3 SAINT MARKS

3 SAINT MARKS, NY

THERMAL ANALYSIS OF MOCK UP

IBAR-INT-ST-23-UFC-13-R5

DATE: 06/06/2023

UNITED FACADE

Revision Notes

Date	Revision	Description
04.17.23	0	First Submittal
04.24.23	1	Therm Calculation
05.17.23	2	Remark Revisions
05.19.23	3	Therm version revision
05.24.23	4	Added materials list
06.06.23	5	Boundary Condition Revision

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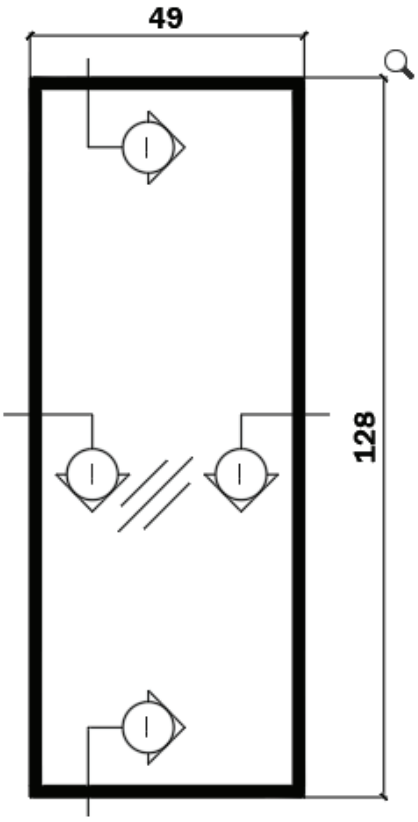
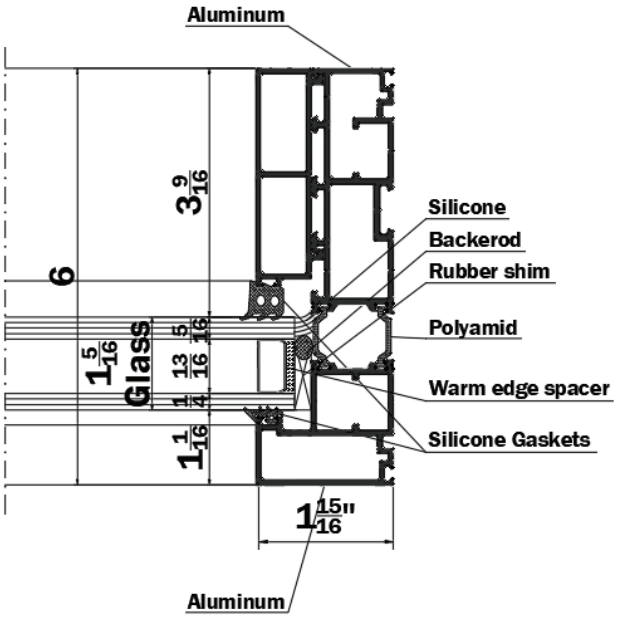
1. INTRODUCTION

This report presents condensation risk assessment and U Value analysis of unitized window wall system for 3 Saint Marks, NY.





1.1. Referenced Standards and Norms

Condensation risk assessment and U Value analysis is based on the standards which are given below.

ISO 15099	Thermal Performance of windows, doors and shading devices
NFRC 100	Procedure for Determining Fenestration Product U-factors
NFRC 200	Procedure for Fenestration Product Solar Heat Gain Coefficient and Visible Transmittance at Normal Incidence
NFRC 500	Procedure for Determining Fenestration Product Condensation Resistance Values
Relevant standards	All standards included in the technical specifications

1.2. Technical Features in terms of Building Physics

Boundary conditions and initial conditions of the analysis is indicated below.

Outdoor temperature	: 14°F
Indoor temperature	: 72°F
Relative humidity (RH)	: 30 %
Dewpoint	: 60 °F

Temperature Difference for U Value Calculation : 69.8 °F -0.4 °F = 70.2 °F

Glass U winter (λ) **:** 0.247 BTU/hr-ft-°F

Used software for thermal analysis	: Therm 7.8.55 and Window 8.0

Table 4-2 – Boundary Conditions

Boundary Condition	Radiation Model	Convective Film Coefficient Boundary	
		Tilt = 90° W/m²K (Btu/h·ft²·°F)	Tilt = 20° W/m²K (Btu/h·ft²·°F)
NFRC 100-2001 Exterior	Blackbody	26.00 (4.578)	26.00 (4.578)
Interior Aluminum Frame (convection only)	Automatic Enclosure Model	3.29 (0.579)	4.65 (0.819)
Interior Thermally Broken Frame (convection only)	Automatic Enclosure Model	3.00 (0.528)	4.09 (0.720)
Interior Thermally Improved Frame (convection only)	Automatic Enclosure Model	3.12 (0.549)	4.32 (0.761)
Interior Wood/Vinyl Frame (convection only)	Automatic Enclosure Model	2.44 (0.429)	3.09 (0.544)
Interior Glazing System boundary condition	Automatic Enclosure Model	Depends on the WINDOW calculations for the imported glazing system	

Boundary Conditions

h_{in} value of interior thermally broken frame is determined as 3.00 W/m^{2}K (0.528 BTU/h.ft^2. °F) by considering Table 4.2.

h_{in} = 3.29 W/m^{2}K (0.579 BTU/h.ft2. °F)

R_{in}= 0.304 m^{2}K/W (1.727 ft^2. °F h / BTU)

Besides, h_{out} value is determined 26 W/m^{2}K as NFRC 100 specifies.

<u>Glazing</u>

Make-up Name	Glass 1 & Coating	Glass 2 & Coating	Visible Light			Solar Energy			Thermal Properties	
			Transmittance	Reflectance		Transmittance	Reflectance	Solar Heat Gain Coefficient (SHGC)	U-Value	
			Visible (τ_v %)	ρ_v % out	ρ_v % in	Solar (τ_e %)	ρ_e % out		Winter Night (Btu/hr·ft²·F)	Summer Day (Btu/hr·ft²·F)
Default Make-up 06	SunGuard ® SN 75 HT (CE) on Guardian UltraClear ® Float Glass (CE)	Guardian UltraClear ® Float Glass (CE)	75	13	14	36	48	0.38	0.247	0.151

Calculation Standard: NFRC 2010

Default Make-up 06

Outdoors

GLASS 1	Guardian UltraClear® Float Glass (CE) Thickness = 1/4" (6mm)	#1 ---- #2 SunGuard® SN 75 HT (CE)
GAP 1	10% Air, 90% Argon, 20mm	
GLASS 2	Guardian UltraClear® Float Glass (CE) Thickness = 3/8" (10mm)	#3 ---- #4 ----

