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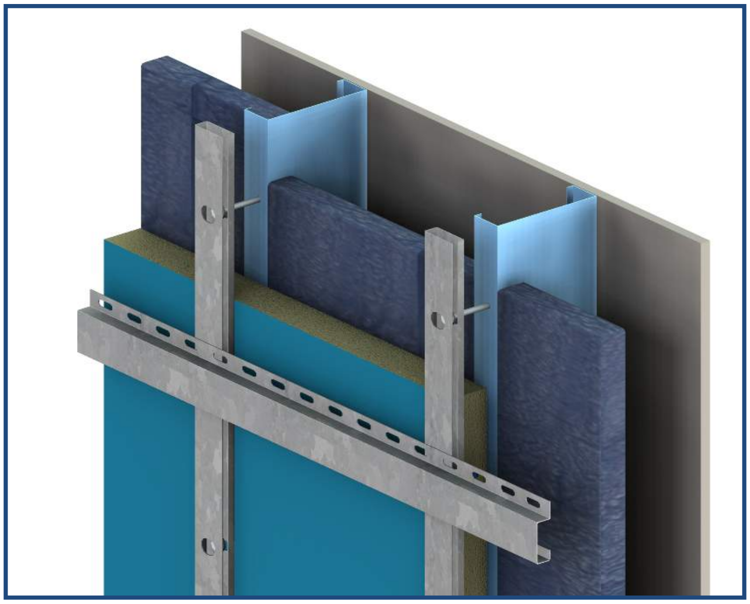
MORRISON HERSHFIELD

3-Dimensional Thermal Analysis of Knight Wall CI Systems



Presented to:

Knight Wall Systems, Inc.
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1. INTRODUCTION AND BACKGROUND

Knight Wall Systems (KWS) manufacture proprietary rain screen cladding and exterior insulation mounting systems. Morrison Hershfield (MH) was contracted by Knight Wall to evaluate the thermal performance, U- and Effective R-Values, of their CI System (Vertical-Girt Continuous Insulation) for a variety of assembly scenarios, including insulation thickness, girt spacing and backup wall configuration. This report is a summary of that analysis.

The CI System, shown in Figures 1 and 2, consists of vertical girts with horizontal panel rails on which the cladding can be mounted. These vertical girts sit outboard of polyiso insulation board and are secured to the substrate by fasteners through the insulation. These fasteners are fitted with head isolators for reducing the contact area for heat flow between the fastener heads and the girts.

Figure 1: *Knight Wall CI Girt and Horizontal Panel Rail (Cut back for Clarity)*

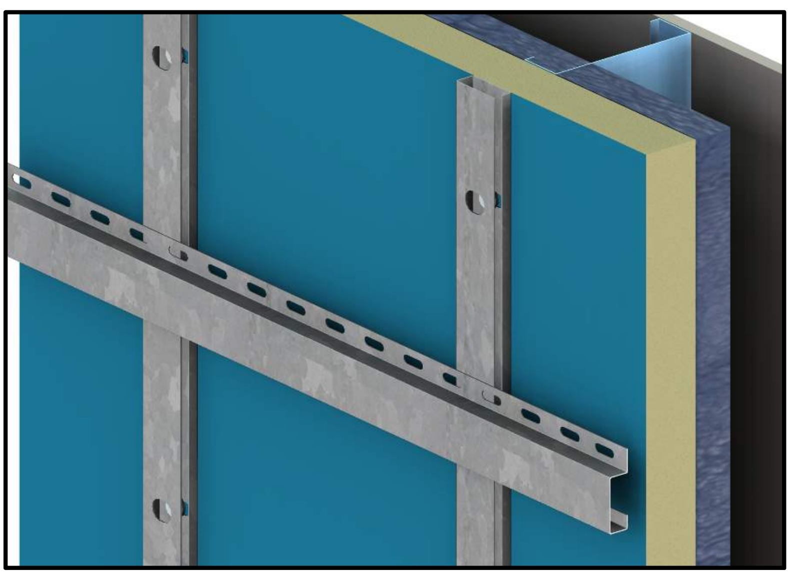
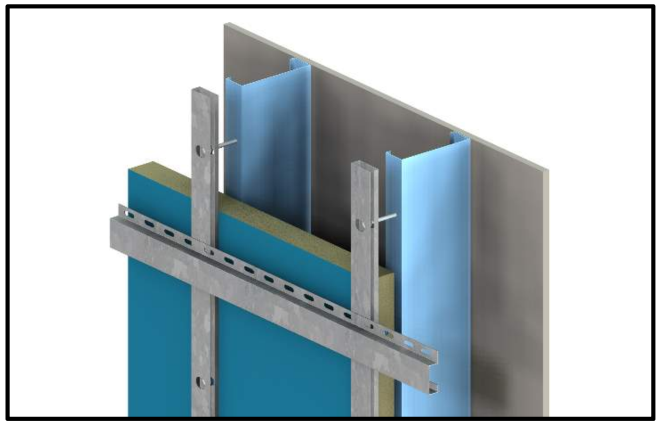


Figure 2: *Knight Wall CI System on Steel Stud Wall Substrate*

The vertical girt and fasteners can support multiple thicknesses of insulation by varying the length of the fastener and can be installed on multiple types of backup walls. For this report, the CI System was analyzed with the following three backup walls for varying thicknesses of exterior polyiso insulation. Fasteners were spaced 16”o.c. horizontally and 8”o.c. and/or 16”o.c. vertically. See further descriptions of each assembly within their respective results in Section 3. Material properties and additional component information can be found in Appendix A.

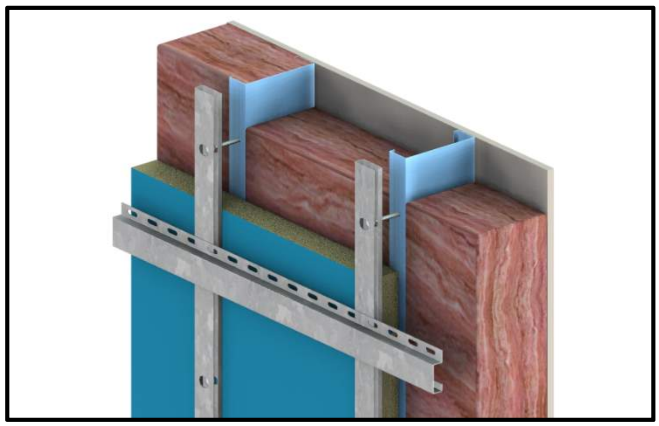
Scenario 1: Steel Stud Backup Wall

- ½” Gypsum
- 6” Steel Stud Cavity, Air Filled
- Exterior Polyiso Insulated Sheathing
- CI Girt Assembly with Stainless Steel Fasteners
- Generic Cladding



