CLADIATOR™
Built to Conquer New Challenges

TECHNICAL DATA SHEET

CL 300

CL 300 is a thermally isolated adjustable cladding support system that can bear the weight of any cladding material and it uniquely integrates the horizontal and vertical tracks for attachment on the same plane, making it easier and faster to install.

Approvals/ Standards	Test	Performance	
ASTM E283[1]	Air Leakage	Infiltration at 75 Pa (1.57 psf)	0.5 L/s/m². (0.09 cfm/ft²)
		Exfiltration at 300 Pa (6.27 psf)	1.2 L/s/m² (0.23 cfm/ft²)
ASTM E331[1]	Water Penetration	@ 720 Pa (15.04 psf)	Pass. No Leakage.
ASTM E330[1]	Uniform Load Deflection	Deflections taken vertically on the panel between horizontal rails +4320 Pa (+90.23 psf) -4320 Pa (-90.23 psf)	7.4 mm (0.29") 4.1 mm (0.16")
		Deflections taken at the center of the panel +4320 Pa (+90.23 psf) -4320 Pa (-90.23 psf)	17.8 mm (0.70") 23.6 mm (0.93")
	Uniform Load Structural	Permanent set taken vertically on the panel between horizontal rails +7200 Pa (+150.38 psf) -6480 Pa (-135.34 psf)	<0.3 mm (<0.01") 0.5 mm (0.02")
		Permanent set taken at the center of the panel +7200 Pa (+150.38 psf) -6480 Pa (-135.34 psf)	5.8 mm (0.23") 6.4 mm (0.25")
ASTM E330[2]	Uniform Static Air Pressure Difference	Negative Design Pressure	-8622 Pa (-180.00 psf)
Gravity Load Testing (Uniform Distributed Static Vertical Load)	Gravity Load Testing, Deflection	@ 1163 Pa (24.3 psf)	1.0 mm (0.04")
	Gravity Load Testing, Permanent Set	@ 1163 Pa (24.3 psf)	0.3 mm (0.01")
	Gravity Load Testing, Deflection	@ 2940 Pa (61.4 psf)	3.0 mm (0.12")
	Gravity Load Testing, Permanent Set	@ 2940 Pa (61.4 psf)	0.5 mm (0.02")
NFPA 285[4]	Fire Test - Exterior Non-Load-Bearing Wall Assembly		Pass.
Thermal Performance[5]	The Effectiveness of The Overall Assembly - Exterior Insulated Steel Stud Wall	2" mineral wool 4" mineral wool	77% effective 91% effective

[1] Temperature during testing was between 17°C - 19°C (63°F-66°F) using CL-580 CLADIATORS ACM Panel.
[2] Temperature during testing was between 22°C (71°F) using Nichiha AWP 3030 Fiber Cement Panels.
[3] Product Size/Area Tested: 5.9m² (64.0 ft2) 2438mm W x 2438 mm L (96" W x 96" L).
[1,2,3,4] All test results provided by Intertek.
[5] Thermal analysis results provided by Morrison Hershfield.

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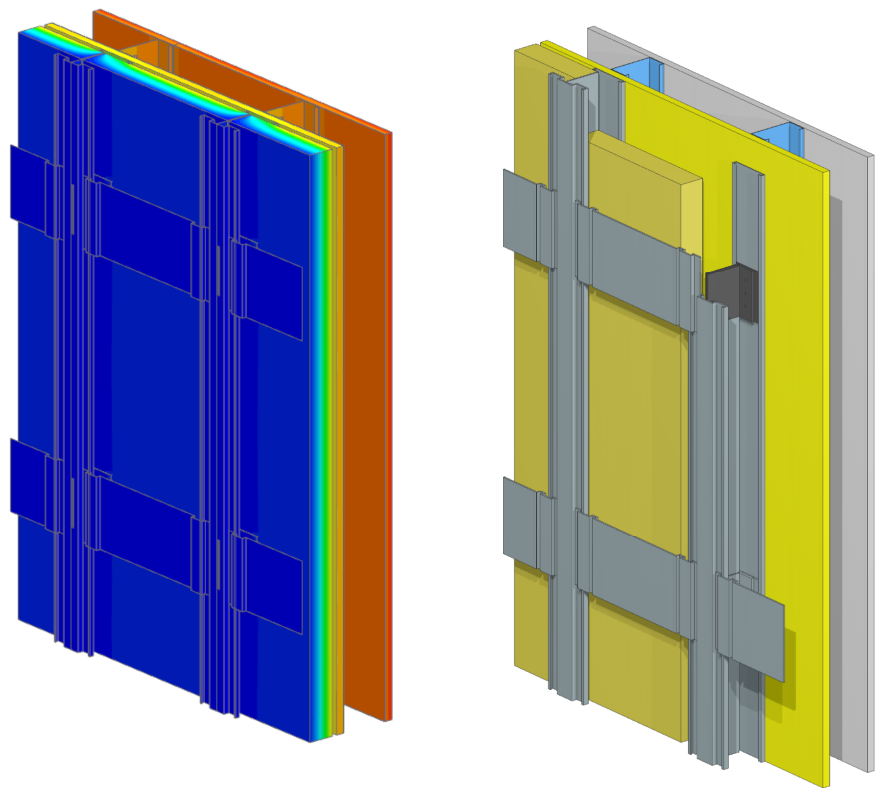
Thermal and Condensation Analysis of CL- 300 Cladding Support System



Presented to:

CLADIATOR
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1. INTRODUCTION AND BACKGROUND

Morrison Hershfield was contracted by CLADIATOR to evaluate the thermal performance of their CL- 300 Cladding Support System for various configurations. This report is a summary of the analysis.

The CL- 300 System in a cladding attachment system intended to support cladding and exterior insulation on a variety of substrates. The CL- 300 consists of an aluminum base track fastened to the substrate. An intermittent polyamide Therme clip (4" or 6" tall) is fastened to the base track and supports a continuous aluminum T-Track which in turn supports the cladding. Aluminum horizontal wall mounts are attached outboard to the T-Track for additional cladding support. The exterior insulation is fit between the Therme clips, inboard of the face of the T-Track and horizontal mounts. Different thicknesses of insulation are accommodated by adjusting the position of the T-Track relative to the Therme clip. The CL- 300 Cladding Support System is shown below in Figure 1.1.

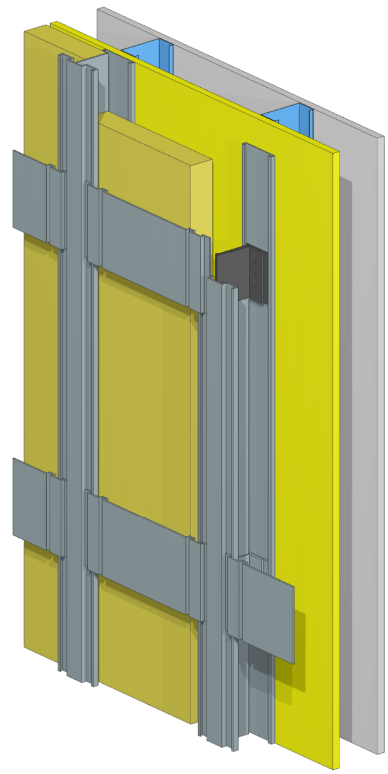
Figure1.1: CL- 300 Cladding Support System with Polyamide Therme clip fastened to a sheathed steel stud wall (cladding hidden)

For the thermal analysis, MH evaluated the CL- 300 Cladding Support System with the 4" tall Therme clips with a steel stud backup wall and 2in., 3in., and 4in. of exterior insulation and 24in., 36in., and 48in. on centre vertical spacing of the Therme clips. For these scenarios the assembly effective R- and U-values as well as temperature indices for key locations within the assembly were found.

The basic layout of the analyzed assembly is shown below:

Exterior Insulated Steel Stud Wall with CL- 300 Cladding Support System

- 5/8" Gypsum Drywall
- 3 5/8" Steel Stud Cavity, 16" o.c., Air Filled
- 5/8" Gypsum Sheathing
- Varying Mineral Wool Insulation
- CL- 300 System
- Generic Cladding (not shown)



2. THERMAL AND CONDENSATION MODELLING PROCEDURES

The thermal performance of the CL- 300 Cladding Support System configurations were evaluated by 3D thermal modelling using the Nx software package from Siemens, which is a general purpose computer aided design (CAD) and finite element analysis (FEA) package. The thermal solver and modelling procedures utilized for this study were extensively calibrated and validated to within +/- 5% of hotbox testing for *ASHRAE Research Project 1365-RP Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction* and for the *Building Envelope Thermal Bridging Guide*[1].

The thermal analysis utilized steady-state conditions, published thermal properties of materials and information provided by CLADIATOR. Additional assumptions for the thermal analysis are listed in Appendix A.

The thermal performance of all configurations of the CL- 300 Cladding Support System were evaluated at 16” o.c. horizontal spacing aligning with the steel studs in the backup wall. The 4” tall Therme clips were evaluated at varying vertical spacing of 24” o.c., 36” o.c., and 48” o.c. Three exterior insulation depths were evaluated: 2”, 3”, and 4”, with the T-Track positioning adjusted as per CLADIATOR documentation. The variation in configuration of the T-Track to accommodate varying insulation thickness is shown below in Figure 2.1.

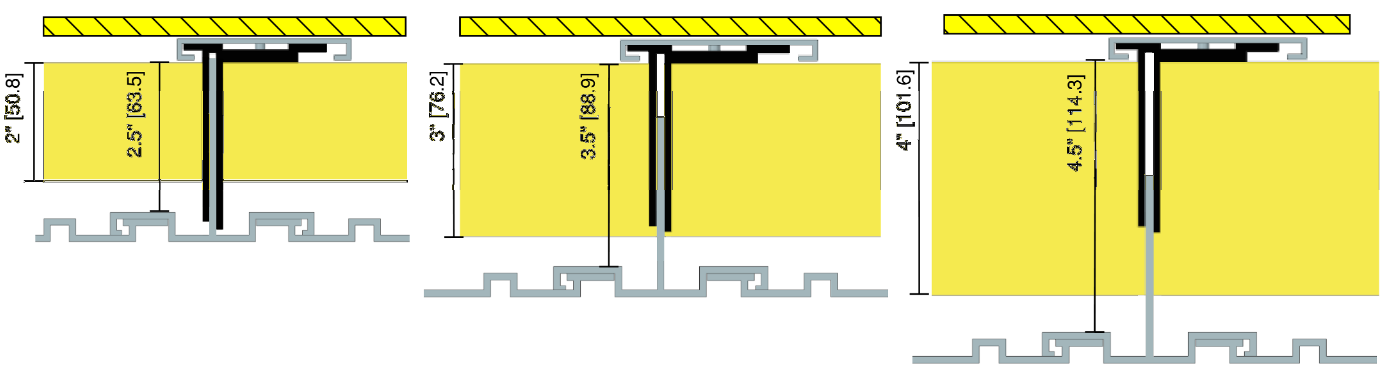


Figure 2.1: Component Arrangement for Varying Insulation Thicknesses

For the condensation analysis, the same software was used as for the thermal analysis described above. The analysis was performed with parametric boundary condition temperatures, where 0 represents the exterior temperature and 1 represents the interior temperature. The resulting temperature index (T_i) can then be found for any surface. Temperature indices can provide insight towards the range of temperatures that can be found in critical areas of the assembly, and for estimating risk for condensation, subject to interior environmental conditions. Further details regarding the temperature index and application can be found in Appendix D.