Total Unit (Nominal) = 1 13/32 in Slope = 90° Window Height = 2 meters

Estimated Nominal Glazing Weight: 7.51 lb/ft²

Indoors

August-Roche Magnus Formula;

The Magnus-Tetens formula for the vapor pressure is given by

$$p_w = 0.6105 \cdot e^{(aT/(b+T))} \quad [\text{kPa}] \tag{1.1}$$

with a=17.27

b=237.7 °C

and Td is in °C.

a=6.105 millibar; b=17.27; c=237.7°C: $0°C \leq T \leq +60°C$ $(\pm 0.4°C)$

The relative humidity and vapour saturation pressure have direct relation with the vapor pressure by

$$p_w = RH \cdot p_{ws} \tag{1.2}$$

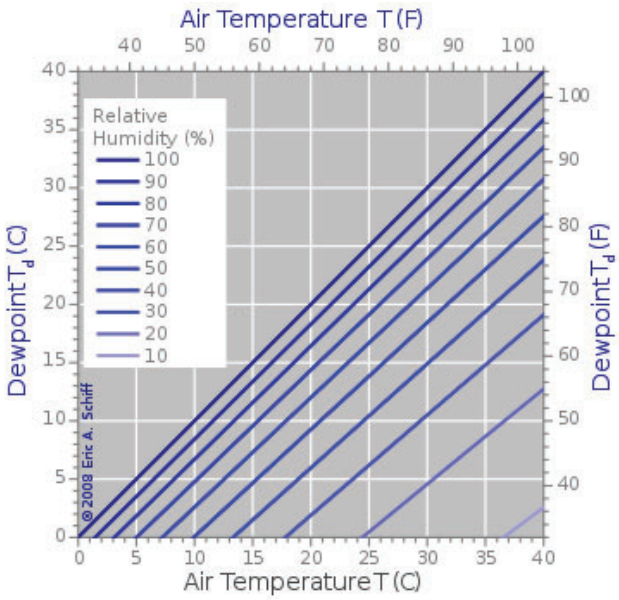
When air is saturated, the air has 100% relative humidity and its temperature is equal to its dew point temperature.

$$\begin{aligned} & p_w = RH \cdot p_{ws} \\ & \Rightarrow 0.6105 \cdot \exp\left[\frac{a \cdot T_d}{b+T_d}\right] = 0.6105 \cdot RH \cdot \exp\left[\frac{a \cdot T}{b+T}\right] \\ & \Rightarrow T_d(T, RH) = \frac{b \cdot \alpha(T, RH)}{a - \alpha(T, RH)} \end{aligned} \tag{1.3}$$

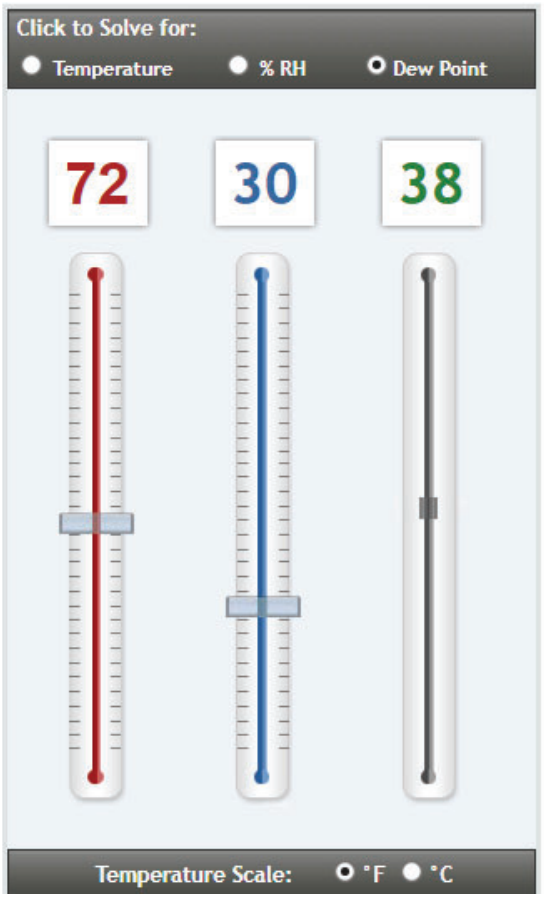
where

$$\alpha(T, RH) = \ln(RH) + \frac{a \cdot T}{b+T} \tag{1.4}$$

Table 1 indicates the corresponding dew points with respect to relative humidity and temperature values according to August-Roche Magnus approach. If temperature of any surface which is in contact with indoor environment is lower than interior dew point, there is condensation formation at the specified surface. Minimum temperature is mostly seen on aluminium profile surface or glass surface.



The change of dew point value according air temperature vs. dew point temperature



1.3. Methodology of Calculation

Calculations is made according to the NFRC norms and ISO 15099. Boundary conditions are defined according to image below.