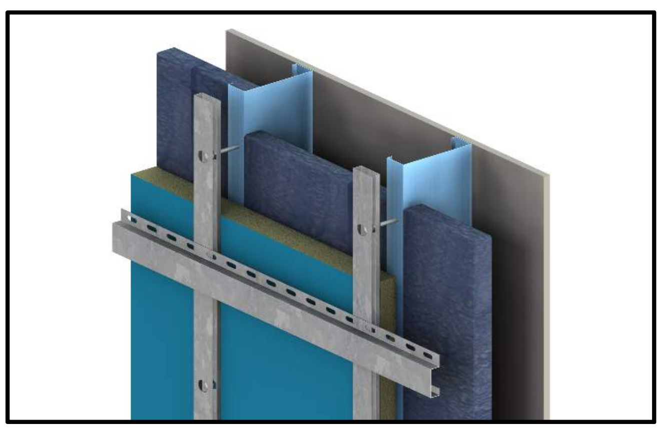
Scenario 2: Steel Stud Backup Wall with R-19 Batt in the insulation cavity

- ½” Gypsum
- Steel Stud Cavity, R-19 Batt Insulation
- Exterior Polyiso Insulated Sheathing
- CI Girt Assembly with Stainless Steel Fasteners
- Generic Cladding



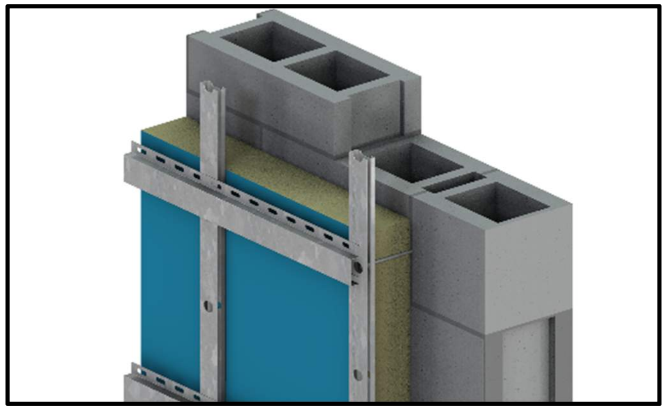
Scenario 3: Steel Stud Backup Wall with Interior Sprayfoam

- ½” Gypsum
- 6” Steel Stud Cavity, 1.5” Sprayfoam (R-9.8)
- Exterior Polyiso Insulated Sheathing
- CI Girt Assembly with Stainless Steel Fasteners
- Generic Cladding



Scenario 4: Concrete Masonry Block Wall

- 8" Concrete Block, Ungrouted Cores
- Exterior Polyiso Insulation
- CI Girt Assembly with Stainless Steel Fasteners
- Generic Cladding



2. MODELING OUTLINE

The thermal modeling for this report was performed using the Nx software package from Siemens, which is a general purpose computer aided design (CAD) and finite element analysis (FEA) software suite. The thermal solver and modeling procedures utilized for this study were extensively calibrated and validated for ASHRAE Research Project 1365-RP "Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction (1365-RP)[1]. This methodology was also used to determine the thermal performance of an extensive amount of building details, including various clip and masonry anchor attachment methods, with comprehensive results presented in the Building Envelope Thermal Bridging Guide[2]. The modeling assumptions are summarized in Appendix B.

3. THERMAL ANALYSIS FOR CI SYSTEM

The following sections provide the U-value and R-value results in tabular form for the evaluated CI System configurations. The tables provide the exterior insulation thickness, nominal R-value of the insulation and the nominal resistance of the assembly (R_{1D} value)[3] for reference. Each table shows the determined assembly U- and effective R-Value that includes the impact of thermal bridging by the structural components, including studs and cladding attachments. Finally, the tables also include the percentage effectiveness of the system, which is a comparison of the effective R-value of the assembly with the CI System and other structural components to the ideal case of the R_{1D} assembly value with no thermal bridging. Example temperature profiles for each scenario are presented in Appendix C.

[1] http://www.morrisonhershfield.com/ashrae1365research/Pages/Insights-Publications.aspx
[2] http://www.bchydro.com/thermalguide
[3] The R_{1D} value is the thermal resistance of the assembly without any thermal bridging. This includes the resistance of planar components in the backup wall, rain screen cavity, cladding and air films. See appendix A for components.

3.1 Scenario 1: Knight Wall CI System with Steel Stud Backup Wall

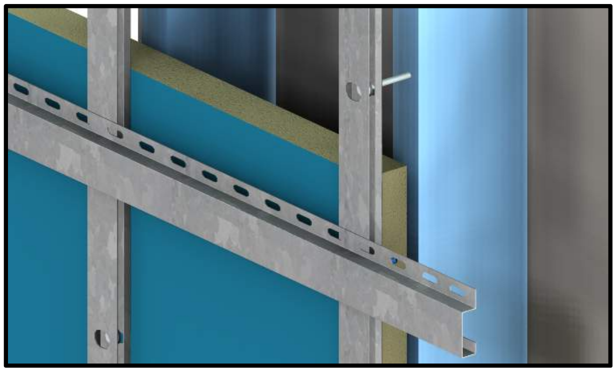


Figure 3: *CI System w/ Steel Stud Backup Wall*

The Knight Wall CI System with a steel stud backup wall (air filled stud cavity) is shown in Figure 3. Clear field U- and R-Values for this scenario are provided below in Table 1. The CI girts were spaced at every stud, 16"o.c. The scenario was analyzed for one vertical spacing of the fasteners and for six thicknesses of polyiso insulation.

Table 1: *Thermal Transmittance and Resistance values for Exterior Steel Stud Wall Assembly with CI System*

Fastener Vertical Spacing	Exterior Polyiso Insulation Thickness	Exterior Insulation Nominal R-Value hr°Fft²/BTU (m²K/W)	Assembly R_{1D} Value hr°Fft²/BTU (m²K/W)	Assembly U-Value BTU/hr°Fft² (W/m²K)	Assembly Effective R-Value hr°Fft²/BTU (m²K/W)	% Effective
16"	1.55"	R-10.1 (1.78)	R-12.8 (2.26)	0.080 (0.46)	**R-12.5 (2.20)**	97%
	2"	R-13.0 (2.29)	R-15.7 (2.77)	0.066 (0.37)	**R-15.3 (2.69)**	97%
	2.5"	R-15.8 (2.78)	R-18.5 (3.26)	0.056 (0.32)	**R-17.9 (3.15)**	97%
	3"	R-19.0 (3.35)	R-21.7 (3.83)	0.048 (0.27)	**R-20.8 (3.65)**	95%
	3.5"	R-22.1 (3.89)	R-24.8 (4.37)	0.042 (0.24)	**R-23.6 (4.16)**	95%
	4"	R-25.2 (4.44)	R-27.9 (4.92)	0.038 (0.22)	**R-26.4 (4.64)**	94%

3.2 Scenario 2: Knight Wall CI System with R-19 Interior Insulated Steel Stud Wall

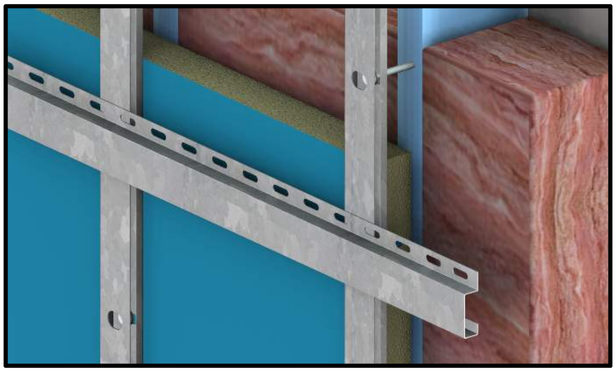


Figure 4: *CI System w/ R-19 Batt Steel Stud Backup Wall*

The Knight Wall CI System with a steel stud backup wall with R-19 interior batt insulation is shown in Figure 4. Clear field U- and R-Values for this scenario are provided below in Table 2. The CI girts were spaced at every stud, 16"o.c. The scenario was analyzed for one vertical spacing of the fasteners and for six thicknesses of polyiso insulation.