[1] https://www.bchydro.com/thermalguide

Surface temperatures due to average steady-state conductive heat flow in three-dimensions were utilized as a means of highlighting where the critical temperature locations are. It must be recognized that the objective of this analysis is **not** to predict in-service surface temperatures subject to transient conditions, air leakage, variable heating systems, and/ or interior obstructions that restrict heating/cooling or air flow to the assembly. For full limitations of this modeling approach, see ASHRAE 1365-RP.

3. THERMAL RESULTS FOR CL- 300 CLADDING SUPPORT SYSTEM

Assembly U- and R-Values

Table 3.1 provides the spacing of the Therme clips, exterior insulation thickness, nominal R-value of the insulation and the determined assembly U- and effective R-Value that includes the impact of thermal bridging by the components, including studs and cladding attachments. Further assembly information, including dimensions and materials are given in Appendix B. Example temperature profiles for each configuration are provided in Appendix C.

Table 3.1: Clear Field Thermal Transmittance for CL-300 System with Steel Stud Backup

Therme Clip Vertical Spacing in	**Exterior Insulation Thickness** in	**Exterior Insulation Nominal R-Value**[2] h·ft²·°F/Btu (m²·°K/W)	**Effective U-Value** Btu/h·ft²·°F (W/m²·°K)	**Effective R-Value** h·ft²·°F/Btu (m²·°K/W)
24	2	R-8.4 (1.48)	0.110 (0.622)	**R-9.1** (1.61)
	3	R-12.6 (2.22)	0.073 (0.416)	**R-13.7** (2.41)
	4	R-16.8 (2.96)	0.057 (0.323)	**R-17.6** (3.09)
36	2	R-8.4 (1.48)	0.108 (0.612)	**R-9.3** (1.63)
	3	R-12.6 (2.22)	0.070 (0.397)	**R-14.3** (2.52)
	4	R-16.8 (2.96)	0.056 (0.317)	**R-17.9** (3.15)
48	2	R-8.4 (1.48)	0.107 (0.606)	**R-9.4** (1.65)
	3	R-12.6 (2.22)	0.069 (0.393)	**R-14.4** (2.54)
	4	R-16.8 (2.96)	0.054 (0.307)	**R-18.5** (3.26)

[2] Note this value is the nominal R-value of the exterior insulation ONLY. Additional components, such as the sheathing, airspaces, and air films also all contribute an additional R-3.5 towards the nominal R-value of the entire assembly.

Temperature Indices for Condensation Analysis

Table 3.2 provides the spacing of the Therme clips, exterior insulation thickness, and minimum temperature index (T_i) on the surface exposed to interior conditions. This location was consistent for all configurations of the analyzed CL-300 Systems: on the interior surface of the sheathing in line with the Therme clips along the steel stud, shown below in Figure 3.1.

Table 3.2: Minimum Temperature Index for the CL-300 System with Steel Stud Backup

Therme Clip Vertical Spacing in	Exterior Insulation Thickness in	Exterior Insulation Nominal R-Value[3] h·ft²·°F/Btu (m²·°K/W)	Temperature Index T_i
24	2	R-8.4 (1.48)	0.74
	3	R-12.6 (2.22)	0.74
	4	R-16.8 (2.96)	0.75
36	2	R-8.4 (1.48)	0.84
	3	R-12.6 (2.22)	0.85
	4	R-16.8 (2.96)	0.85
48	2	R-8.4 (1.48)	0.88
	3	R-12.6 (2.22)	0.88
	4	R-16.8 (2.96)	0.88

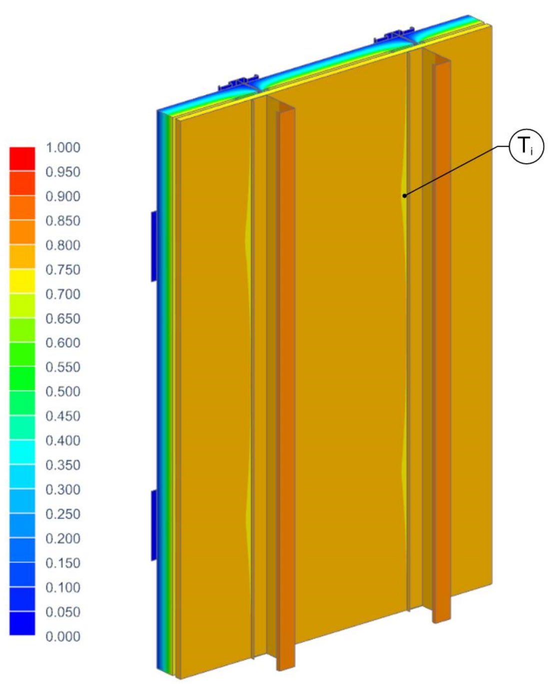


Figure 3.1: Location of the Minimum Temperature Index (T_i). Illustrated on 24"o.c. Therme Clip Spacing, 2" Exterior Insulation; Interior Gypsum Hidden

[3] Note this value is the nominal R-value of the exterior insulation ONLY. Additional components, such as the sheathing, airspaces, and air films also all contribute an additional R-3.5 towards the nominal R-value of the entire assembly.

4. ENERGY CODE COMPLIANCE

In the United States, the vast majority of states have an adopted energy code that set out the minimum requirements for energy efficiency for that jurisdiction, including requirements for the building envelope. The two most commonly referenced energy standards used as the basis for commercial and mid- to high-rise construction in these energy codes are ASHRAE 90.1[4] or IECC[5], depending on the building type. Similarly in Canada, many provincial energy codes use ASHRAE 90.1 or NECB[6] as the referenced energy standards. These standards may differ in specific values and requirements/exemptions, however they generally employ three main options for compliance: **Prescriptive, Trade-off and Performance Paths**.

The prescriptive path awards compliance for explicitly meeting all provisions of the code relevant to the project in question. For the building envelope, assemblies must be lower than a given maximum thermal transmittance U-value or must meet or exceed insulation values for a prescribed assembly. These requirements are based on climate region, construction type and occupancy type. The prescriptive path is fairly straightforward and building components need only be assessed individually. However, some of the prescriptive requirements may be difficult to achieve due to design trends. For example, in ASHRAE 90.1-2007, the prescriptive path requires a glazing to wall ratio of less than 40%. If these prescriptive requirements cannot be met, then another compliance path must be used.

The trade-off path allows for projects to trade-off the performance of building envelope components (i.e. roofs, walls, and windows) when the prescriptive requirements are not met for each and every assembly. This approach allows for flexibility in compliance if the performance of some envelope assemblies may be lower than the prescriptive values, as long as other better performing assemblies can make up for it based on area weighting of performance. For example, a low thermally performing wall may be compensated by a large roof that is above its prescriptive value. This approach can be demonstrated using either specific calculations (provided in the standards) or through computer software that is typically provided by the authors of the standard.

The performance path requires an evaluation of the annual energy use of the whole building that includes the interaction the building envelope, mechanical and electrical systems. This must be done using computer simulation, where the proposed building and its systems are modelled and compared to a compliance building. The compliance building contains the same shape, size, occupancy and scheduling of proposed building, but all of its individual components meet the minimum requirements of the standard. For example, the thermal performance of the walls of the compliance building must match the prescriptive U-values of the standard. The proposed design is acceptable if the annual energy use is less than or equal to that of the compliance building. The performance paths allows the greatest flexibility of all the compliance paths but requires a much more detailed accounting of the design. The performance path takes into account other variables such as building orientation, higher efficiency HVAC systems, and lighting controls, which would not give any benefit with the other two compliance paths. Each standard gives requirements that specify what can and cannot be included with the energy model and which energy modelling programs can be used.

[4] ASHRAE 90.1 "*Energy Standard for Buildings Except Low-Rise Residential Buildings*"
[5] IECC "International Energy Conservation Code"
[6] NECB "National Energy Code for Buildings"

Each standard outlines their own prescriptive values for the envelope. While a jurisdiction may adopt an energy standard, each state, province or even city may modify the standard and its prescriptive values to meet their own specific energy goals. Beyond that, these standards are also updated periodically. For instance, ASHRAE 90.1 is typically updated every 3 years whereby currently versions 2007, 2010, 2013 and 2016 are used in various locations across North America. The prescriptive values in these standards typically become more stringent with each update. A local energy code may not always adopt the latest version, leading to variability of requirements across North America. With that in mind, it is always recommended for designers to be aware of the specific requirements set by the local authorities having jurisdiction for their particular project. Please see the following website from the U.S. Department of Energy for the most current energy code adoptions in the US at the state level:

https://www.energycodes.gov/status-state-energy-code-adoption

The U-values found in this report for the CL-300 system can be used to determine energy code compliance using any of the three compliance paths listed previously. For quick reference, the prescriptive U-value requirements for ASHRAE 90.1-2010, 2013 and 2016 has been reproduced in Appendix E of this report, along with comparisons to the CL-300 System with an empty steel stud backup wall. The maximum climate zone achievable prescriptively using the CL-300 system for the analyzed insulation thickness and spacing has been provided for each of those ASHRAE 90.1 versions.

5. CONCLUSIONS

This report summarizes the evaluation of thermal performance (U-value and effective R-values) for the CL-300 Cladding Support System with an *empty* steel stud backup wall with varying exterior insulation thicknesses (2”, 3” and 4” of mineral wool insulation) and CLADIATOR Therme clip vertical spacings (24”, 36” and 48”o.c.). The following conclusions for the analyzed system scenarios can be made:

- For the exterior insulated steel stud scenarios with 2”-4” of mineral wool insulation, the assembly U-values range from 0.054 BTU/hr·ft2·oF – 0.110 BTU/hr·ft2·oF (0.307 W/m2K – 0.622 W/m2K)

- The Therme clip spacing from 24” o.c. vertically to 48”o.c. vertically can improve the thermal performance by up to 5% for the scenarios analyzed.

- The effectiveness of the overall assembly (thermal transmittance of assembly with thermal bridging vs thermal transmittance of the assembly with no thermal bridging) ranges from 77-91% effective depending on insulation thickness and component spacing (low end 77% for the 2” mineral wool system with 24”o.c. spacing of the Therme clips to high end 91% for the 4” mineral wool system with 48”o.c. spacing of the Therme clips)

The U-values shown here can be used in compliance calculations through any of the compliance paths set forth in additional energy codes and standards such as ASHRAE 90.1, IECC, and/or NECB as of the published date of this report.

If there are any questions regarding the content or modelling conducted for this report, please contact the undersigned.