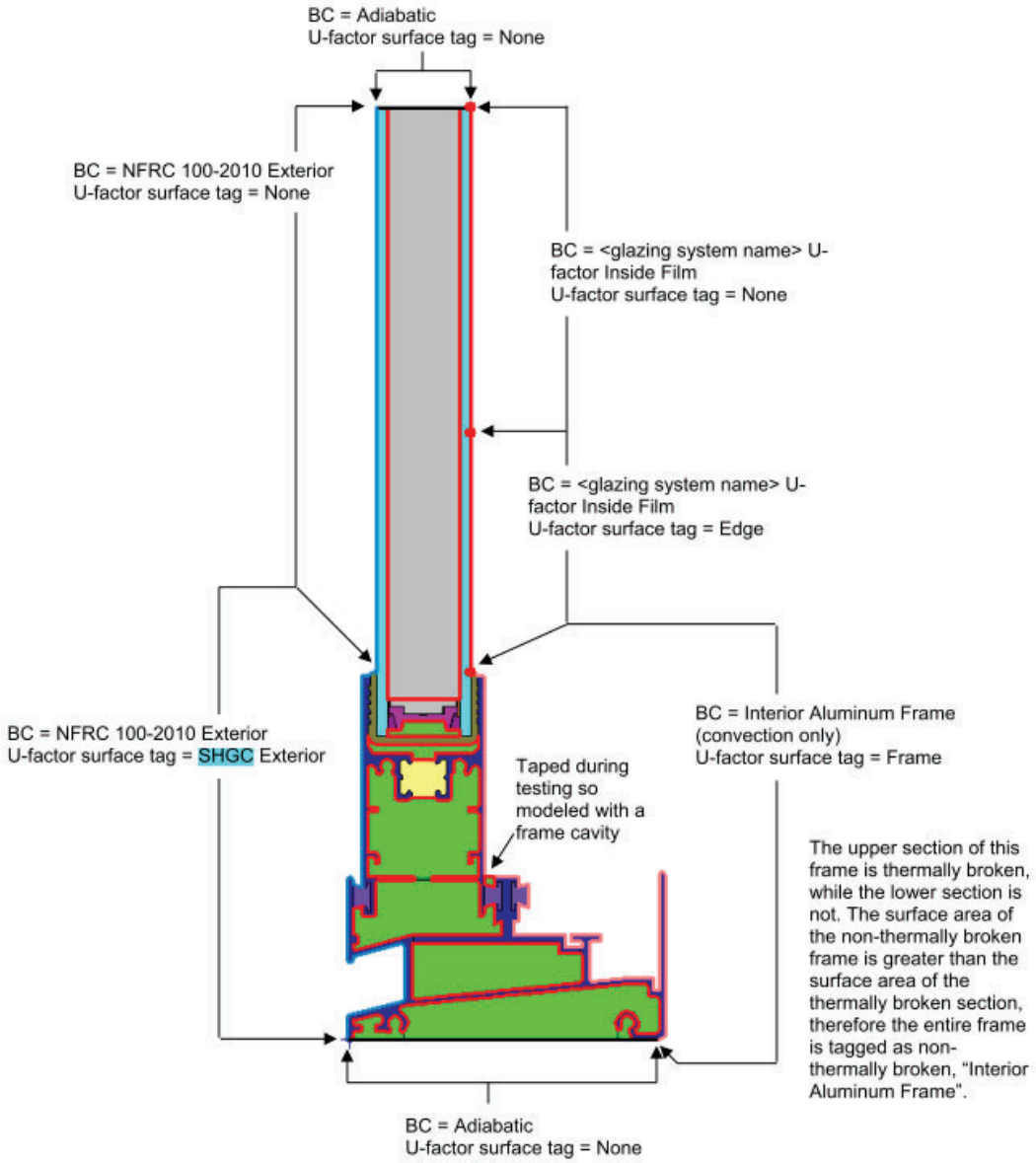


Figure 6-25. Defining the boundary conditions for a cross section.

[4-1]

$$U_t = \frac{\left[\sum(U_f * A_f) + \sum(U_d * A_d) + \sum(U_e * A_e) + \sum(U_{de} * A_{de}) + \sum(U_c * A_c)\right]}{A_{pf}}$$

U_t = Total product U-factor, W/m²-°K , (Btu/hr-ft²-°F).

A_{pf} = Projected fenestration product area, m² (ft²).

U_f = Frame U-factor, W/m²-°K , (Btu/hr-ft²-°F).

A_f = Frame area, m² (ft²).

U_d = Divider U-factor, W/m²-°K , (Btu/hr-ft²-°F).

A_d = Divider area, m² (ft²).

U_e = Edge-of-glazing U-factor, W/m²-°K , (Btu/hr-ft²-°F).

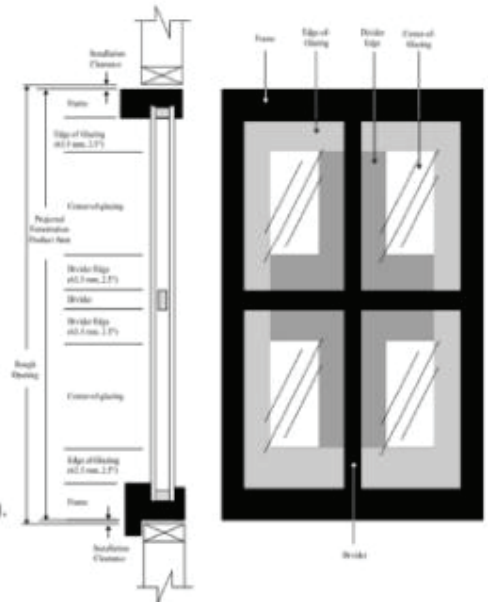
A_e = Edge-of-glazing area, m² (ft²).

U_{de} = Edge-of-divider U-factor, W/m²-°K , (Btu/hr-ft²-°F).

A_{de} = Edge-of-divider Area, m² (ft²).

U_c = Center-of-glazing U-factor, W/m²-°K , (Btu/hr-ft²-°F).

A_c = Center-of-glazing area in ft² (m²).



Overall SHGC

$$SHGC = SHGC_0 + SHGC_c(SHGC_1 - SHGC_0) \qquad \text{Equation 4-1}$$

Where

$SHGC_0$ = The total fenestration product SHGC for the center-of glazing SHGC of 0.0

$SHGC_1$ = The total fenestration product SHGC for the center-of-glazing SHGC of 1.0