Table 2: *Thermal Transmittance and Resistance values for Exterior Steel Stud Wall Assembly with CI System*

Fastener Vertical Spacing	Exterior Polyiso Insulation Thickness	Exterior Insulation Nominal R-Value hr°Fft²/BTU (m²K/W)	Assembly R_{1D} Value hr°Fft²/BTU (m²K/W)	Assembly U-Value BTU/hr°Fft² (W/m²K)	Assembly Effective R-Value hr°Fft²/BTU (m²K/W)	% Effective
16"	1.55"	R-10.1 (1.78)	R-30.9 (5.45)	0.046 (0.26)	**R-21.7 (3.83)**	70%
	2"	R-13.0 (2.29)	R-33.8 (5.96)	0.041 (0.23)	**R-24.4 (4.30)**	72%
	2.5"	R-15.8 (2.78)	R-36.6 (6.45)	0.037 (0.21)	**R-26.9 (4.74)**	74%
	3"	R-19.0 (3.35)	R-39.8 (7.01)	0.034 (0.19)	**R-29.8 (5.24)**	75%
	3.5"	R-22.1 (3.89)	R-42.9 (7.56)	0.031 (0.18)	**R-32.4 (5.71)**	76%
	4"	R-25.2 (4.44)	R-46.0 (8.11)	0.029 (0.16)	**R-35.0 (6.17)**	76%

3.3 Scenario 3: Knight Wall CI System with Steel Stud Wall and Interior Sprayfoam

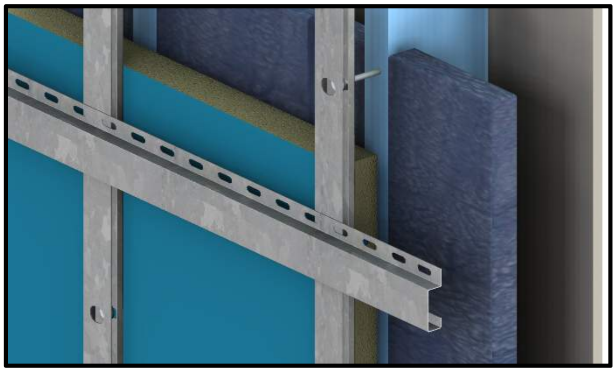


Figure 5: *CI System w/ Steel Stud Backup Wall and Interior Sprayfoam*

The Knight Wall CI System with a steel stud backup wall and interior R-10 sprayfoam is shown in Figure 5. Clear field U- and R-Values for this scenario are provided below in Table 3. The CI girts were spaced at every stud, 16"o.c. The scenario was analyzed for two vertical spacings of the fasteners and for two thicknesses of polyiso insulation.

Table 3: *Thermal Transmittance and Resistance values for Exterior Insulated Steel Stud Wall with Interior Sprayfoam with CI System*

Fastener Vertical Spacing	Exterior Polyiso Insulation Thickness	Exterior Insulation Nominal R-Value hr°Fft²/BTU (m²K/W)	Assembly R_{1D} Value hr°Fft²/BTU (m²K/W)	Assembly U-Value BTU/hr°Fft² (W/m²K)	Assembly Effective R-Value hr°Fft²/BTU (m²K/W)	% Effective
8"	1.55"	R-10.1 (1.78)	R-22.6 (3.98)	0.056 (0.32)	**R-18.0** (3.17)	80%
	3"	R-19.0 (3.35)	R-31.5 (5.64)	0.039 (0.22)	**R-25.6** (4.50)	81%
16"	1.55"	R-10.1 (1.78)	R-22.6 (3.98)	0.053 (0.30)	**R-18.8** (3.32)	83%
	3"	R-19.0 (3.35)	R-31.5 (5.64)	0.037 (0.21)	**R-27.0** (4.76)	86%

3.4 Scenario 4: Knight Wall CI System with Concrete Masonry Unit Wall

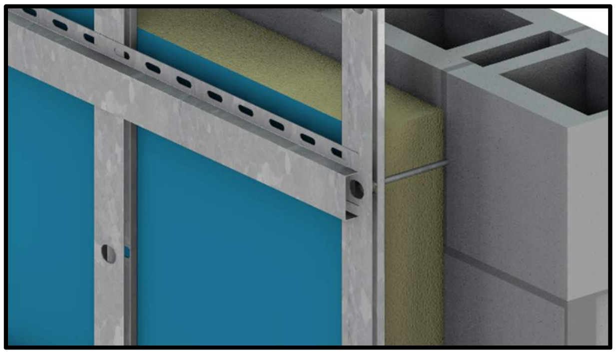


Figure 6: *CI System w/ CMU Backup Wall*

The Knight Wall CI System with a Concrete Masonry Unit Wall is shown in Figure 6. Clear field U- and R-Values for this scenario are provided below in Table 4. The CI girts were spaced at 16"o.c. The scenario was analyzed for one vertical spacing of the fasteners and for three thicknesses of polyiso insulation.

Table 4: *Thermal Transmittance and Resistance values for CMU Backup Wall Assembly with CI System*

Fastener Vertical Spacing	Exterior Polyiso Insulation Thickness	Exterior Insulation Nominal R-Value hr°Fft²/BTU (m²K/W)	Assembly R_{1D} Value hr°Fft²/BTU (m²K/W)	Assembly U-Value BTU/hr°Fft² (W/m²K)	Assembly Effective R-Value hr°Fft²/BTU (m²K/W)	% Effective
16"	1.55"	R-10.1 (1.78)	R-12.7 (2.24)	0.082 (0.47)	**R-12.2** (2.14)	96%
	2.5"	R-15.8 (2.78)	R-18.4 (3.24)	0.058 (0.33)	**R-17.3** (3.05)	94%
	4"	R-25.2 (4.44)	R-27.8 (4.90)	0.039 (0.22)	**R-25.6** (4.50)	92%

4. CONCLUSIONS

In summary, the following information can be gathered from this report regarding the analyzed Knight Wall CI System:

- The CI system with the steel stud backup wall varied between U-0.080 (USI-0.46) and U-0.038 (USI-0.22) for 1.55” to 4” of polyiso insulation respectively with fasteners spaced 16”o.c. vertically. This is a varied effectiveness of the system between 94%-97%.