Morrison Hershfield Limited

Katie Hay

Katie Hay, P.Eng.
Building Science Consultant

PROFESSIONAL ENGINEER PROVINCE OF N. K. C. NORRIS # 41343

July 16/18

Neil Norris, M.A.Sc., P.Eng.
Principal, Building Science Consultant

APPENDIX A – MODELLING PARAMETERS AND ASSUMPTIONS

A.1 Thermal Modelling Assumptions

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.
- Cladding materials and secondary structures outboard of the insulation can vary widely. It has been found in ASHRAE 1365, for rainscreen cavity systems most lightweight claddings have an insignificant impact on the thermal performance other than shielding the insulation from direct wind exposure. To provide general information for the system, the cladding, secondary structure outboard of the vertical rails and rainscreen cavity were not explicitly modelled, but was incorporated into the exterior film coefficient.
- Material properties were taken from information provided by CLADIATOR, published material information from Lawrence Berkeley National Laboratory and ASHRAE Handbook – Fundamentals for common materials. These values are typically reported at operating temperatures between 0°C and 21°C Materials used in this analysis were assumed to have a constant thermal conductivity.
- From the calibration in 1365-RP, contact resistances between materials were modeled and varied between R-0.01 and R-0.2 depending on the materials and interfaces.
- Insulation and other components were considered tight to adjacent interfaces. Air gaps smaller than 2mm were assumed incorporated with the contact resistances.
- Placement of weather barriers and membranes were assumed not to impact the thermal conduction through the system and were not included in the analysis.
- Impacts of air leakage within the assembly were not included.
- The temperature difference between interior and exterior was modelled as a dimensionless temperature index between 0 and 1 (see Appendix A.3).
- As per standard U-value evaluation, no solar heating impacts were included.

A.2 Thermal Transmittance

The methodology presented in the Building Envelope Thermal Bridging Guide separates the thermal performance of clear field assemblies and transition details (slabs, parapets, window interfaces) in order to simplify heat loss calculations.

For this report, only clear field transmittances for this system were evaluated, and not any transition details. The presented U-values in the Tables in this report contain only uniform repeating thermal bridges, such as studs and clips, and do not include any interface details, such as slab intersections or top and bottom stud tracks.

A.3 Boundary Conditions

Table A-1: Boundary Conditions

Boundary Location	Combined Convective and Radiation Heat Transfer Coefficient BTU/hft^2°F (W/m^{2}K)
Exterior (15mph wind) with Cladding and Airspace	1.5 (8.3)
Interior Walls	1.5 (8.3)

APPENDIX B –
ASSEMBLY INFORMATION AND MATERIAL PROPERTIES

B.1 CL-300 Cladding Support System with Steel Stud Backup Wall

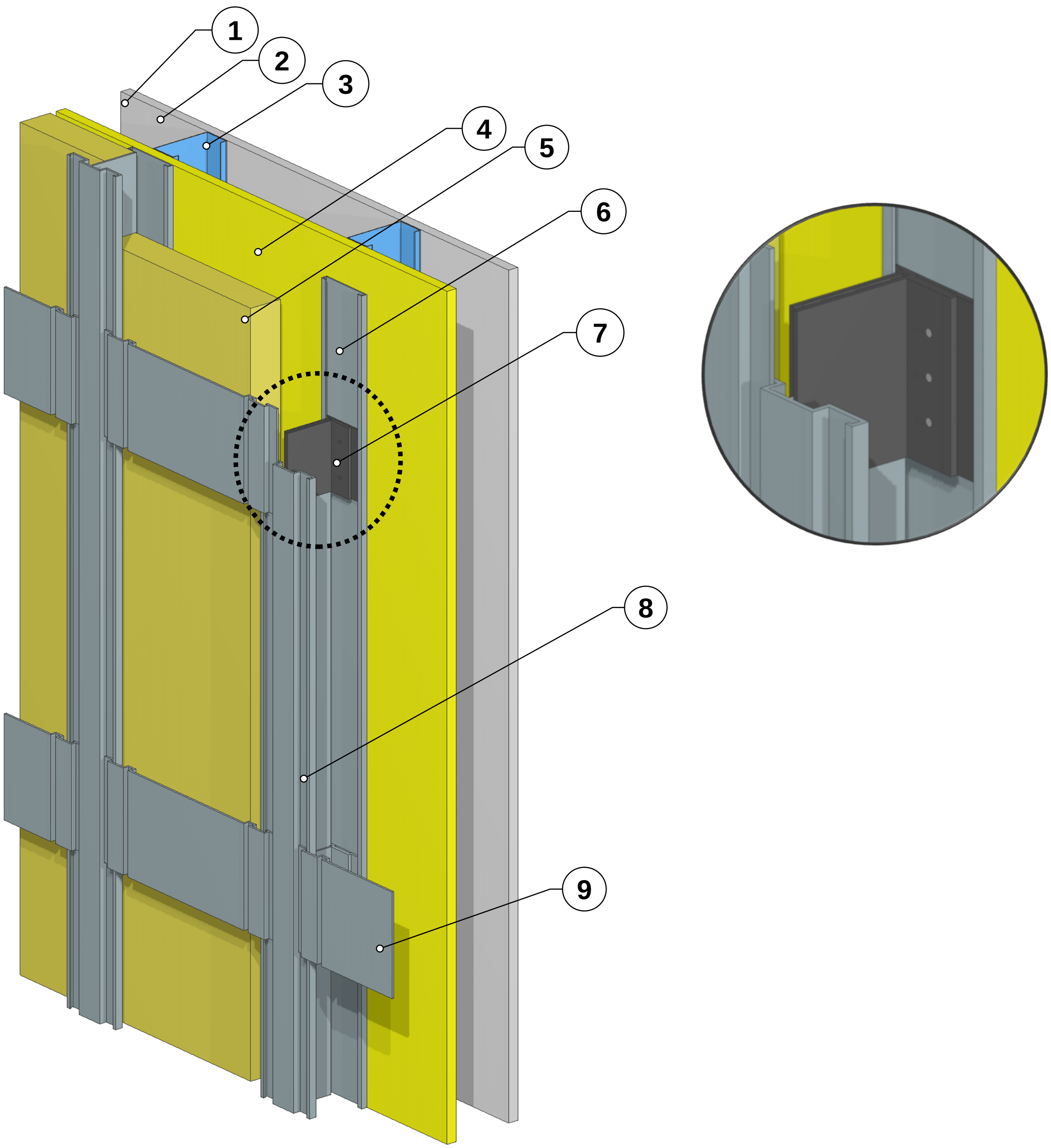


Table B.1: Thermal Properties of Materials

Ref.	Component	Thickness Inches (mm)	Conductivity Btu·in / ft^2·hr·^{o}F (W/m K)	Nominal Resistance hr· ft^2· ^{o}F/BTU (m^{2}K/W)
--	Interior Film	-	-	R-0.7 (RSI-0.12)
1	Gypsum Board	5/8" (16)	1.1 (0.16)	R-0.6 (RSI-0.10)
2	Air in Stud Cavity	1 5/8" (41)	-	R-0.9 (RSI-0.16)
3	3 5/8" x 1 5/8" Steel Studs, 16" o.c.	16 gauge	430 (62)	-
4	Gypsum Sheathing	5/8" (16)	1.1 (0.16)	R-0.6 (RSI-0.10)
5	Exterior Insulation (Mineral Wool)	2" to 4" (51 to 102)	0.24 (0.034)	R-8.4 to R-16.8 (RSI-1.48 to RSI-2.96)
6	Aluminum Base Track, 16" o.c. horizontally	1/8" (3.3)	1422 (205)	-
7	Therme Polyamide Clip	-	1.73 (0.25)	-
8	Aluminum T-Track, 16" o.c. horizontally	1/8" (3.3)	1422 (205)	-
9	Aluminum Wall Mount Supports	1/8" (3.3)	1422 (205)	-
--	Exterior Film, including Cladding and Rainscreen airspace	-	-	R-0.7 (RSI-0.12)

APPENDIX C –
SIMULATED TEMPERATURE PROFILES

C.1 CL-300 with Steel Stud Backup Wall

As an example of the thermal profiles of the CL-300 system, the following figures illustrate typical temperature distribution for the CL-300 system with 2in., 3in., and 4in. exterior insulation at 24in. o.c. vertical Therme clip spacing. The profiles presented as a temperature index (between 0 and 1). See Appendix A.3 for more information.

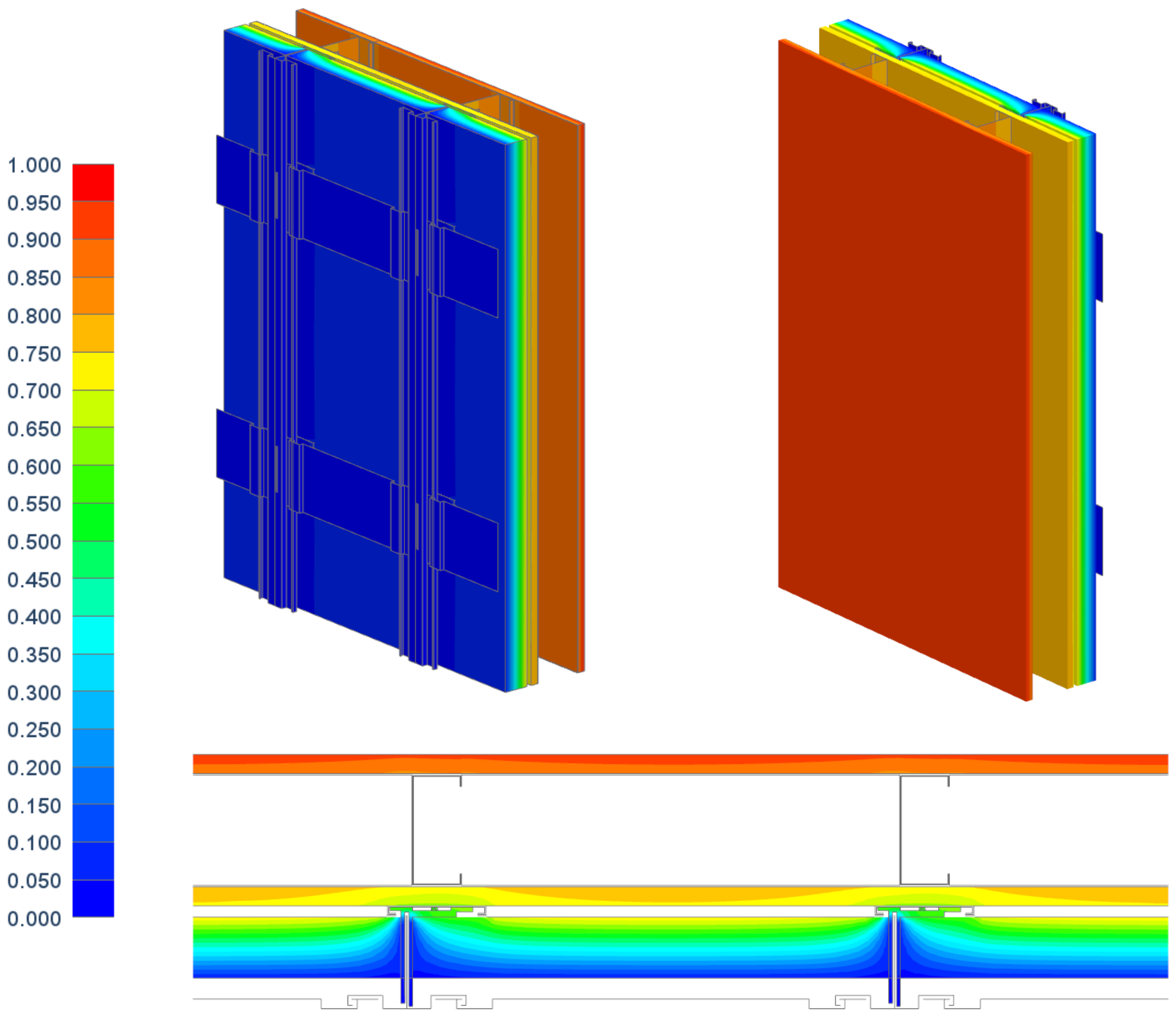


Figure C1.1: Temperature Profile of CL-300 Cladding Support System: 2in. Exterior Insulation isometric view from exterior, interior and plan view through clip