Overall VT

$$VT = VT_0 + VT_c(VT_1 - VT_0) \qquad \text{Equation 4-2}$$

Where

VT_0 = The total fenestration product VT for the center-of-glazing VT of 0.0

VT_1 = The total fenestration product VT for the center-of-glazing VT of 1.0

1.4. MATERIALS

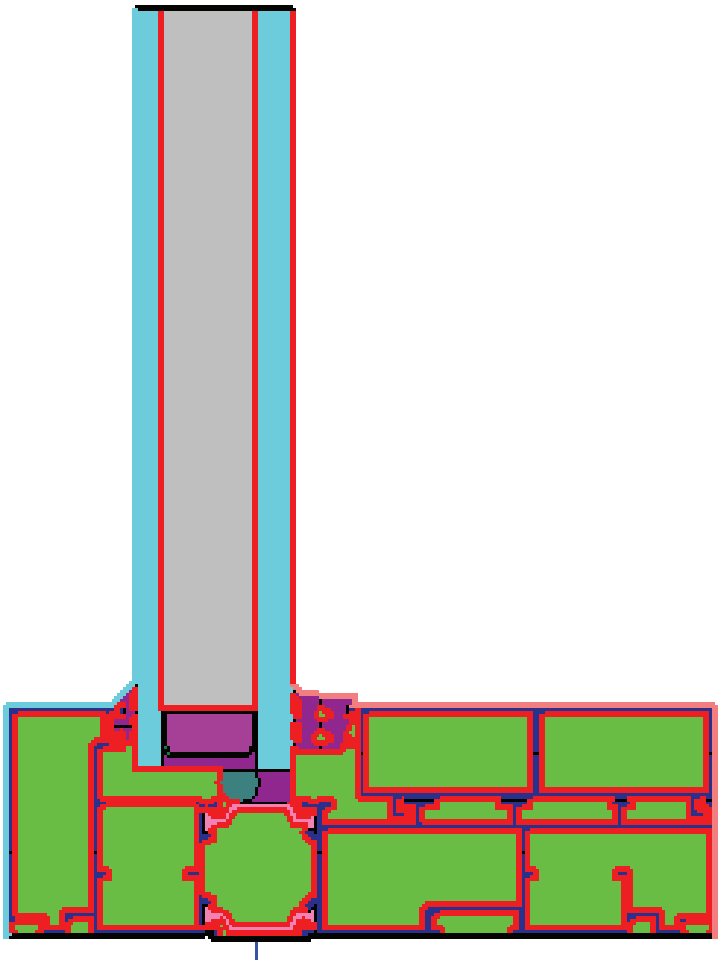
1.4. **MATERIALS**

Materials			
Name	Conductivity Btu/h-ft-F	Emissivity	Colour
Silicone-Gasket	0.202	0.9	
Aluminium Alloy (painted)	92.446	0.9	
Technoform warm edge space-polypropylene	0.098	0.9	
Polyamide	0.173	0.9	
Backing Rod	0.029	0.9	