- The CI system with interior R-19 Batt inuslation and steel stud backup wall varied between U-0.046 (USI-0.26) and U-0.029 (USI-0.16) for 1.55” to 4” of polyiso insulation at 16”o.c. vertical spacing of the fasteners. With interior insulation, the effectiveness varied between 70% and 76%. While these U-values are lower (and effective R-values are higher) than the air filled stud cavity, the “effectiveness” of the system is lower due to the thermal bridging from the steel studs between the interior batt insulation.

- The CI system with interior sprayfoam insulation and steel stud backup wall varied between U-0.056 (USI-0.32) and U-0.037 (USI-0.21) for 1.55” to 3” of polyiso insulation and 8”o.c. or 16”o.c. vertical spacing of the fasteners. With interior sprayfoam, the effectiveness varied between 80% and 86%. Similarly to Scenario 2 with R-19 batt insulation, the effectiveness of the system is lower due to the thermal bridging from the steel studs.

- There is a slight improvement of up to R-1.4, with moving from 8” to 16” vertical spacing of the fasteners for the steel stud wall with interior sprayfoam.

- The CI system with CMU backup wall varies between U-0.082 (USI-0.47) and U-0.039 (USI-0.22) for 1.55” to 4” of polyiso insulation at 16”o.c. vertical spacing of the fasteners. The effectiveness varies between 92% and 96%.

The U-values provided in this report can be used for compliance calculation through any of the compliance paths set forth in relevant energy codes and standards such as ASHRAE 90.1, IECC, and/or NECB.

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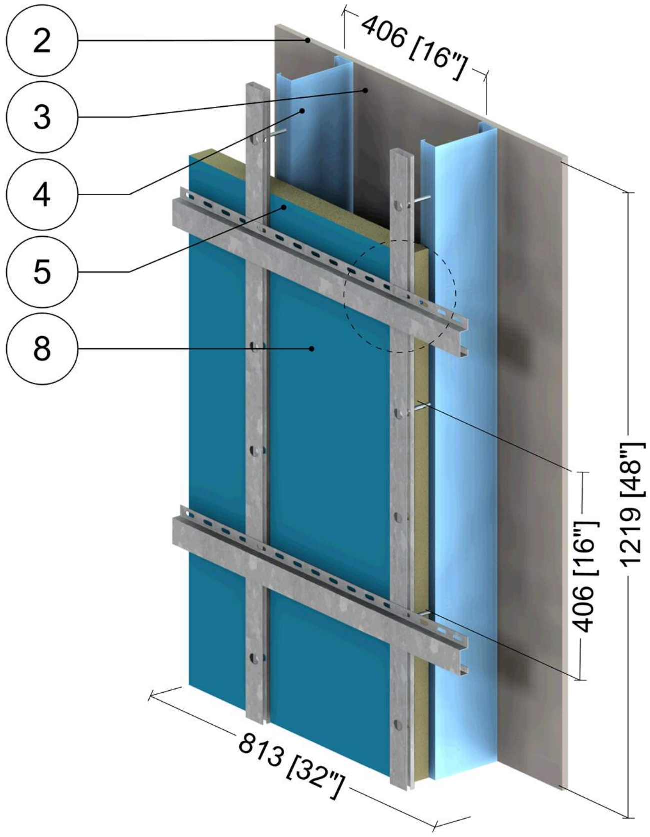
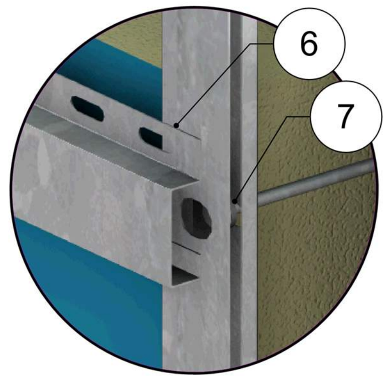
APPENDIX A– ASSEMBLY INFORMATION AND MATERIAL PROPERTIES

Scenario 1

Knight Wall CI System with Steel Stud Backup Wall

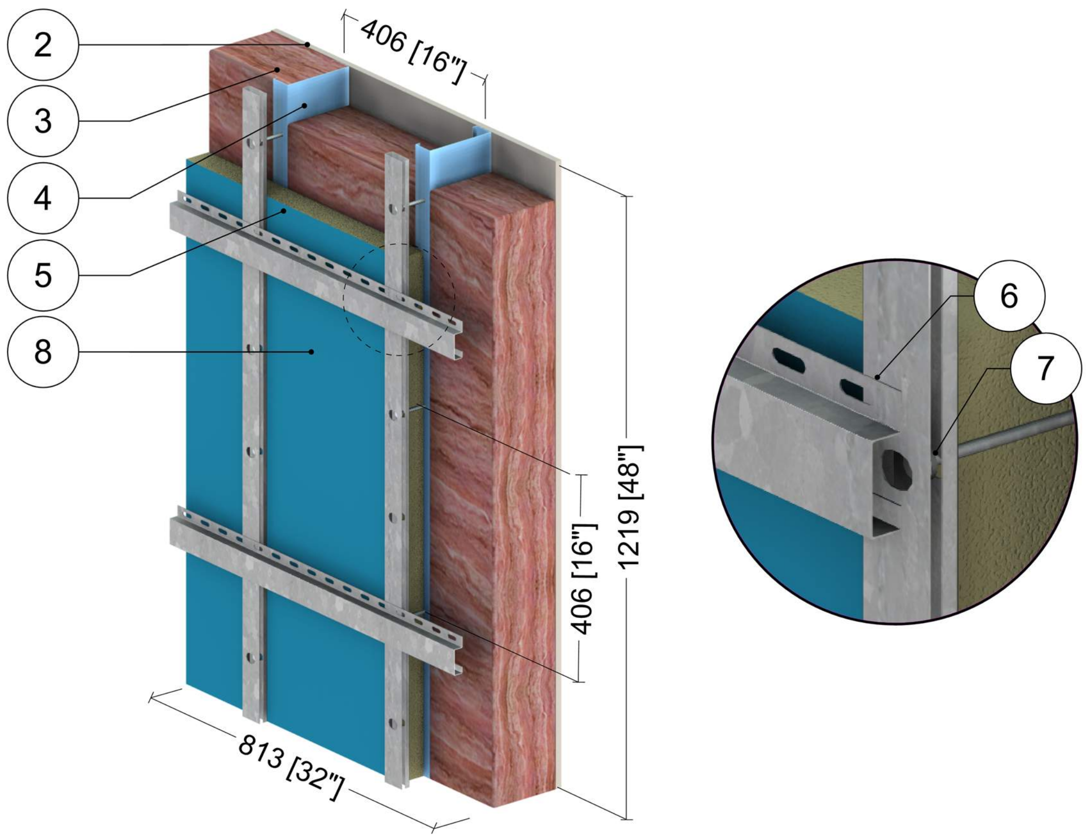




	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Air in Stud Cavity	6" (152)	-	R-0.9 (0.16 RSI)	0.075 (1.2)	0.24 (1000)
4	6" Steel Studs	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Polyiso Insulation	1.55" to 3" (39 to 76)	0.16 (0.022)	R-10.1 to R-19.0 (1.78 RSI to 3.35 RSI)	2.5 (40)	0.35 (1453)
6	Knight Wall CI Girt and Panel Rails	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
7	Isolator	0.173" (4)	1.4 (0.21)	-	89 (1420)	0.36 (1500)
7	Stainless Steel Fasteners	0.15" D (3.8)	118 (17)	-	500 (8000)	0.13 (530)
8	Rainscreen Cavity	-	-	R-0.5 (0.09 RSI)	0.075 (1.2)	0.24 (1000)
9	Exterior Film and Cladding	-	-	R-0.2 (0.0. RSI)	-	-