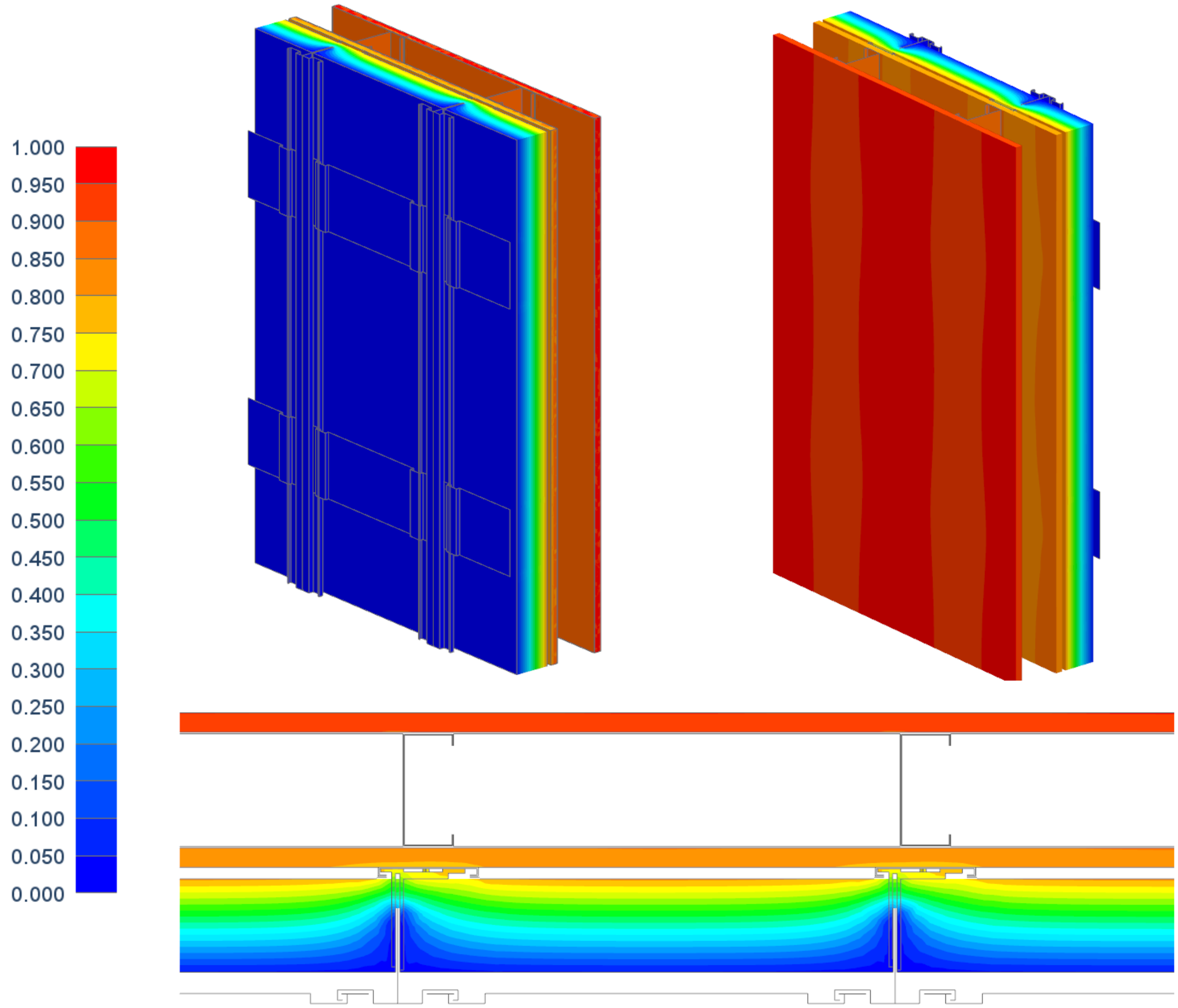


Figure C1.2: Temperature Profile of CL-300 Cladding Support System: 3in. Exterior Insulation isometric view from exterior, interior and plan view through clip

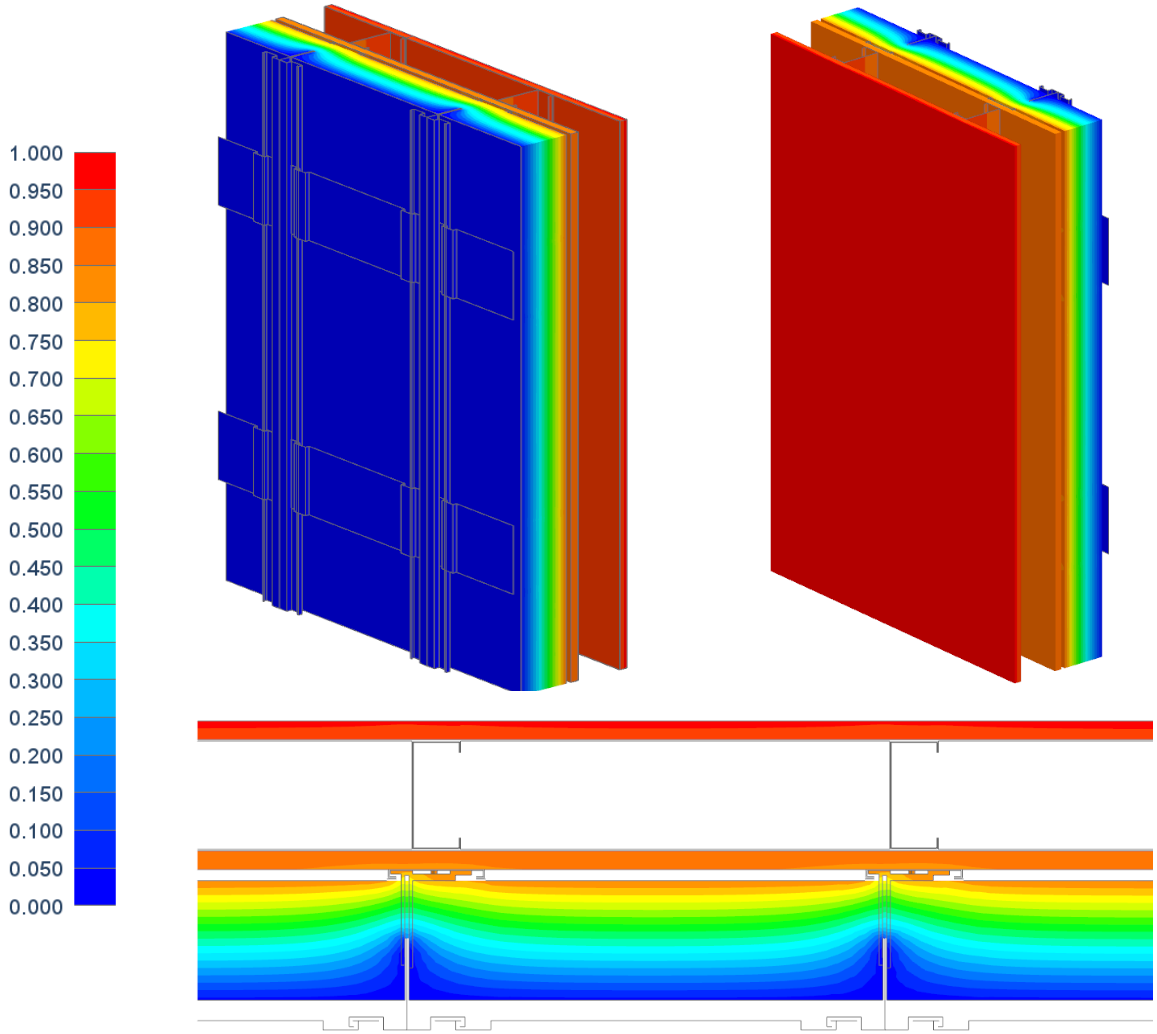


Figure C1.3: Temperature Profile of CL-300 Cladding Support System: 4in. Exterior Insulation isometric view from exterior, interior and plan view through clip

APPENDIX D – TEMPERATURE INDEX AND CONDENSATION EVALUATION

D.1 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.

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

Note, these indices shown in the temperature profiles for this analysis are for general information only and are **not** intended to predict in-service surface temperatures subject to transient conditions, variable heating systems, and/ or interior obstructions that restrict heating of the assembly. For full limitations of this modeling approach, see ASHRAE 1365-RP.

To calculate the minimum surface temperature of the CL-300 System, Equation 1 can be used with known interior and exterior conditions. For example, if the system was installed in New York, NY, the ASHRAE 90.1 design temperature is 17.4ºF (-8.1ºC). Assuming an interior temperature of 68ºF (20ºC), the surface temperature of the CL-300 System with 24"o.c. Therme clip spacing and 2" exterior insulation (T_i = 0.74 from Table 3.2) can be calculated as follows:

$T_i = \frac{T_{surface} - T_{outside}}{T_{inside} - T_{outside}}$	EQ 1
$T_{surface} = T_i(T_{inside} - T_{outside}) + T_{outside}$	EQ 1 Rearranged
$T_i = 0.74$ $T_{inside} = 68^oF$ $T_{outside} = 17.4^oF$	Defining known variables
$T_{surface} = 0.74(68^oF - 17.4^oF) + 17.4^oF$	Substituting values
$\boldsymbol{T_{surface} = 54.8^oF\ (12.7^oC)}$	

D.2 Condensation Evaluation

Temperature indices and surface temperatures can be used to help determine the risk for condensation within an assembly. If the expected interior relative humidity is known from the mechanical design, then the interior dewpoint can be calculated using the interior temperature and the design relative humidity using psychrometrics.

Continuing the example above, let us assume that the architect knows that the mechanical design has assumed about 40% RH for the space in the winter. With a T_{int} of 68°F (20°C) and a design RH of 40%, the dewpoint temperature (T_{dew}) can be calculated using a psychrometrics chart to be **42.9°F (6.0°C)**. The surface temperature calculated above is **54.8°F (12.7°C)**, which is above the dewpoint temperature. Thus for these conditions it is unlikely that condensation will develop.

Temperature indices can also be used to determine the maximum interior humidity at which the interior cavity temperatures drop below the dewpoint. With this approach, it is assumed that the dewpoint temperature (T_{dew}) is equal to the calculated surface temperature. The interior RH is then back calculated using that assumption. This approach is useful if the interior humidity is expected to fluctuate in the space over time.

For our example, the interior temperature (T_{int}) is 68°F (20°C), and the T_{dew} is assumed to be the surface temperature ($T_{surface}$) of 54.8°F (12.7°C). Using psychrometrics and back calculating, the maximum interior relative humidity is **63%**. This indicates that the interior humidity must be 63% or greater for there to be a potential for condensation.

D.3 Temperature Index Comparison with Continuous Girt Systems

To compare the temperature indices for the CLADIATOR system, the temperature indices at the interior surface of the sheathing were identified for continuous girt systems in the *Building Envelope Thermal Bridging Guide*[1]. The pertinent details and their associated temperature indices are shown below in Table D-1.