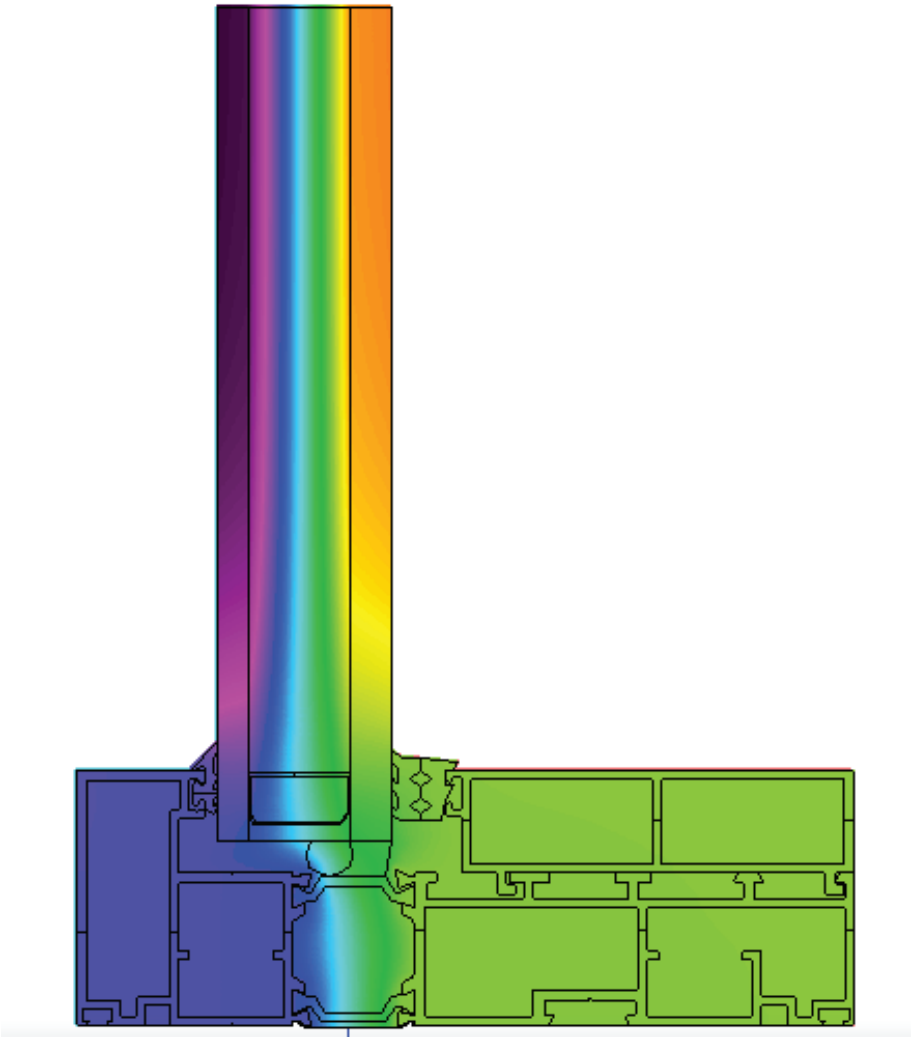
2. ASSESSMENT OF VISION FRAME PROFILES

2.1. CONDENSATION

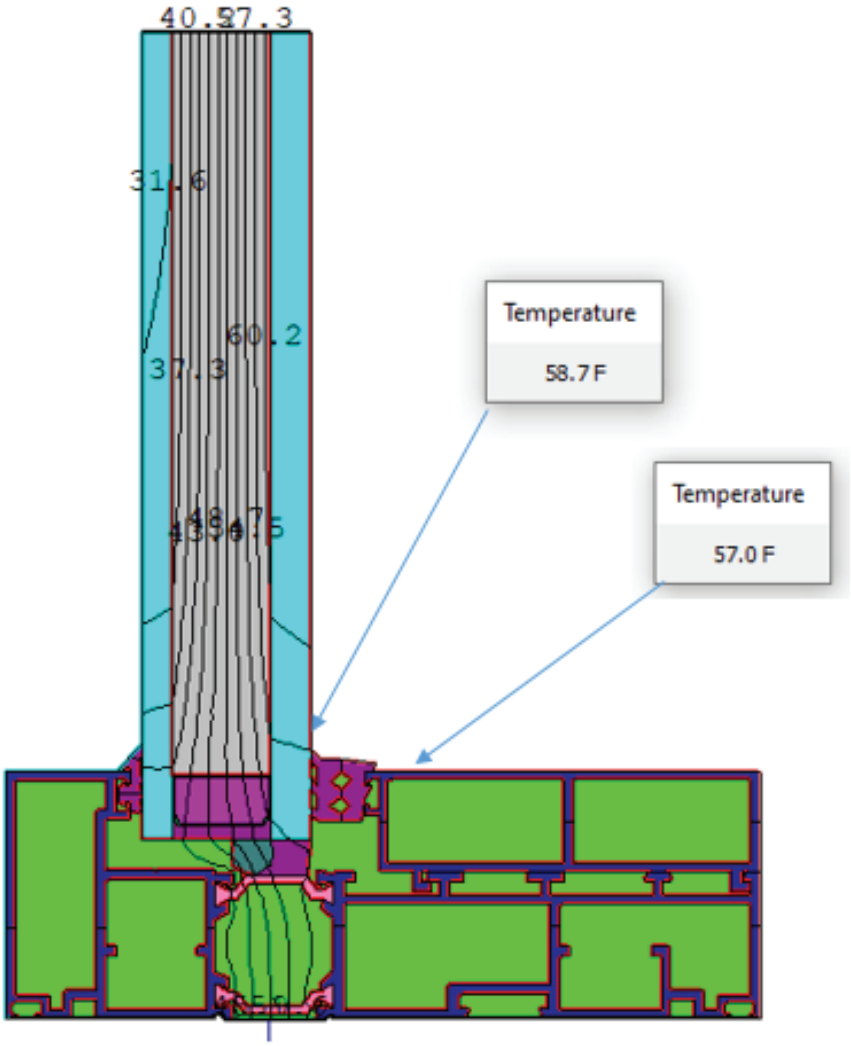
2.1.1. Detail-1



Detail



Temperature Distribution Plot



Temperature Distribution of the Profile with Isothermal Lines (Imperial Units)

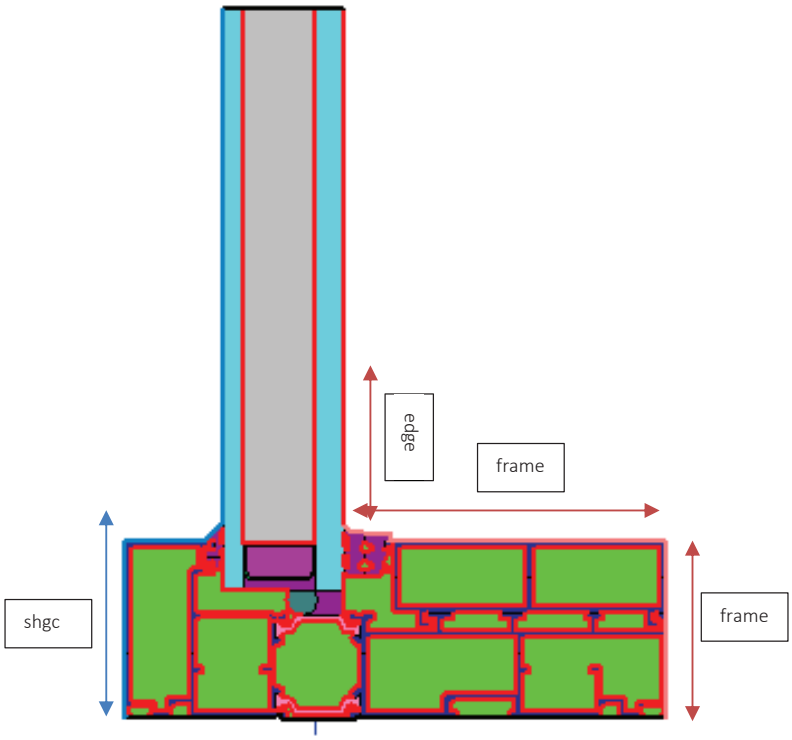
Result :

Minimum temperature on glass surface = 58.7°F > 38.0°F There is no condensation

Minimum temperature on aluminum surface = 57.0°F > 38.0°F There is no condensation

2.2. U VALUE

2.2.1. Detail-1



U-Factors

	U-factor Btu/h-ft2-F	delta T F	Length inches	Rotation
Frame	0.4388	70.2	2.16055	90.0
SHGC Exterior	0.4813	70.2	2.19022	90.0
Edge	0.2979	70.2	2.49954	90.0

Display
(•) U-factor
( ) R-value

% Error Energy Norm 9.34%

U-Factors

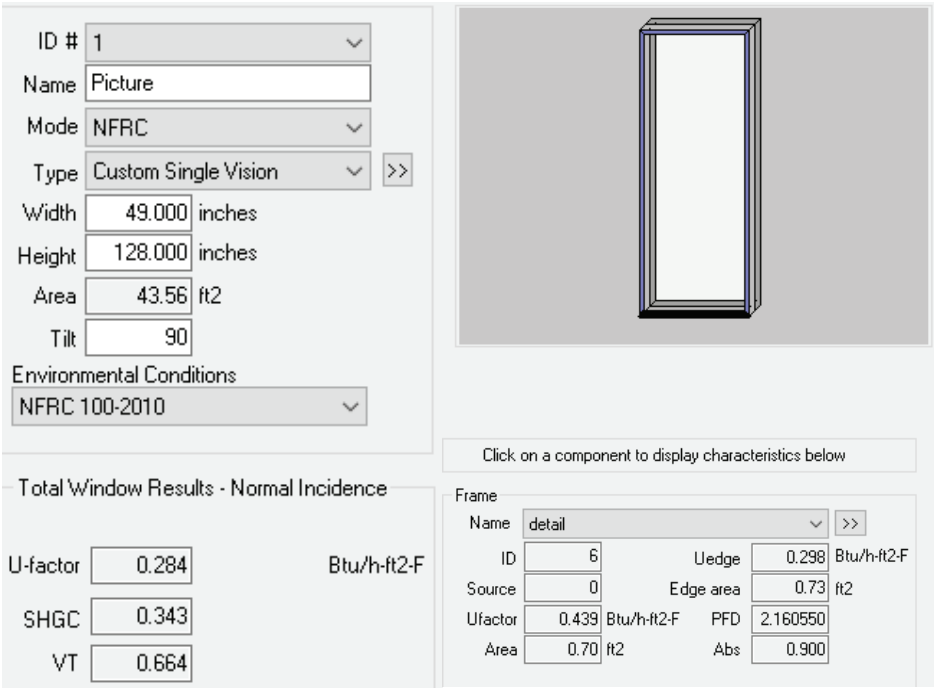
3. CONCLUSION

There is a condensation in all detail. The overall U and the Shgc calculation result value are shown below.