Scenario 2

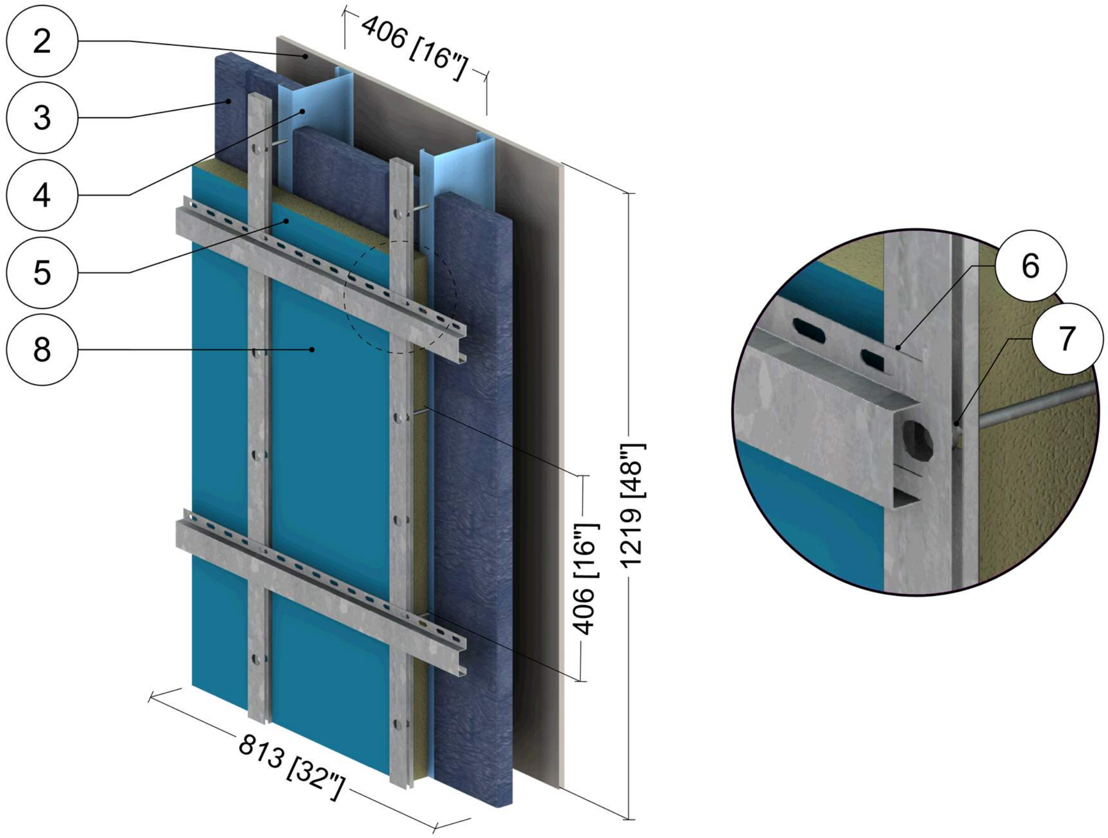
Knight Wall CI System with Steel Stud Backup Wall and R-19 Interior Batt Insulation



	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Fibreglass Batt Insulation	6” (152)	0.29 (0.042)	R-19 (3.35 RSI)	0.9 (14)	0.17 (710)
4	6” Steel Studs	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Polyiso Insulation	1.55” to 3” (39 to 76)	0.16 (0.022)	R-10.1 to R-19.0 (1.78 RSI to 3.35 RSI)	2.5 (40)	0.35 (1453)
6	Knight Wall CI Girt and Panel Rails	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
7	Isolator	0.173” (4)	1.4 (0.21)	-	89 (1420)	0.36 (1500)
7	Stainless Steel Fasteners	0.15” D (3.8)	118 (17)	-	500 (8000)	0.13 (530)
8	Rainscreen Cavity	-	-	R-0.5 (0.09 RSI)	0.075 (1.2)	0.24 (1000)
9	Exterior Film and Cladding	-	-	R-0.2 (0.0. RSI)	-	-

Scenario 3

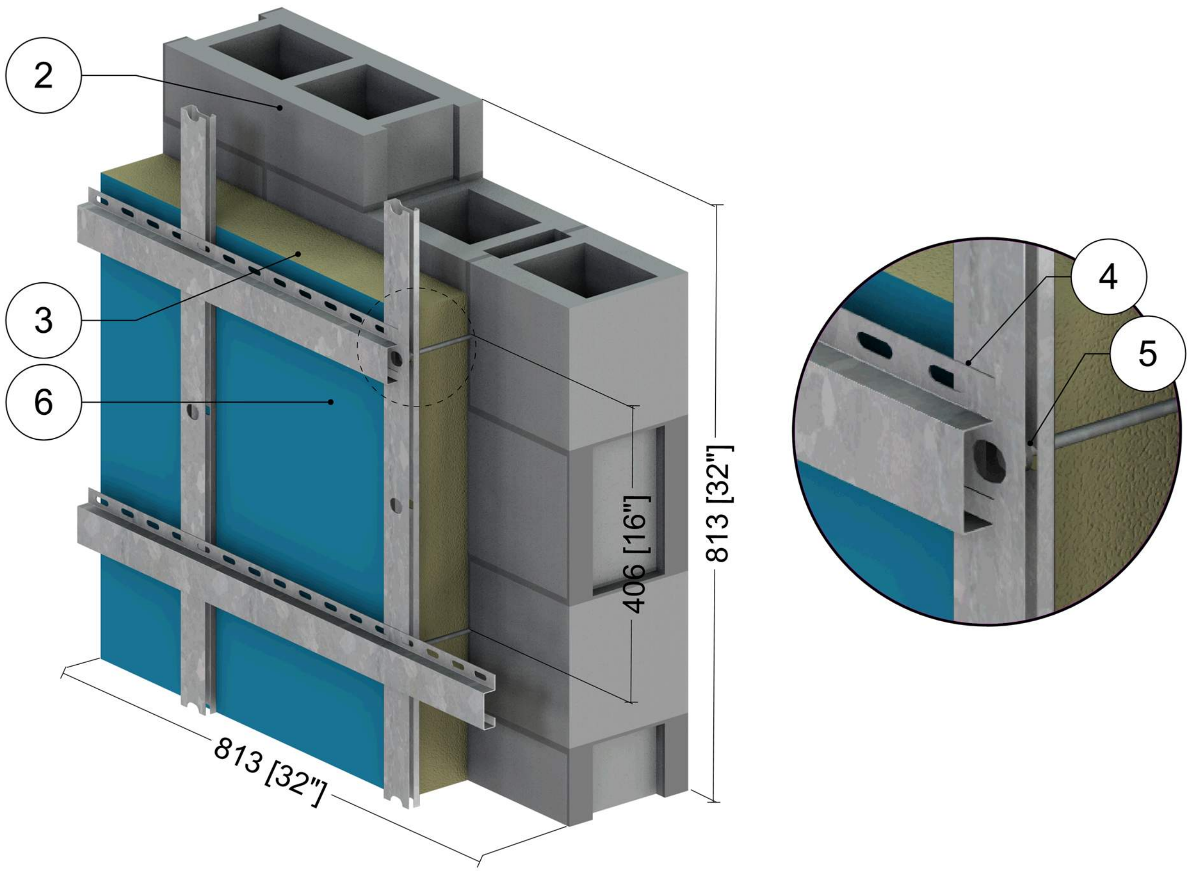
Knight Wall CI System with Steel Stud Backup Wall and Interior Sprayfoam Insulation