Table D-1: Temperature Indices for Continuous Girt Systems from the Thermal Bridging Guide

Detail Description	Temperature Index (T_i) with Specified Exterior Insulation		
	R-8.4	**R-12.6**	**R-16.8**
BETBG: 5.1.3 Continuous Vertical Girts	0.68	0.71	0.73
BETBG: 5.1.5 Continuous Horizontal Girts	0.67	0.71	0.73
CL-300, 24" Vertical Spacing	0.74	0.74	0.75

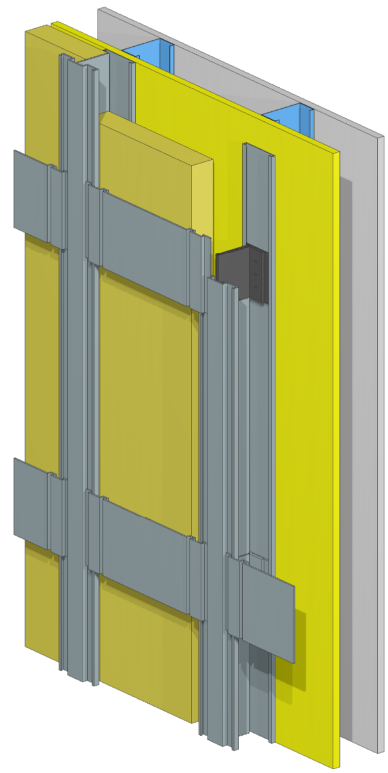
[1] https://www.bchydro.com/thermalguide

Report Number: 180181400
July 16th, 2018

MORRISON HERSHFIELD

CL-TALON has been re-branded to CLADIATOR as of APR9-2021.
Any reference to the CL-TALON 300 product is now CL 300 respectively.

Structural, Thermal, and Condensation Analysis of CL 300 Cladding Support System



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1. INTRODUCTION AND BACKGROUND

Morrison Hershfield was contracted by CLADIATOR to evaluate the structural and thermal performance of their CL-300 Cladding Support System for various configurations. This report is a summary of the analysis.

The CL- 300 System in a cladding attachment system intended to support cladding and exterior insulation on a variety of substrates. The CL-300 consists of an aluminum base track fastened to the substrate. An intermittent polyamide Therme clip (4" or 6" tall) is fastened to the base track and supports a continuous aluminum T-Track which in turn supports the cladding. Aluminum horizontal wall mounts are attached outboard to the T-Track for additional cladding support. The exterior insulation is fit between the Therme clips, inboard of the face of the T-Track and horizontal mounts. Different thicknesses of insulation are accommodated by adjusting the position of the T-Track relative to the Therme clip. The CL- 300 Cladding Support System is shown below in Figure 1.1.

Figure1.1: CL-300 Cladding Support System with Polyamide Therme clip fastened to a sheathed steel stud wall (cladding hidden)

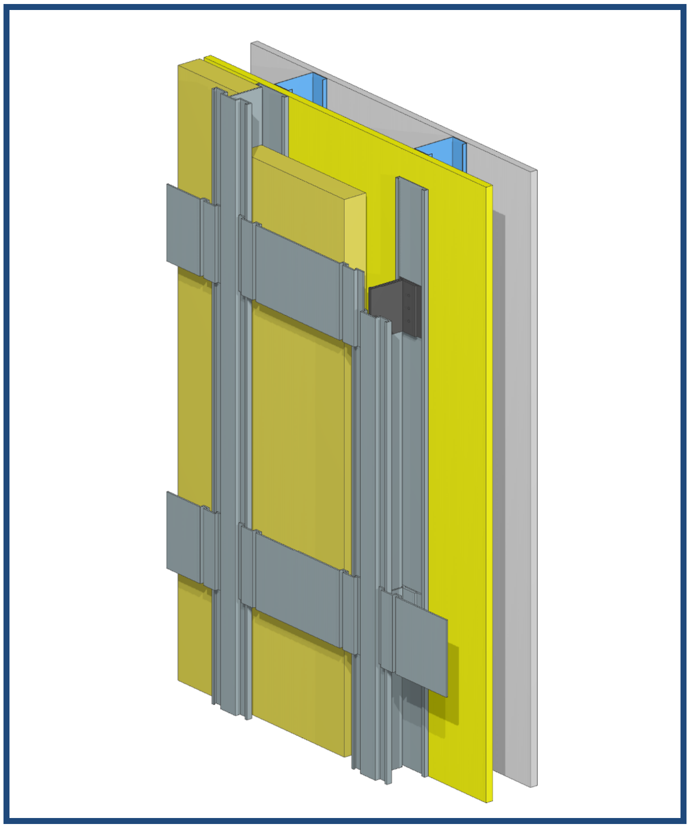
MH performed the structural analysis for the CL- 300 Cladding Support System with the 4” and 6” tall Therme clips with a steel stud backup wall for two cladding weights (4 and 10 psf), four nominal wind loads (+/- 30, 60, 90 and 120 psf) with three deflection limits considered (L/360, L/240, L/120). For these scenarios the maximum spacing of the wall mounts and the clips were found.

For the thermal analysis, MH evaluated the CL- 300 Cladding Support System with the 4” tall Therme clips with a steel stud backup wall and 2in., 3in., and 4in. of exterior insulation and 24in., 36in., and 48in. on centre vertical spacing of the Therme clips. For these scenarios the assembly effective R- and U-values as well as temperature indices for key locations within the assembly were found.

The basic layout of the analyzed assembly is shown below:

Exterior Insulated Steel Stud Wall with CL-300 Cladding Support System

- 5/8” Gypsum Drywall
- 3 5/8” Steel Stud Cavity, 16” o.c., Air Filled
- 5/8” Gypsum Sheathing
- Varying Mineral Wool Insulation
- CL-300 System
- Generic Cladding (not shown)



2. STRUCTURAL ANALYSIS

The following sections present the structural analysis to determine the maximum spacing of components for the CL-300 System with the steel stud backup wall described in Section 1.

Calculation Procedures and Limitations

The structural analysis of the CL-300 Cladding Support System was performed in accordance with Allowable Stress Design (ASD) as outlined in the International Building Code (IBC) and the Aluminum Design Manual (ADM). The structural analysis used static loading conditions and published material properties from manufacturers (including CLADIATOR) and the Aluminum Design Manual. The analysis also used the specific fasteners outlined in information provided by CLADIATOR. The system was evaluated for 2 cladding weights (dead load of 4 or 10psf) and 4 wind loads (30, 60, 90 or 120psf). These were compared to 3 deflection limits (L/360, L/240 and L/120). This analysis was done for both the 4" and 6" Therme clips as well as the 3" and 6" horizontal wall mount supports.

The structural analysis of all loading and deflection scenarios of the CL-300 Cladding Support System were evaluated with a 16 gauge steel stud wall with studs spaced horizontally at 16"o.c. The analysis was conducted with three 10' T-Tracks in line with the studs, supported by Therme clips. The analysis was performed with the T-Track in the "fully compressed" condition. One clip per T-Track was assumed to be fully fixed to support the dead load and the remaining clips are slotted at the fastener holes to support the wind load only. The Therme clips were analyzed as being fastened through the base track and sheathing into the steel studs. The base track fasteners provide redundancy to the system and are included for additional system stability.

The CL-300 System was evaluated for 5 different shared loading cases of the T-Track and horizontal wall mounts. This was done to give a better understanding of the system when subject to various methods of secondary attachment of the cladding to these members. Case 1 represents 100% of the load is supported by the vertical T-Track only, Cases 2-4 represent various shared loading between the T-Track and wall mounts, while Case 5 represents a uniform load applied along the length of the horizontal wall mount supports. In Case 1, the governing factor is either the pull out strength of the clip fastener or bending of the T-Track between the Therme clips. For all allowable configurations of the horizontal wall mount supports listed in the Cases 2-5, the maximum spacing of the Therme clips will not change. Worst case point loading from the horizontal wall mount supports in the allowable configurations was considered. In the shared loading in Cases 2-5, the governing factor is the deflection limit due to the spacing of the horizontal wall mounts.

Movement in the system is intended to be accommodated by a combination of fully fixed or slotted fastener Therme clips. Seismic loading and temperature induced expansion and contraction was not explicitly examined in this analysis.

Additional assumptions and analysis provisions, including fastener information, is included in Appendix A.

NOTE: This report and the tables herein are intended to be used as a design aid and to improve project estimations. Every effort has been made to ensure the accuracy of the results however under no circumstances should the results included in this report be used in place of project specific engineering.

Structural Spacing Results for CL-300 Cladding Support System

Table 2.1 provides the maximum vertical spacing of the 4" and 6" Therme clips under the various loading scenarios and the fastener spacing of the base track into the steel studs. Table 2.2 shows the spacing of the 3" and 6" wall mount supports under the different loading conditions and deflection criteria. Where the analysis determined the component cannot support the required loads at any vertical spacing is indicated by (--). For all the shared loading Cases in Table 2.2, the spacing of the polyamide clip found in Table 2.1 still applies.

Table 2.1: Maximum Vertical Spacing for CL- 300 System Therme Clips and Base Track

Dead Load (psf)		4				10			
Nominal Wind Load (psf)		30	60	90	120	30	60	90	120
Component	**Deflection Requirement**	**Maximum Vertical Spacing** in (mm)							
4" Therme Clip	ALL	52.0 (1320.8)	38.0 (965.2)	31.0 (787.4)	27.0 (685.8)	43.4 (1103.0)	21.7 (551.5)	14.5 (367.7)	10.9 (275.7)
6" THEMRE Clip	ALL	52.0 (1320.8)	38.0 (965.2)	31.0 (787.4)	27.0 (685.8)	52.0 (1320.8)	38.0 (965.2)	31.0 (787.4)	27.0 (685.8)
Base Track Fastener	ALL	16.0 (406.4)	16.0 (406.4)	16.0 (406.4)	16.0 (406.4)	16.0 (406.4)	16.0 (406.4)	16.0 (406.4)	16.0 (406.4)

Table 2.2: Maximum Vertical Spacing for CL-300 System Horizontal Wall Mounts with Steel Stud Backup