Uw : 0.284 btu/h.ft²F

Shgc : 0.343

VT : 0.664



4. APPENDIX

APPENDIX A BASIC SET OF GENERIC THERMOPHYSICAL PROPERTY VALUES OF MATERIALS

Table A.1: Thermophysical Properties of Solid Materials

Name	Conductivity k			Source[1]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Elastomers					
Butadiene	0.250	0.144	1.733	1,15	0.9
Butyl rubber (isobutene, solid/hot melt)	0.240	0.139	1.664	1,3	0.9
Expanded rubber (rigid)	0.032	0.018	0.222	2	0.9
Ethylene propylene diene monomer (EPDM)	0.250	0.144	1.733	1	0.9
Foam Rubber	0.060	0.035	0.416	1	0.9
Neoprene (polychloroprene)	0.230	0.133	1.595	1	0.9
Polyisobutylene (PIB)	0.200	0.116	1.387	1,15	0.9
Polysulphide	0.400	0.231	2.773	1,15	0.9
Polymers					
PVB	0.224	0.129	1.553	13	0.9
Polyamide (PA 66/Nylon – 25% glass fill)	0.300	0.173	2.080	15	0.9
Polyamide (Nylon – no fill)	0.250	0.144	1.733	15	0.9
Polycarbonate	0.200	0.116	1.387	1	0.9
Polypropylene	0.220	0.127	1.525	1	0.9
Polystyrene	0.160	0.092	1.109	1	0.9
Polytetrafluoroethylene(PTFE)	0.250	0.144	1.733	1	0.9
Polyurethane	0.250	0.144	1.733	1	0.9
Polyurethane foam	0.050	0.029	0.347	1	0.9
Polyvinylchloride (PVC) flexible	0.140	0.081	0.971	1	0.9
PVC/Vinyl (rigid)	0.170	0.098	1.179	1	0.9
Silicone	0.350	0.202	2.427	1	0.9
Polyurethane (urethane) thermal break	0.210	0.121	1.456	1	0.9
Composites					
Fiberglass	0.300	0.173	2.080	9	0.9
Timbers					
Coniferous woods (Softwoods)	0.140	0.081	0.971	4	0.9
Deciduous woods (Hardwoods)	0.160	0.092	1.109	4	0.9

Name	Conductivity k			Source[1]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Wood based panels					
Fiberboard	0.140	0.081	0.971	1	0.9
Particleboard	0.180	0.104	1.248	1	0.9
Plywood	0.240	0.139	1.664	1	0.9
Metals					
Aluminum alloys (mill finish)	160.000	92.446	1109.357	1,12	0.05
Aluminum alloys (anodized)	160.000	92.446	1109.357	1,12	0.8
Aluminum alloys (painted)	160.000	92.446	1109.357	1	0.9
Steel (plated)	50.000	28.890	346.674	1,6	0.05
Steel (painted)	50.000	28.890	346.674	1	0.9
Steel (rolled, ground)	50.000	28.890	346.674	1, 6	0.1
Steel (rolled, ground, plated)	50.000	28.890	346.674	1, 6	0.2
Steel Stainless (oxidized)	17.000	9.822	117.869	1, 6	0.8
Steel Stainless (buffed)	17.000	9.822	117.869	1, 6	0.2
Steel-galvanized sheet (0.14%C)	52.0	30.045	360.541	6, 17	0.2
Steel-galvanized sheet (0.14%C) (painted)	52.0	30.045	360.541	6, 17	0.9
Glazing Materials					
Glass, Soda-Lime (Plate or Float)	1.000	0.578	6.933	1	0.84
Glass mosaic	1.200	0.693	8.320	1	0.84
Glass-Flint (lead)	1.400	0.809	9.707	2	0.84
Glass-Quartz	1.400	0.809	9.707	1	0.9
Acrylic sheet	0.200	0.116	1.387	1	0.9
Insulating Materials					
Cellulosic fiber, loose fill	0.046	0.027	0.319	2	0.9
Cotton fiber	0.042	0.024	0.291	2	0.9
Expanded perlite, organic bonded	0.052	0.030	0.361	2	0.9
Expanded Polystyrene (EPS)	0.038	0.022	0.261	1	0.9
Extruded Polystyrene (XPS)	0.034	0.020	0.236	1	0.9
Felt	0.050	0.029	0.347	2	0.9
Glass fiberboard	0.035	0.020	0.243	2	0.9
Insulation fiberboard	0.049	0.028	0.340	8	0.9
Polyester fiber	0.040	0.023	0.277	1	0.9
Rock and slag wool batts	0.037	0.021	0.257	2	0.9
Vermiculite	0.077	0.044	0.532	10	0.9

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Name	Conductivity k			Source[1]	Emissivity ε
	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F	-	-
Miscellaneous					
Foam glass	0.040	0.023	0.277	1, 11	0.9
Mohair (polyester) sweep	0.140	0.081	0.971	15	0.9
Desiccated matrix – butyl based	0.130	0.075	0.901	1	0.9
Desiccant–molecular sieve	0.100	0.058	0.693	14	0.9
Paints	N/A	N/A	N/A	-	0.9

[1] Numbers listed in this column refer to documents listed in Section 10.2
[2] Values are for 6% moisture content, see Appendix D. This value may be applied to products of any moisture content for the purposes of this document.

Table A.2: Thermophysical Properties of Gases (Source 5)

	Conductivity $k = a + bT+cT^2$ [W/m•K]			Dynamic Viscosity $\mu = a + bT+cT^2$ [kg/m•s]		
Gas	**Coefficient a** [W/m•K]	**Coefficient b** [W/m•K^2]	**Coefficient c** [**W/m•K^3**]	**Coefficient a** [kg/m•s]	**Coefficient b** [kg/m•s•K]	**Coefficient c** [kg/m•s•K^2]
Air*	$2.873x10^{-3}$	$7.760x10^{-5}$	0	$3.723x10^{-6}$	$4.94x10^{-8}$	0
Argon	$2.285x10^{-3}$	$5.149x10^{-5}$	0	$3.379x10^{-6}$	$6.451x10^{-8}$	0
Krypton	$9.443x10^{-4}$	$2.826x10^{-5}$	0	$2.213x10^{-6}$	$7.777x10^{-8}$	0
Xenon	$4.538x10^{-4}$	$1.723x10^{-5}$	0	$1.069x10^{-6}$	$7.414x10^{-8}$	0
CO_2	$-5.8181x10^{-3}$	$7.4714x10^{-5}$	0	$8.5571x10^{-7}$	$4.7143x10^{-8}$	0
SF_6	$1.300x10^{-2}$	0	0	$7.214x10^{-7}$	$4.928x10^{-8}$	0
Helium	$4.524x10^{-2}$	$3.6947x10^{-4}$	0	$5.951x10^{-6}$	$4.664x10^{-8}$	0
Neon	$1.567x10^{-3}$	$1.089x10^{-4}$	0	$1.014x10^{-5}$	$7.045x10^{-8}$	0
Octaflouropropane	$-1.576x10^{-3}$	$1.804x10^{-5}$	$9.830x10^{-8}$	$-2.009x10^{-6}$	$5.475x10^{-8}$	$-2.054x10^{-11}$