	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film	-	-	R-0.7 (0.12 RSI)	-	-
2	Gypsum Board	1/2" (13)	1.1 (0.16)	R-0.5 (0.08 RSI)	50 (800)	0.26 (1090)
3	Sprayfoam Insulation	1.5” (38)	0.17 (0.024)	R-9.8 (1.73 RSI)	1.8 (28)	0.29 (1220)
4	6” Steel Studs	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Polyiso Insulation	1.55” to 3” (39 to 76)	0.16 (0.022)	R-10.1 to R-19.0 (1.78 RSI to 3.35 RSI)	2.5 (40)	0.35 (1453)
6	Knight Wall CI Girt and Panel Rails	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
7	Isolator	0.173” (4)	1.4 (0.21)	-	89 (1420)	0.36 (1500)
7	Stainless Steel Fasteners	0.15” D (3.8)	118 (17)	-	500 (8000)	0.13 (530)
8	Rainscreen Cavity	-	-	R-0.5 (0.09 RSI)	0.075 (1.2)	0.24 (1000)
9	Exterior Film and Cladding	-	-	R-0.2 (0.0. RSI)	-	-

Scenario 4

Knight Wall CI System with CMU Backup Wall



	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr·ft²·°F/Btu (m²K/W)	Density lb/ft³ (kg/m³)	Specific Heat Btu/lb·°F (J/kg K)
1	Interior Film	-	-	R-0.7 (0.12 RSI)	-	-
2	Standard Concrete Block	8" (203)	-	-	119 (1900)	0.19 (800)
3	Polyiso Insulation	1.55" to 3" (39 to 76)	0.16 (0.022)	R-10.1 to R-19.0 (1.78 RSI to 3.35 RSI)	2.5 (40)	0.35 (1453)
4	Knight Wall CI Girt and Panel Rail	18 Gauge	430 (62)	-	489 (7830)	0.12 (500)
5	Isolator	0.173" (4)	1.4 (0.21)	-	89 (1420)	0.36 (1500)
5	Stainless Steel Fasteners	0.15" D (3.8)	118 (17)	-	500 (8000)	0.13 (530)
6	Rainscreen Cavity	-	-	R-0.5 (0.09 RSI)	0.075 (1.2)	0.24 (1000)
7	Exterior Film and Cladding	-	-	R-0.2 (0.0. RSI)	-	-

APPENDIX B – ASHRAE 1365-RP METHODOLOGY AND MODEL ASSUMPTIONS

B.1 General Modeling Approach

For this report, a steady-state conduction model was used. The following parameters were also assumed:

- Air cavity conductivities were taken from ISO 10077 and Table 3, p. 26.13 of 2013 ASHRAE Handbook – Fundamentals
- Interior/exterior air films were taken from Table 1, p. 26.1 of 2009 ASHRAE Handbook – Fundamentals depending on surface orientation. The exterior air films were based on an exterior windspeed of 15mph.
- Material properties were taken from information provided by Knight Wall and from ASHRAE Handbook – Fundamentals
- The cladding and air space was not explicitly modelled, but included with the exterior film coefficient.
- From the calibration in 1365-RP, contact resistances between materials were modeled. This varied between R-0.01 and R-0.2 depending on the materials. These values, along with other modeling parameters, are given in ASHRAE 1365-RP, Chapter 5.
- This was modelled as a clear field assembly away from major details, such as slab edges or parapets. As a result, these assemblies do not include top and bottom steel stud tracks (See Appendix B.2).
- The temperature difference between interior and exterior was modeled as a dimensionless temperature index between 0 and 1 (see Appendix B.3).

B.2 Thermal Transmittance

The methodology presented in ASHRAE 1365-RP separates the thermal performance of assemblies and details in order to simplify heat loss calculations. The thermal transmittance of an assembly is divided into three categories: clear field, linear and point transmittances.

The clear field transmittance is the heat flow from the wall or roof assembly, including uniformly distributed thermal bridges that are not practical to account for on an individual basis, such as structural framing and cladding attachments shown in this report. This is defined as a U-value, U_o (heat flow per area). Linear transmittances are for details that can be accounted for in a linear nature, such as corners, slab edges, balconies etc. Point transmittances are for single areas of thermal bridging that can be practically accounted for, such as beam penetrations. Note: **THIS REPORT CONTAINS ONLY CLEAR FIELD VALUES**.