Dead Load (psf)		4				10			
Nominal Wind Load (psf)		30	60	90	120	30	60	90	120
Component	Deflection Requirement	Maximum Vertical Spacing in (mm)							
Load Case 1: 100% of Load Carried By T-Track, 0% By Wall Mount Supports									
3" Wall Mount Support	ALL	Not Applicable, Governed By Therme Clip Spacing Only							
6" Wall Mount Support	ALL	Not Applicable, Governed by Therme Clip Spacing Only							
Load Case 2: 75% of Load Carried by T-Track, 25% By Wall Mount Supports									
3" Wall Mount Support	L/360	15.6 (395.9)	7.8 (197.9)	5.2 (132.0)	3.9 (99.0)	15.6 (395.9)	7.8 (197.9)	5.2 (132.0)	3.9 (99.0)
	L/240	23.4 (593.8)	11.7 (296.9)	7.8 (197.9)	5.8 (148.5)	23.4 (593.8)	11.7 (296.9)	7.8 (197.9)	5.8 (148.5)
	L/120	46.8 (1187.6)	23.4 (593.8)	15.6 (395.9)	11.7 (296.9)	46.8 (1187.6)	23.4 (593.8)	15.6 (395.9)	11.7 (296.9)
6" Wall Mount Support	L/360	31.2 (791.8)	15.6 (395.9)	10.4 (263.9)	7.8 (197.9)	31.2 (791.8)	15.6 (395.9)	10.4 (263.9)	7.8 (197.9)
	L/240	46.8 (1187.6)	23.4 (593.8)	15.6 (395.9)	11.7 (296.9)	46.8 (1187.6)	23.4 (593.8)	15.6 (395.9)	11.7 (296.9)
	L/120	93.5 (2375.3)	46.8 (1187.6)	31.2 (791.8)	23.4 (593.8)	93.5 (2375.3)	46.8 (1187.6)	31.2 (791.8)	23.4 (593.8)
Load Case 3: 50% of Load Carried by T-Track, 50% By Wall Mount Supports									
3" Wall Mount Support	L/360	7.8 (197.9)	3.9 (99.0)	--	--	7.8 (197.9)	3.9 (99.0)	--	--
	L/240	11.7 (296.9)	5.8 (148.5)	3.9 (99.0)	--	11.7 (296.9)	5.8 (148.5)	3.9 (99.0)	--
	L/120	23.4 (593.8)	11.7 (296.9)	7.8 (197.9)	5.8 (148.5)	23.4 (593.8)	11.7 (296.9)	7.8 (197.9)	5.8 (148.5)
6" Wall Mount Support	L/360	15.6 (395.9)	7.8 (197.9)	--	--	15.6 (395.9)	7.8 (197.9)	--	--
	L/240	23.4 (593.8)	11.7 (296.9)	7.8 (197.9)	--	23.4 (593.8)	11.7 (296.9)	7.8 (197.9)	--
	L/120	46.8 (1187.6)	23.4 (593.8)	15.6 (395.9)	11.7 (296.9)	46.8 (1187.6)	23.4 (593.8)	15.6 (395.9)	11.7 (296.9)

Table 2.2 (Cont.): Maximum Vertical Spacing for CL-300 System Horizontal Wall Mounts with Steel Stud Backup

Dead Load (psf)		4				10			
Nominal Wind Load (psf)		30	60	90	120	30	60	90	120
Component	Deflection Requirement	Maximum Vertical Spacing in (mm)							
Load Case 4: 25% of Load Carried by T-Track, 75% By Wall Mount Supports									
3" Wall Mount Support	L/360	5.2 (132.0)	--	--	--	5.2 (132.0)	--	--	--
	L/240	7.8 (197.9)	3.9 (99.0)	--	--	7.8 (197.9)	3.9 (99.0)	--	--
	L/120	15.6 (395.9)	7.8 (197.9)	5.2 (132.0)	3.9 (99.0)	15.6 (395.9)	7.8 (197.9)	5.2 (132.0)	3.9 (99.0)
6" Wall Mount Support	L/360	10.4 (263.9)	--	--	--	10.4 (263.9)	--	--	--
	L/240	15.6 (395.9)	7.8 (197.9)	--	--	15.6 (395.9)	7.8 (197.9)	--	--
	L/120	31.2 (791.8)	15.6 (395.9)	10.4 (263.9)	7.8 (197.9)	31.2 (791.8)	15.6 (395.9)	10.4 (263.9)	7.8 (197.9)
Load Case 5: Uniform Load Applied to Length of Wall Mount Supports									
3" Wall Mount Support	L/360	4.9 (124.5)	--	--	--	4.9 (124.5)	--	--	--
	L/240	7.3 (185.4)	3.7 (94.0)	--	--	7.3 (185.4)	3.7 (94.0)	--	--
	L/120	14.7 (373.4)	7.3 (185.4)	4.9 (124.5)	3.7 (94.0)	14.7 (373.4)	7.3 (185.4)	4.9 (124.5)	3.7 (94.0)
6" Wall Mount Support	L/360	9.8 (248.9)	--	--	--	9.8 (248.9)	--	--	--
	L/240	14.7 (373.4)	7.3 (185.4)	--	--	14.7 (373.4)	7.3 (185.4)	--	--
	L/120	29.4 (746.8)	14.7 (373.4)	9.8 (248.9)	7.3 (185.4)	29.4 (746.8)	14.7 (373.4)	9.8 (248.9)	7.3 (185.4)

3. THERMAL ANALYSIS

The following sections present the thermal performance results (U-values and effective R-values that include thermal bridging) of the evaluated steel stud scenarios for the system described in Section 1.

Thermal and Condensation Modelling Procedures

The thermal performance of the CL-300 Cladding Support System configurations were evaluated by 3D thermal modelling using the Nx software package from Siemens, which is a general purpose computer aided design (CAD) and finite element analysis (FEA) package. The thermal solver and modelling procedures utilized for this study were extensively calibrated and validated to within +/- 5% of hotbox testing for *ASHRAE Research Project 1365-RP Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction* and for the *Building Envelope Thermal Bridging Guide*[1].

The thermal analysis utilized steady-state conditions, published thermal properties of materials and information provided by CLADIATOR. Additional assumptions for the thermal analysis are listed in Appendix A.

The thermal performance of all configurations of the CL-300 Cladding Support System were evaluated at 16" o.c. horizontal spacing aligning with the steel studs in the backup wall. The 4" tall Therme clips were evaluated at varying vertical spacing of 24" o.c., 36" o.c., and 48" o.c. Three exterior insulation depths were evaluated: 2", 3", and 4", with the T-Track positioning adjusted as per CLADIATOR documentation. The variation in configuration of the T-Track to accommodate varying insulation thickness is shown below in Figure 3.1.

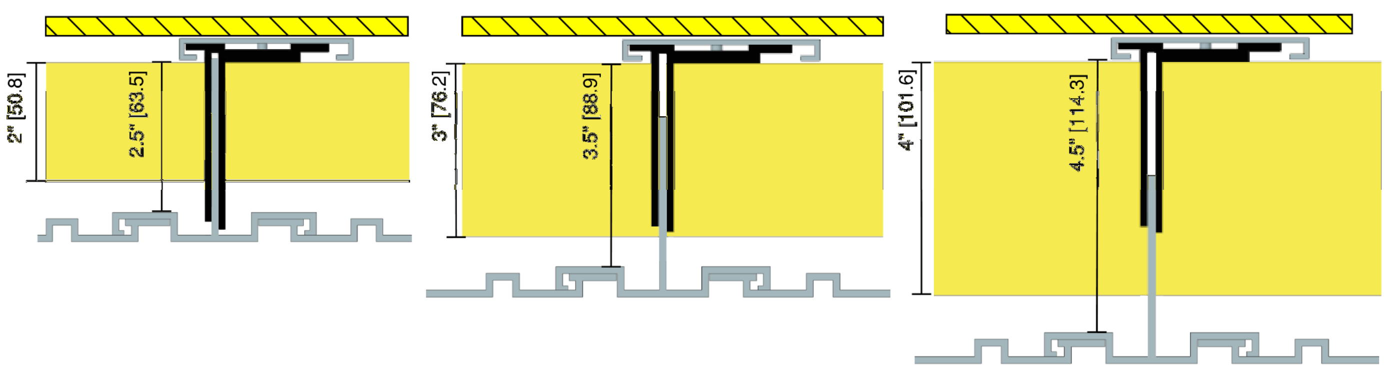


Figure 3.1: Component Arrangement for Varying Insulation Thicknesses

[1] https://www.bchydro.com/thermalguide

For the condensation analysis, the same software was used as for the thermal analysis described above. The analysis was performed with parametric boundary condition temperatures, where 0 represents the exterior temperature and 1 represents the interior temperature. The resulting temperature index (T_i) can then be found for any surface. Temperature indices can provide insight towards the range of temperatures that can be found in critical areas of the assembly, and for estimating risk for condensation, subject to interior environmental conditions. Further details regarding the temperature index and application can be found in Appendix D.

Surface temperatures due to average steady-state conductive heat flow in three-dimensions were utilized as a means of highlighting where the critical temperature locations are. It must be recognized that the objective of this analysis is **not** to predict in-service surface temperatures subject to transient conditions, air leakage, variable heating systems, and/ or interior obstructions that restrict heating/cooling or air flow to the assembly. For full limitations of this modeling approach, see ASHRAE 1365-RP.

Thermal Results for CL-300 Cladding Support System

Assembly U- and R-Values

Table 3.1 provides the spacing of the Therme clips, exterior insulation thickness, nominal R-value of the insulation and the determined assembly U- and effective R-Value that includes the impact of thermal bridging by the components, including studs and cladding attachments. Further assembly information, including dimensions and materials are given in Appendix B. Example temperature profiles for each configuration are provided in Appendix C.

Table 3.1: Clear Field Thermal Transmittance for CL- 300 System with Steel Stud Backup

Therme Clip Vertical Spacing in	**Exterior Insulation Thickness** in	**Exterior Insulation Nominal R-Value**[2] h·ft²·°F/Btu (m²·°K/W)	**Effective U-Value** Btu/h·ft²·°F (W/m²·°K)	**Effective R-Value** h·ft²·°F/Btu (m²·°K/W)
24	2	R-8.4 (1.48)	0.110 (0.622)	**R-9.1** (1.61)
	3	R-12.6 (2.22)	0.073 (0.416)	**R-13.7** (2.41)
	4	R-16.8 (2.96)	0.057 (0.323)	**R-17.6** (3.09)
36	2	R-8.4 (1.48)	0.108 (0.612)	**R-9.3** (1.63)
	3	R-12.6 (2.22)	0.070 (0.397)	**R-14.3** (2.52)
	4	R-16.8 (2.96)	0.056 (0.317)	**R-17.9** (3.15)
48	2	R-8.4 (1.48)	0.107 (0.606)	**R-9.4** (1.65)
	3	R-12.6 (2.22)	0.069 (0.393)	**R-14.4** (2.54)
	4	R-16.8 (2.96)	0.054 (0.307)	**R-18.5** (3.26)

[2] Note this value is the nominal R-value of the exterior insulation ONLY. Additional components, such as the sheathing, airspaces, and air films also all contribute an additional R-3.5 towards the nominal R-value of the entire assembly.

Temperature Indices for Condensation Analysis

Table 3.2 provides the spacing of the Therme clips, exterior insulation thickness, and minimum temperature index (T_i) on the surface exposed to interior conditions. This location was consistent for all configurations of the analyzed CL-300 Systems: on the interior surface of the sheathing in line with the Therme clips along the steel stud, shown below in Figure 3.1.