*Note: Nitrogen shall be treated as air

	Specific Heat $Cp = a + bT + cT^2$ [J/kg•K] -				Molecular Mass
Gas	**Coefficient a** [J/kg•K]	**Coefficient b** [J/kg•K^2]	**Coefficient c** [J/kg•K^3]		Mass [kg/kmol]
Air*	$1.00274x10^3$	$1.2324x10^{-2}$	0		28.97
Argon	$5.21929x10^2$	0	0		39.948
Krypton	$2.48091x10^2$	0	0		83.80
Xenon	$1.58340x10^2$	0	0		131.30
CO_2	$5.76903x10^2$	$9.18088x10^{-1}$	0		44.01
SF_6	$4.1860X10^2$	0	0		146.10
Helium	$5.1965x10^3$	0	0		4.000
Neon	$1.03042x10^3$	0	0		20.180
Octaflouropropane	$6.332x10^2$	$-3.805x10^{-1}$	$3.119x10^{-3}$		188.02

*Note: Nitrogen shall be treated as air.

APPENDIX B EXTENDED SET OF GENERIC THERMOPHYSICAL PROPERTY VALUES OF MATERIALS

Table B.1: Thermophysical Properties of Solid Materials

Name	Density[1] (ρ)	Conductivity (k)			Source[2]	Emissivity (ε)
	kg/m³	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F		-
Elastomers						
Hard rubber (ebonite), solid	1200	0.170	0.098	1.179	1, 16	0.9
Natural rubber	910	0.130	0.075	0.901	1, 16	0.9
Rubber, Neoprene	146	0.036	0.021	0.246	10	0.9
Vulcanized rubber, hard	1190	0.160	0.092	1.109	2	0.9
Vulcanized rubber, soft	1100	0.100	0.058	0.693	2	0.9
Polymers						
ABS (extruded)	1200	0.200	0.116	1.387	20	0.9
ABS (molded)	3500	0.190	0.110	1.318	20	0.9
Acrylic	1050	0.200	0.116	1.387	1	0.9
Cellular Polyvinylchloride (cPVC)	577-705	0.067	0.039	0.462	19	0.9
Elastomeric foam, flexible	60-80	0.050	0.029	0.347	1	0.9
Epoxy resin	1200	0.200	0.116	1.387	1	0.9
Phenolic resin	1300	0.300	0.173	2.080	1	0.9
Polyacetate	1410	0.300	0.173	2.080	1	0.9
Polyester resin	1400	0.300	0.110	1.317	1	0.9
Polyethylene/polythene HD (high density	980	0.500	0.289	3.467	1	0.9
Polyethylene/polythene LD (low density	920	0.330	0.191	2.288	1	0.9
Polyethylene foam	70	0.050	0.029	0.347	1	0.9
Polymethylmethacrylate (PMMA)	1180	0.180	0.104	1.248	1	0.9
Polypropylene with 25% glass fiber	1200	0.250	0.144	1.733	1	0.9
Polyurethane foam, low density, open cell	10	0.042	0.024	0.291	2	0.9
Polyurethane foam, closed cell, aged 180 days	51	0.029	0.017	0.201	2	0.9
Silicone, filled	1450	0.500	0.289	3.467	1	0.9

Name	Density[1] (ρ)	Conductivity (k)			Source[2]	Emissivity (ε)
	kg/m³	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F		-
Timbers[3]						
Balsa	140	0.060	0.035	0.416	4	0.9
Birch, yellow	660	0.160	0.092	1.109	4	0.9
Redwood, old growth	410	0.110	0.064	0.763	2	0.9
Redwood, new growth	370	0.100	0.058	0.693	4	0.9
Cedar, Atlantic white	340	0.090	0.052	0.624	4	0.9
Cedar, Eastern red	480	0.120	0.069	0.832	4	0.9
Cedar, Northern white	310	0.090	0.052	0.624	4	0.9
Cedar, Port-Orford	430	0.110	0.064	0.763	4	0.9
Cedar, Western red	330	0.090	0.052	0.624	4	0.9
Cedar, yellow	460	0.120	0.069	0.832	4	0.9
Cypress, bald	470	0.120	0.069	0.832	4	0.9
Elm, American	540	0.140	0.081	0.971	4	0.9
Elm, Rock	670	0.170	0.098	1.179	4	0.9
Elm, Slippery	560	0.140	0.081	0.971	4	0.9
Fir, balsam	370	0.100	0.058	0.693	4	0.9
Fir, white	410	0.110	0.064	0.763	4	0.9
Douglas-fir, coast	510	0.130	0.075	0.901	4	0.9
Douglas-fir, interior north	500	0.130	0.075	0.901	4	0.9
Douglas-fir, interior west	520	0.130	0.075	0.901	4	0.9
Hemlock, eastern	420	0.110	0.064	0.763	4	0.9
Hemlock, western	480	0.120	0.069	0.832	4	0.9
Larch (western)	560	0.140	0.081	0.971	4	0.9
Mahogany	550	0.130	0.075	0.901	2, 7	0.9
Maple, black	600	0.150	0.087	1.040	4	0.9
Maple, red	560	0.140	0.081	0.971	4	0.9
Maple, silver	500	0.130	0.075	0.901	4	0.9
Maple, sugar	660	0.160	0.092	1.109	4	0.9
Oak, black	660	0.160	0.092	1.109	4	0.9
Oak, bur	660	0.160	0.092	1.109	4	0.9
Oak, Northern red	650	0.160	0.092	1.109	4	0.9
Oak, Southern red	620	0.150	0.087	1.040	4	0.9
Oak, white	720	0.180	0.104	1.248	4	0.9
Pine, Eastern white	370	0.100	0.058	0.693	4	0.9
Pine, jack	450	0.120	0.069	0.832	4	0.9
Pine, loblolly	540	0.140	0.081	0.971	4	0.9
Pine, lodgepole	430	0.110	0.064	0.763	4	0.9
Pine, longleaf	620	0.150	0.087	1.040	4	0.9
Pine, pitch	530	0.130	0.075	0.901	4	0.9
Pine, ponderosa	420	0.110	0.064	0.763	4	0.9

