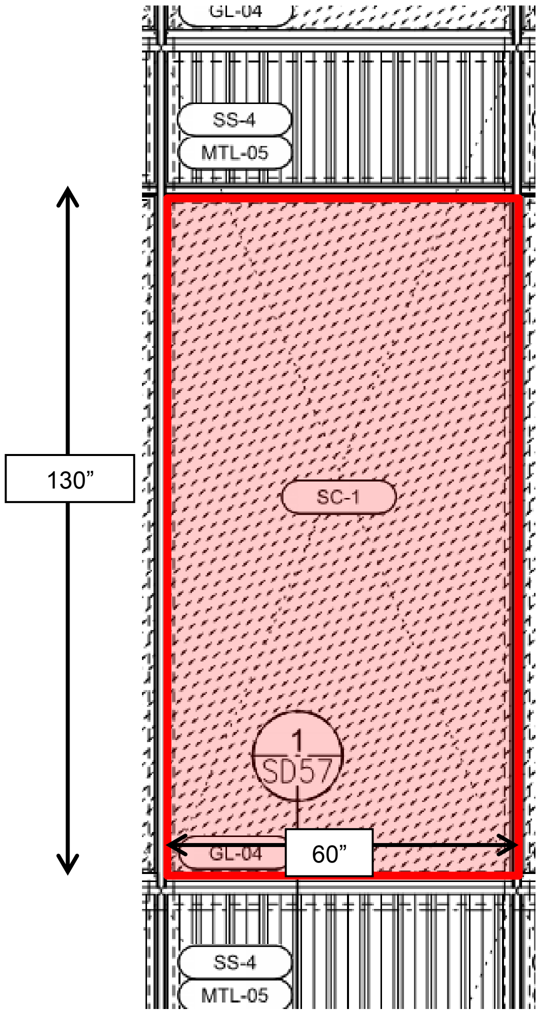


Figure 17: Typical Spandrel Unit

Components	U-Value [Btu/h.ft².F]	Area [in²]	Area [ft²]	U * A
Mullion - Spandrel / Spandrel	0.63	601.90	4.18	2.63
Left Section	0.24	308.13	2.14	0.51
Right Section	0.24	308.13	2.14	0.51
Transom - Metal / Spandrel	0.64	235.32	1.63	1.05
Top Section	0.41	132.18	0.92	0.38
Bottom Section	0.40	132.18	0.92	0.37
Glass Vision	0.04	6082.18	42.24	1.69
Totals		7800	54	7.14

Spandrel U-Value	0.13	[Btu/h.ft².F]

Table 7: Wall Type E Spandrel U-Value