Table 3.2: Minimum Temperature Index for the CL-300 System with Steel Stud Backup

Therme Clip Vertical Spacing in	**Exterior Insulation Thickness** in	**Exterior Insulation Nominal R-Value**[3] h·ft²·°F/Btu (m²·°K/W)	**Temperature Index** T_i
24	2	R-8.4 (1.48)	0.74
	3	R-12.6 (2.22)	0.74
	4	R-16.8 (2.96)	0.75
36	2	R-8.4 (1.48)	0.84
	3	R-12.6 (2.22)	0.85
	4	R-16.8 (2.96)	0.85
48	2	R-8.4 (1.48)	0.88
	3	R-12.6 (2.22)	0.88
	4	R-16.8 (2.96)	0.88

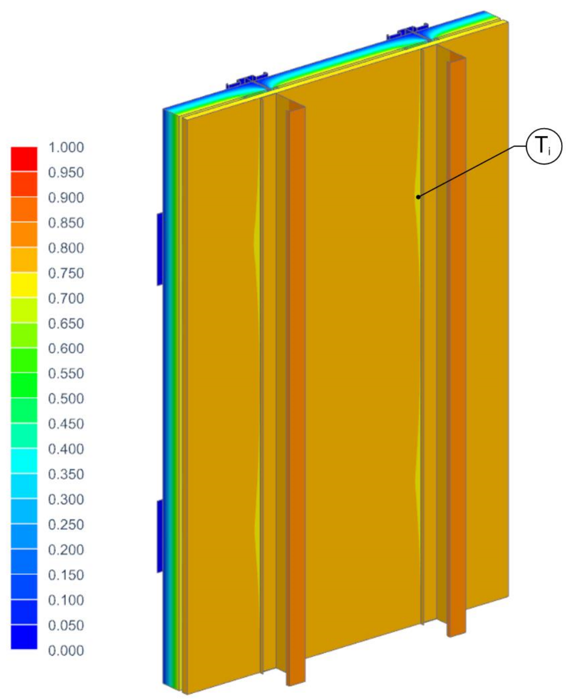


Figure 3.1: Location of the Minimum Temperature Index (T_i). Illustrated on 24"o.c. Therme Clip Spacing, 2" Exterior Insulation; Interior Gypsum Hidden

[3] Note this value is the nominal R-value of the exterior insulation ONLY. Additional components, such as the sheathing, airspaces, and air films also all contribute an additional R-3.5 towards the nominal R-value of the entire assembly.

4. ENERGY CODE COMPLIANCE

In the United States, the vast majority of states have an adopted energy code that set out the minimum requirements for energy efficiency for that jurisdiction, including requirements for the building envelope. The two most commonly referenced energy standards used as the basis for commercial and mid- to high-rise construction in these energy codes are ASHRAE 90.1[4] or IECC[5], depending on the building type. Similarly in Canada, many provincial energy codes use ASHRAE 90.1 or NECB[6] as the referenced energy standards. These standards may differ in specific values and requirements/exemptions, however they generally employ three main options for compliance: **Prescriptive, Trade-off and Performance Paths**.

The prescriptive path awards compliance for explicitly meeting all provisions of the code relevant to the project in question. For the building envelope, assemblies must be lower than a given maximum thermal transmittance U-value or must meet or exceed insulation values for a prescribed assembly. These requirements are based on climate region, construction type and occupancy type. The prescriptive path is fairly straightforward and building components need only be assessed individually. However, some of the prescriptive requirements may be difficult to achieve due to design trends. For example, in ASHRAE 90.1-2007, the prescriptive path requires a glazing to wall ratio of less than 40%. If these prescriptive requirements cannot be met, then another compliance path must be used.

The trade-off path allows for projects to trade-off the performance of building envelope components (i.e. roofs, walls, and windows) when the prescriptive requirements are not met for each and every assembly. This approach allows for flexibility in compliance if the performance of some envelope assemblies may be lower than the prescriptive values, as long as other better performing assemblies can make up for it based on area weighting of performance. For example, a low thermally performing wall may be compensated by a large roof that is above its prescriptive value. This approach can be demonstrated using either specific calculations (provided in the standards) or through computer software that is typically provided by the authors of the standard.

The performance path requires an evaluation of the annual energy use of the whole building that includes the interaction the building envelope, mechanical and electrical systems. This must be done using computer simulation, where the proposed building and its systems are modelled and compared to a compliance building. The compliance building contains the same shape, size, occupancy and scheduling of proposed building, but all of its individual components meet the minimum requirements of the standard. For example, the thermal performance of the walls of the compliance building must match the prescriptive U-values of the standard. The proposed design is acceptable if the annual energy use is less than or equal to that of the compliance building. The performance paths allows the greatest flexibility of all the compliance paths but requires a much more detailed accounting of the design. The performance path takes into account other variables such as building orientation, higher efficiency HVAC systems, and lighting controls, which would not give any benefit with the other two compliance paths. Each standard gives requirements that specify what can and cannot be included with the energy model and which energy modelling programs can be used.

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[4] ASHRAE 90.1 "*Energy Standard for Buildings Except Low-Rise Residential Buildings*"
[5] IECC "International Energy Conservation Code"
[6] NECB "National Energy Code for Buildings"

Each standard outlines their own prescriptive values for the envelope. While a jurisdiction may adopt an energy standard, each state, province or even city may modify the standard and its prescriptive values to meet their own specific energy goals. Beyond that, these standards are also updated periodically. For instance, ASHRAE 90.1 is typically updated every 3 years whereby currently versions 2007, 2010, 2013 and 2016 are used in various locations across North America. The prescriptive values in these standards typically become more stringent with each update. A local energy code may not always adopt the latest version, leading to variability of requirements across North America. With that in mind, it is always recommended for designers to be aware of the specific requirements set by the local authorities having jurisdiction for their particular project. Please see the following website from the U.S. Department of Energy for the most current energy code adoptions in the US at the state level:

https://www.energycodes.gov/status-state-energy-code-adoption

The U-values found in this report for the CL-300 system can be used to determine energy code compliance using any of the three compliance paths listed previously. For quick reference, the prescriptive U-value requirements for ASHRAE 90.1-2010, 2013 and 2016 has been reproduced in Appendix E of this report, along with comparisons to the CL- 300 System with an empty steel stud backup wall. The maximum climate zone achievable prescriptively using the CL-300 system for the analyzed insulation thickness and spacing has been provided for each of those ASHRAE 90.1 versions.

5. CONCLUSIONS

This report summarizes the evaluation of structural performance (maximum spacing of components) and thermal performance (U-value and effective R-values) for the CL-300 Cladding Support System with an *empty* steel stud backup wall with varying exterior insulation thicknesses (2", 3" and 4" of mineral wool insulation) and CLADIATOR Therme clip vertical spacings (24", 36" and 48"o.c.). The following conclusions for the analyzed system scenarios can be made:

Structural Analysis

- In the fully compressed condition analyzed, the 4" and 6" polyamide Therme clip can be spaced up to 52.0" (1321mm) vertically depending on the loading scenario. At 10psf dead weight and 120psf wind load, the maximum vertical spacing of the 4" and 6" clip are 10.9" (276mm) and 27.0" (686mm) respectively. Therme clip spacings will vary for scenarios where the T-Track is extended further from the wall.

- The vertical spacing of the horizontal wall mounts have been provided for various shared loading cases. Significant loading of the horizontal wall mounts will result in much tighter vertical spacings.

- The Therme clip fasteners should be installed through the base track and sheathing into the back-up wall steel studs. The length of fastener should be chosen so that a minimum of three threads have engaged the steel stud.

- Within the ranges of wind and dead loads applied in this analysis, the connections between the Therme clips and the T-Track should consist of a minimum of three (3) #10 fasteners. The fasteners should be installed in the circular holes at one clip per T-Track (close to the middle) and into the vertically slotted holes at all other clips on the same T-Track.

Thermal Analysis

- For the exterior insulated steel stud scenarios with 2"-4" of mineral wool insulation, the assembly U-values range from 0.054 BTU/hr·ft^2·°F – 0.110 BTU/hr·ft^2·°F (0.307 W/m^{2}K – 0.622 W/m^{2}K)

- The Therme clip spacing from 24" o.c. vertically to 48"o.c. vertically can improve the thermal performance by up to 5% for the scenarios analyzed.

- The effectiveness of the overall assembly (thermal transmittance of assembly with thermal bridging vs thermal transmittance of the assembly with no thermal bridging) ranges from 77-91% effective depending on insulation thickness and component spacing (low end 77% for the 2" mineral wool system with 24"o.c. spacing of the Therme clips to high end 91% for the 4" mineral wool system with 48"o.c. spacing of the Therme clips)

The U-values shown here can be used in compliance calculations through any of the compliance paths set forth in additional energy codes and standards such as ASHRAE 90.1, IECC, and/or NECB as of the published date of this report.

If there are any questions regarding the content or modelling conducted for this report, please contact the undersigned.

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APPENDIX A – MODELLING PARAMETERS AND ASSUMPTIONS

A.1 Structural Analysis Assumptions and Provisions

For this report, the analysis was performed as per the Allowable Stress Design (ASD) requirements as outlined in the International Building Code (IBC) and the Aluminum Design Manual (ADM). The following parameters were also assumed:

- Material properties for the polyamide used in this analysis were obtained from CLADIATOR™ and other publicly available resource materials.
- Aluminum 6063-T5 properties and member capacities were determined based on the 2015 Aluminum Design Manual.
- PDF drawings of the systems supplied by CLADIATOR were relied upon for dimensions and calculations of section properties.
- Fasteners in an aluminum rainscreen system are recommended to be a 300 series stainless steel for optimal resistance to the effects of corrosion, dissimilar metals and hydrogen-induced embrittlement. For this analysis, fasteners into steel studs were assumed to be #10 Bi-Metal HWH SS fasteners and the allowable pull-out from 16ga 50ksi steel values were used. For the aluminum-aluminum or aluminum-polyamide connections, a generic self-drilling #10 HWH stainless steel fastener was assumed and allowable loads were calculated according to the ADM. A safety factor of 3 was used to obtain the allowable loads of the fasteners. The results of this analysis are based on the specific capacities of the chosen fasteners. Changes to the fasteners will change the results. Likewise, changes to the thickness or grade of the back-up wall steel studs will change the results.
- The cladding was assumed to distribute the load evenly to the sub-framing; point loading from the cladding was not considered.
- Connections between the polyamide clips and the vertical T-Track were assumed such that the dead load would be supported by one clip and the remaining clips would be configured to resist wind load but allow temperature induced expansion and contraction in the T-Track.

A.2 Thermal Modelling Assumptions

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.
- Cladding materials and secondary structures outboard of the insulation can vary widely. It has been found in ASHRAE 1365, for rainscreen cavity systems most lightweight claddings have an insignificant impact on the thermal performance other than shielding the insulation from direct wind exposure. To provide general information for the system, the cladding, secondary structure outboard of the vertical rails and rainscreen cavity were not explicitly modelled, but was incorporated into the exterior film coefficient.

- Material properties were taken from information provided by CLADIATOR, published material information from Lawrence Berkeley National Laboratory and ASHRAE Handbook – Fundamentals for common materials. These values are typically reported at operating temperatures between 0ºC and 21ºC Materials used in this analysis were assumed to have a constant thermal conductivity.
- From the calibration in 1365-RP, contact resistances between materials were modeled and varied between R-0.01 and R-0.2 depending on the materials and interfaces.
- Insulation and other components were considered tight to adjacent interfaces. Air gaps smaller than 2mm were assumed incorporated with the contact resistances.
- Placement of weather barriers and membranes were assumed not to impact the thermal conduction through the system and were not included in the analysis.
- Impacts of air leakage within the assembly were not included.
- The temperature difference between interior and exterior was modelled as a dimensionless temperature index between 0 and 1 (see Appendix A.3).
- As per standard U-value evaluation, no solar heating impacts were included.

A.3 Thermal Transmittance

The methodology presented in the Building Envelope Thermal Bridging Guide separates the thermal performance of clear field assemblies and transition details (slabs, parapets, window interfaces) in order to simplify heat loss calculations.

For this report, only clear field transmittances for this system were evaluated, and not any transition details. The presented U-values in the Tables in this report contain only uniform repeating thermal bridges, such as studs and clips, and do not include any interface details, such as slab intersections or top and bottom stud tracks.