Name	Density[1] (ρ)	Conductivity (k)			Source[2]	Emissivity (ε)
	kg/m³	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F		-
Pine, Radiata	500	0.120	0.069	0.832	4	0.9
Pine, red	460	0.120	0.069	0.832	4	0.9
Pine, shortleaf	540	0.140	0.081	0.971	4	0.9
Pine, slash	610	0.150	0.087	1.040	4	0.9
Pine, sugar	370	0.100	0.058	0.693	4	0.9
Pine, Western white	400	0.110	0.064	0.763	4	0.9
Spruce, black	430	0.110	0.064	0.763	4	0.9
Spruce, Engelmann	370	0.100	0.058	0.693	4	0.9
Spruce, red	420	0.110	0.064	0.763	4	0.9
Spruce, Sitka	420	0.110	0.064	0.763	4	0.9
Spruce, white	370	0.100	0.058	0.693	4	0.9
Wood based panels						
Cement-bonded particleboard	1200	0.230	0.133	1.595	1	0.9
Cement-bonded wood wool panels	500	0.100	0.058	0.693	1	0.9
Cement-bonded wood wool panels	700	0.140	0.081	0.971	1	0.9
Fiberboard (medium density, dry process)	250	0.070	0.040	0.485	1	0.9
Fiberboard (medium density, dry process)	400	0.100	0.058	0.693	1	0.9
Fiberboard (medium density, dry process)	600	0.140	0.081	0.971	1	0.9
Fiberboard (medium density, dry process)	800	0.180	0.104	1.248	1	0.9
Oriented strand board (OSB)	650	0.130	0.075	0.901	1	0.9
Particleboard	300	0.100	0.058	0.693	1	0.9
Particleboard	600	0.140	0.081	0.971	1	0.9
Particleboard	900	0.180	0.104	1.248	1	0.9
Plywood	300	0.090	0.052	0.624	1	0.9
Plywood	500	0.130	0.075	0.901	1	0.9
Plywood	700	0.170	0.098	1.179	1	0.9
Plywood	1000	0.240	0.139	1.664	1	0.9
Insulating Materials						
Aerogel – Silica	73	0.024	0.014	0.166	10	0.9
Cellular glass	136	0.051	0.029	0.354	2	0.9

Name	Density[1] (ρ)	Conductivity (k)			Source[2]	Emissivity (ε)
	kg/m³	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F		-
Cellulose, sprayed into open cavities	42	0.040	0.023	0.277	10	0.9
Cellulosic fiber	56	0.040	0.023	0.277	2	0.9
Glass fiber, batts	8.2	0.048	0.028	0.333	2	0.9
Glass fiber, batts	12	0.043	0.025	0.298	2	0.9
Glass fiber, batts	14	0.039	0.023	0.027	2	0.9
Glass fiber (semi-rigid) Sheathing	-	0.034	0.020	0.236	2	0.9
Glass fiber (spray applied)	16	0.042	0.024	0.291	2	0.9
Glass wool	50-60	0.033	0.019	0.229	1	0.9
Mineral fiber-low density (rock, slag, glass)	64	0.042	0.024	0.291	2	0.9
Phenolic foam board with facing	-	0.023	0.013	0.159	2	0.9
Polyisocyanurate-unfaced, aged	37	0.025	0.014	0.173	2	0.9
Polyisocyanurate – foil-faced, aged	-	0.023	0.013	0.159	2	0.9
Polystyrene expanded, molded beads (EPS)	16	0.037	0.021	0.257	2	0.9
Polystyrene expanded, molded beads (EPS)	24	0.035	0.020	0.243	2	0.9
Polystyrene expanded, molded beads (EPS)	29	0.033	0.019	0.229	2	0.9
Polyester fiber	25	0.038	0.022	0.263	1	0.9
Polyester fiber	35	0.036	0.021	0.250	1	0.9
Polyester fiber	45	0.035	0.020	0.243	1	0.9
Polyurethane foam, HFC 245fa blown	31	0.020	0.012	0.139	18	0.9
Polyurethane foam, HFC 134a blown	-	0.023	0.013	0.159	18	0.9
Polyurethane foam, cyclopentane blown	-	0.020	0.012	0.139	18	0.9
Straw thatch	240	0.070	0.040	0.485	2	0.9
Masonry Materials						
Concrete – medium density	1,800	1.15	0.664	7.974	1	0.90
Concrete – high density	2,400	2.00	1.156	13.867	1	0.90
Concrete – reinforced (2% steel)	2,400	2.50	1.444	17.334	1	0.90
Brick, Fired clay – high density	2,400	1.47	0.849	10.192	2	0.90
Brick, Fired clay – medium density	1,600	0.74	0.428	5.131	2	0.90

Name	Density[1] (ρ)	Conductivity (k)			Source[2]	Emissivity (ε)
	kg/m³	W/m•K	Btu/hr•ft•F	Btu•in/hr•ft²•°F		-
Brick, Fired clay – low density	1,120	0.45	0.260	3.120	2	0.90
Gypsum plasterboard	640	0.160	0.092	1.109	2	0.90
Metals						
Aluminum	2700	237	136.94	1643.24	8	0.9
Aluminum alloy 195 cast (4.5 Cu)	2790	168	97.07	1164.83	8	0.9
Aluminum alloy 2024 T6 (4.5 Cu, 1.5 Mg, 0.6 Mn)	2770	177	102.27	1227.23	8	0.9
Aluminum alloy 1100-O	2713	221.90	128.21	1538.54	2, 7	0.9
Aluminum alloy 3003-O	2713	163.28	94.34	1132.13	7	0.9
Aluminum alloy 5056-O	2630	117.23	67.73	812.81	7	0.9
Aluminum alloy (96% Al, 1.8% Cu, 0.9% Fe, 0.9% Cr, 0.4% Si)	-	104.67	60.48	725.73	9	0.9
Aluminum bronze (76% Cu, 22% Zn, 2% Al)	8280	100	57.78	693.35	2	0.9
Aluminum bronze (95% Cu, 5% Al)	7800	82.6	47.73	572.71	9	0.9
Bronze	8,700	65	37.56	450.68	1	0.20
Brass	8,400	120	69.34	832.02	1	0.20
Copper	8,900	380	219.56	2634.72	1	0.80
Iron, cast	7,500	50	28.89	346.67	9	0.80
Lead	11,300	35	20.22	242.67	9	0.80
Steel (0.1% Carbon at 0°C)	7850	59	34.09	409.08	9	0.9
Steel (0.2% Carbon at 20°C)	7850	50	28.89	346.67	9	0.9
Steel (0.6% Carbon at 20°C)	7850	46.5	26.87	322.41	9	0.9
Zinc	7200	110	63.56	762.68	17	0.28

[1] Densities shown are nominal values. Densities of actual materials may vary and do not need to be verified by NFRC certified simulators.
[2] Numbers listed in this column refer to documents listed in Section 10.2
[3] Values are for 6% moisture content, see Appendix D. This value may be applied to products of any moisture content for the purposes of this document.