B.3 Temperature Index

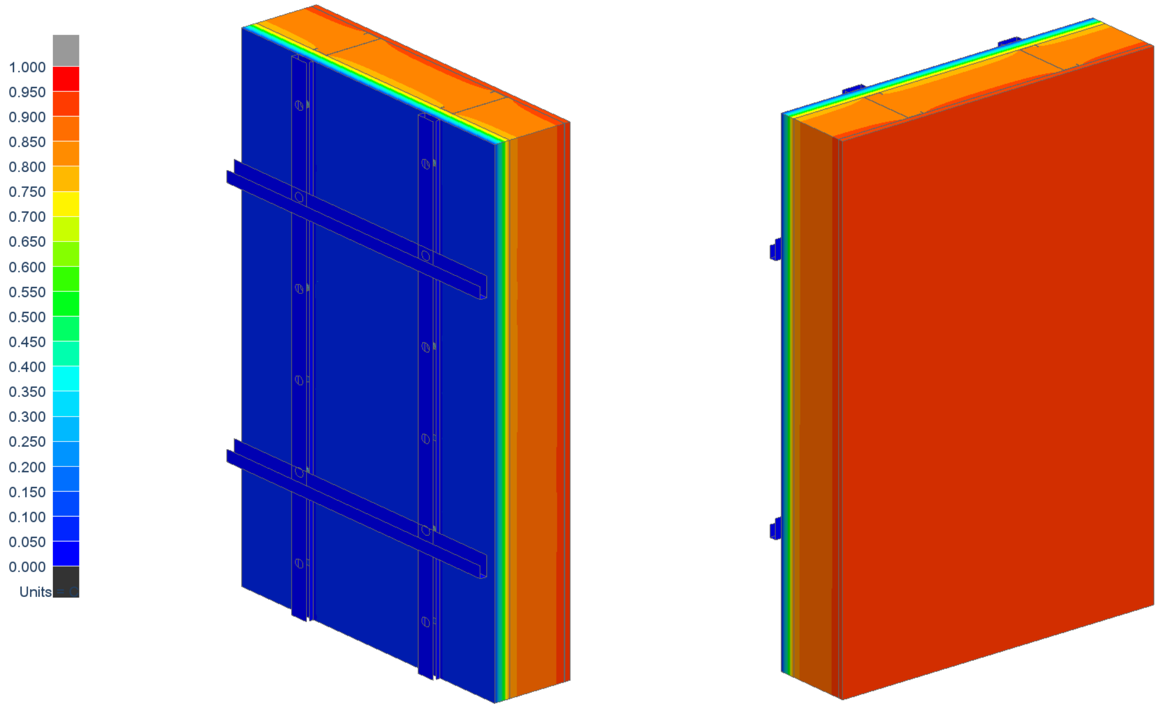
The temperature index is the ratio of the surface temperature relative to the interior and exterior temperatures. The temperature index has a value between 0 and 1, where 0 is the exterior temperature and 1 is the interior temperature. If T_i is known, Equation 1 can be rearranged for $T_{surface}$. This arrangement allows the modelled surface temperatures to be applicable to any climate.

$$T_i = \frac{T_{surface} - T_{outside}}{T_{inside} - T_{outside}} \quad \text{EQ 1}$$

Example temperature profiles for the assemblies and details modeled in this report are shown in Appendix C.

APPENDIX C –SIMULATED TEMPERATURE PROFILES

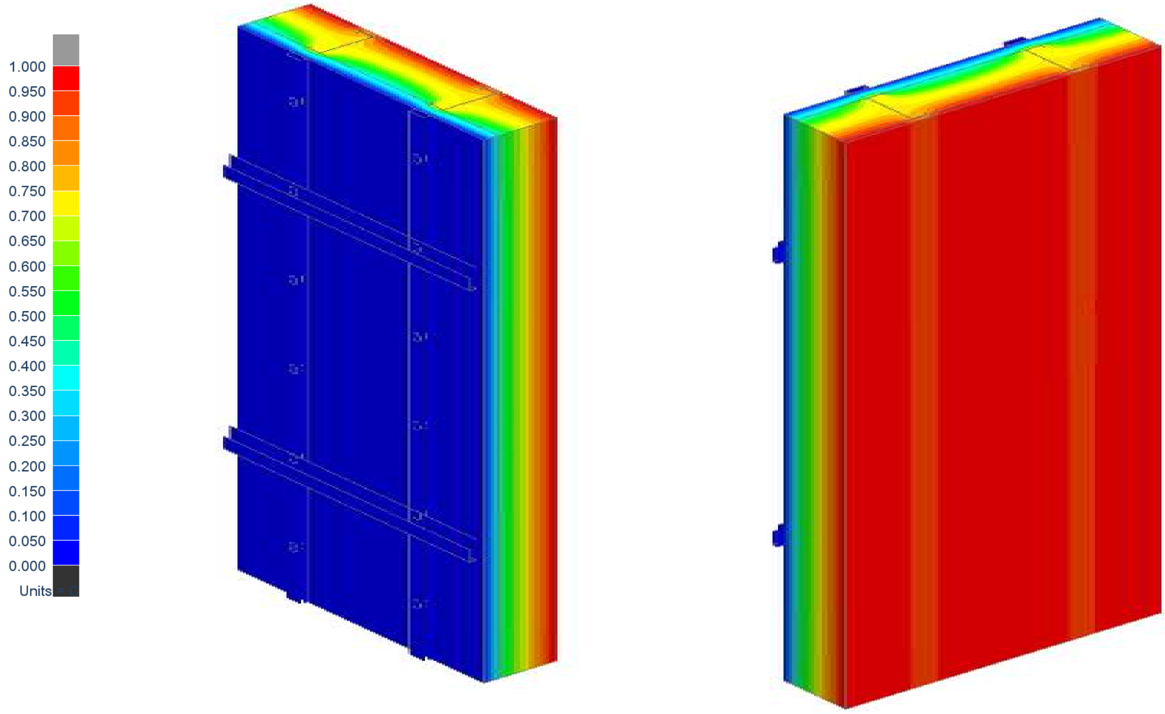
Scenario 1: Knight Wall CI System with Exterior Insulated Steel Stud Assembly



Exterior Thermal Profile Interior Thermal Profile

Figure C.1: Exterior Insulated Steel Stud Assembly with 1.55” of Polyiso and Knight Wall CI System with fasteners spaced 16” o.c. vertically

Scenario 2: Knight Wall CI System with Exterior and R-19 Batt Interior Insulated Steel Stud Assembly



Exterior Thermal Profile Interior Thermal Profile

Figure C.2: Exterior Insulated Steel Stud Assembly with 1.55" of Polyiso and Knight Wall CI System with fasteners spaced 16" o.c. vertically

Scenario 3: Knight Wall CI System with Exterior and R-10 Interior Sprayfoam Insulated Steel Stud Assembly

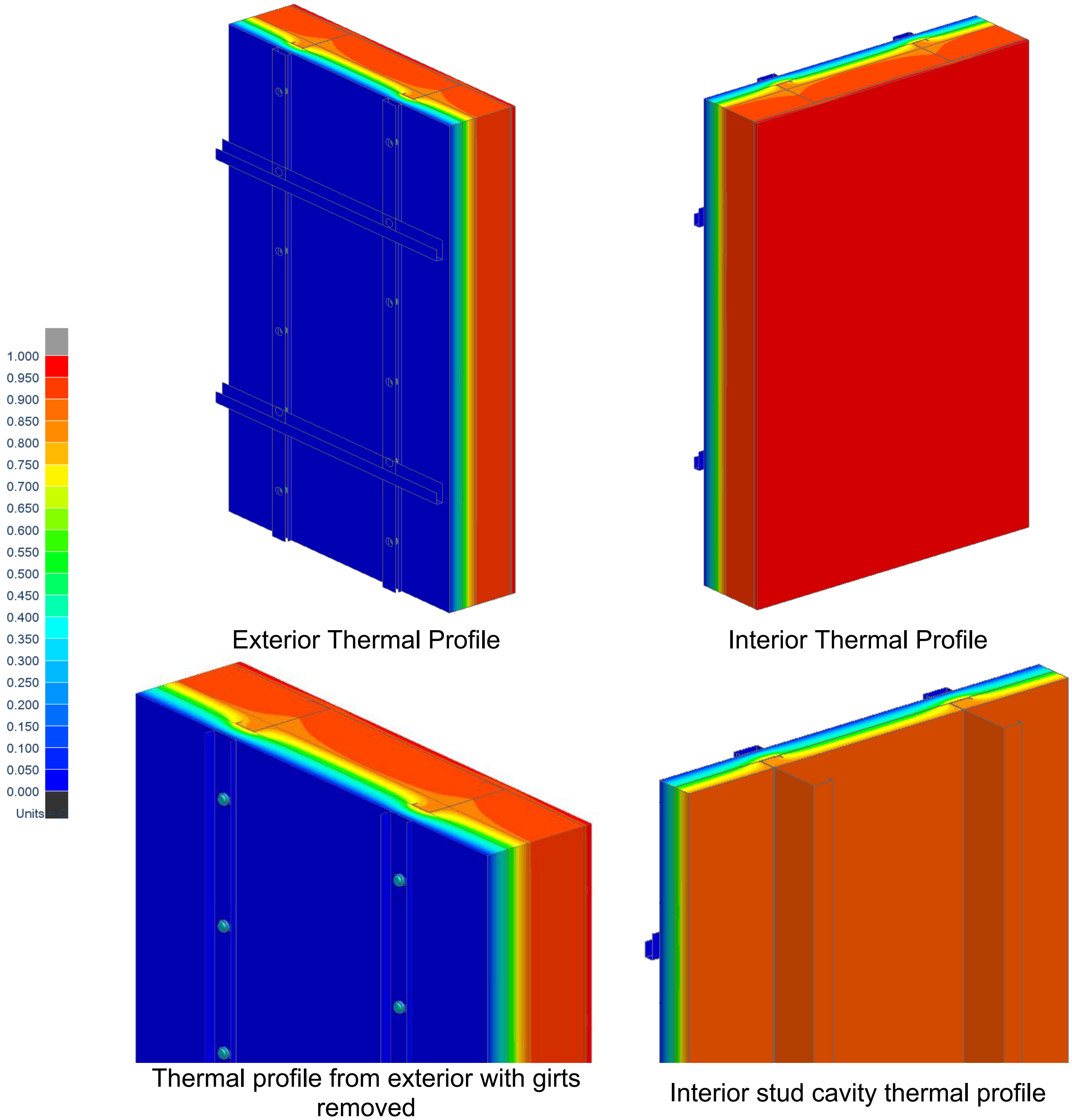
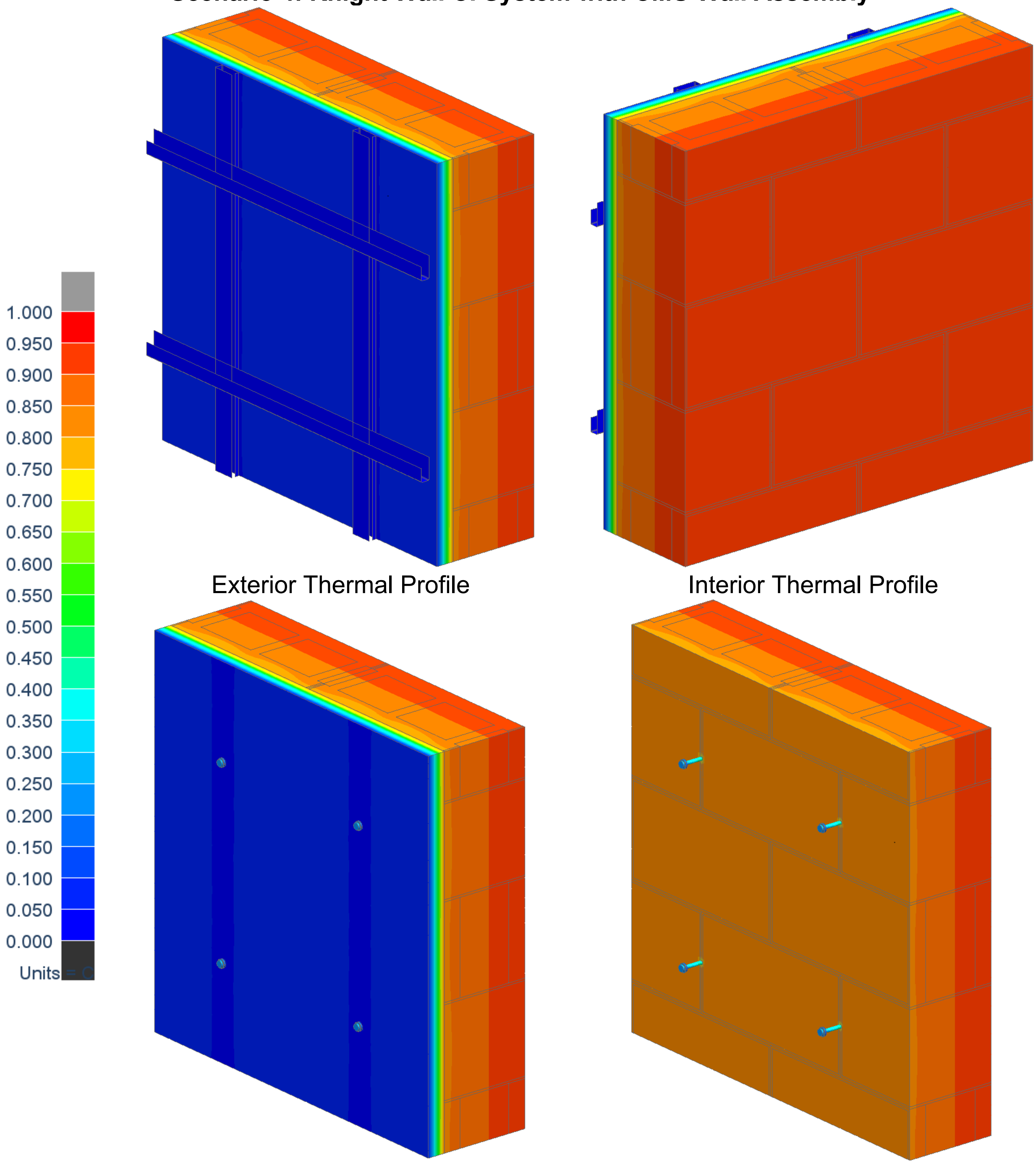


Figure C.3: Exterior and R-10 Interior Sprayfoam Insulated Steel Stud Assembly with 1.55" of Polyiso and Knight Wall CI System with fasteners spaced 16" o.c. vertically

Scenario 4: Knight Wall CI System with CMU Wall Assembly



Thermal profile from exterior with girts removed

Thermal profile from exterior with insulation removed

Figure C.4: Exterior Insulated CMU Assembly with 1.55” of Polyiso and Knight Wall CI System with fasteners spaced 16” o.c. vertically and horizontally