A.4 Boundary Conditions

Table A-1: Boundary Conditions

Boundary Location	Combined Convective and Radiation Heat Transfer Coefficient BTU/hft^{2}ºF (W/m^{2}K)
Exterior (15mph wind) with Cladding and Airspace	1.5 (8.3)
Interior Walls	1.5 (8.3)

APPENDIX B –
ASSEMBLY INFORMATION AND MATERIAL PROPERTIES

B.1 CL- 300 Cladding Support System with Steel Stud Backup Wall

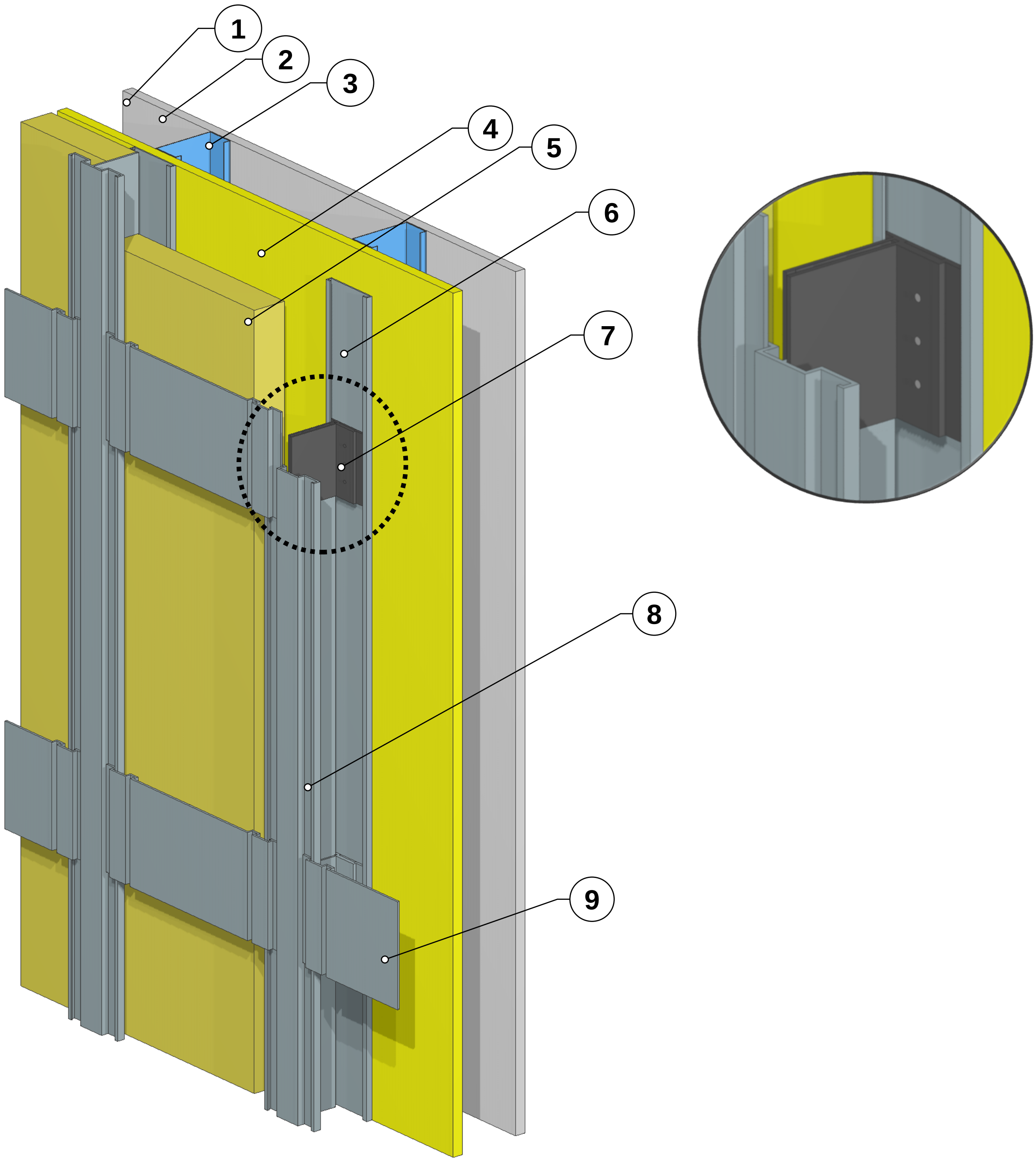

Table B.1: Thermal Properties of Materials

Ref.	Component	Thickness Inches (mm)	Conductivity Btu·in / ft²·hr·°F (W/m K)	Nominal Resistance hr· ft²· °F/BTU (m²K/W)
--	Interior Film	-	-	R-0.7 (RSI-0.12)
1	Gypsum Board	5/8" (16)	1.1 (0.16)	R-0.6 (RSI-0.10)
2	Air in Stud Cavity	1 5/8" (41)	-	R-0.9 (RSI-0.16)
3	3 5/8" x 1 5/8" Steel Studs, 16" o.c.	16 gauge	430 (62)	-
4	Gypsum Sheathing	5/8" (16)	1.1 (0.16)	R-0.6 (RSI-0.10)
5	Exterior Insulation (Mineral Wool)	2" to 4" (51 to 102)	0.24 (0.034)	R-8.4 to R-16.8 (RSI-1.48 to RSI-2.96)
6	Aluminum Base Track, 16" o.c. horizontally	1/8" (3.3)	1422 (205)	-
7	Therme Polyamide Clip	-	1.73 (0.25)	-
8	Aluminum T-Track, 16" o.c. horizontally	1/8" (3.3)	1422 (205)	-
9	Aluminum Wall Mount Supports	1/8" (3.3)	1422 (205)	-
--	Exterior Film, including Cladding and Rainscreen airspace	-	-	R-0.7 (RSI-0.12)

Table B.2: Structural Properties of Materials

Material	Parameter	Value
6063-T6 Aluminum	Yield Strength	16.0 ksi (110 MPa)
	Ultimate Strength	22.0 ksi (152 MPa)
	Elastic Modulus	10,100 ksi (70,000 MPa)
PA6.6 Polyamide	Tensile Yield Strength	5.08 ksi (35 MPa)
	Compressive Yield Strength	6.67 ksi (46 MPa)
	Elastic Modulus	650 ksi (4,500 MPa)
Base-wall Steel Studs	Thickness	16ga – 54mils (1.37mm)
	Grade	50 ksi (345 MPa)
#10 HWH SS Fastener: Horizontal Wall Mount Support to T-Track	Allowable Tension Load	119.7 lbf (532 N)
	Allowable Shear Load	274.3 lbf (1220 N)
#10 HWH SS Fastener: Polyamide Clip to T-Track	Allowable Shear Load	167.5 lbf (745 N)
#10 HWH SS Hilti Bi-Metal KWIK FLEX Fastener: Polyamide Clip and Base Track to Base-wall Steel Studs	Allowable Tension Load	205.3 lbf (913 N)
	Allowable Shear Load	186.0 lbf (827 N)

**Fastener Allowable Loads = Ultimate Load/Safety Factor (3.0)*

APPENDIX C –
SIMULATED TEMPERATURE PROFILES

C.1 CL-300 with Steel Stud Backup Wall

As an example of the thermal profiles of the CL-300 system, the following figures illustrate typical temperature distribution for the CL-300 system with 2in., 3in., and 4in. exterior insulation at 24in. o.c. vertical Therme clip spacing. The profiles presented as a temperature index (between 0 and 1). See Appendix A.3 for more information.

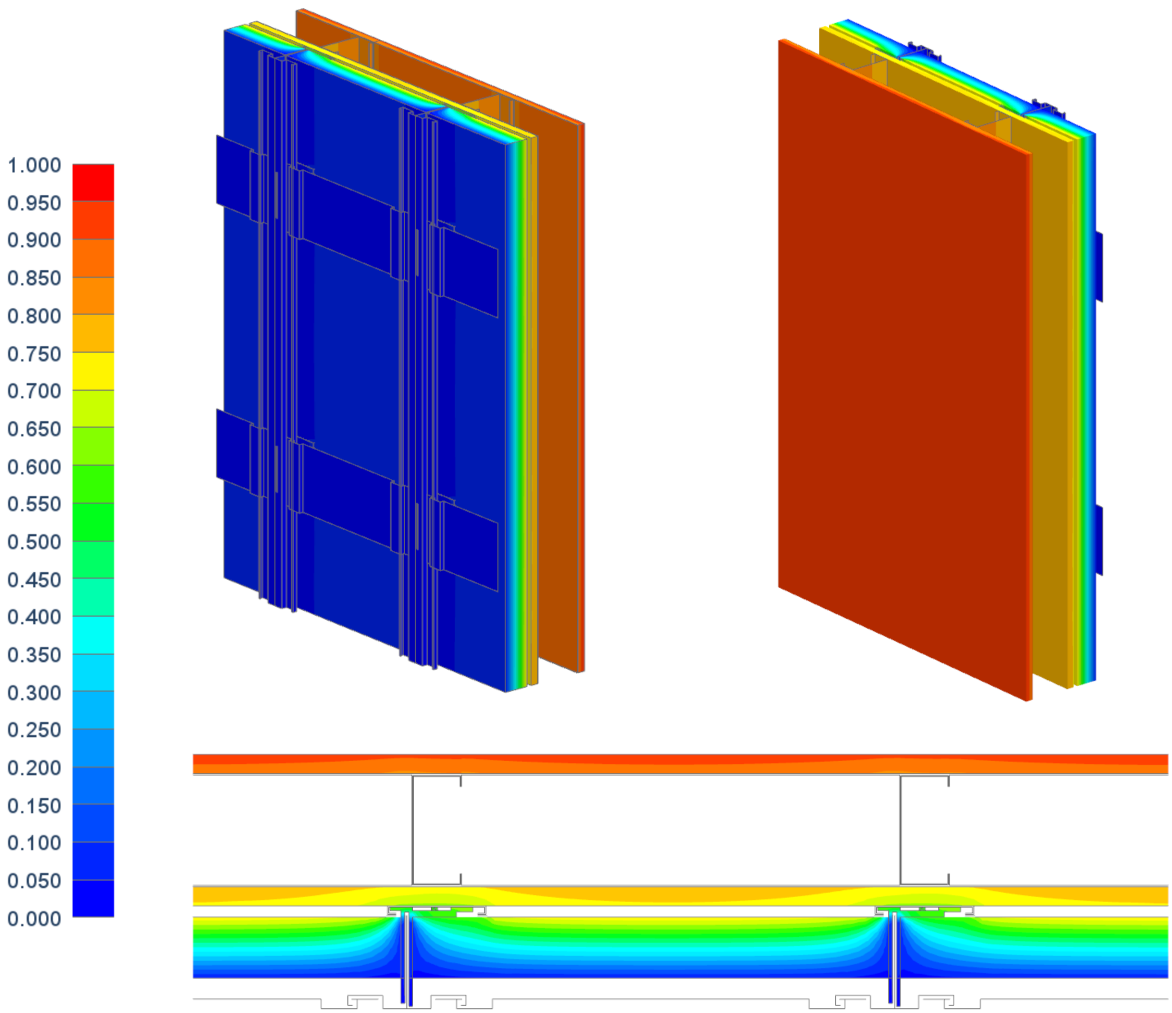

Figure C1.1: Temperature Profile of CL-300 Cladding Support System: 2in. Exterior Insulation isometric view from exterior, interior and plan view through clip

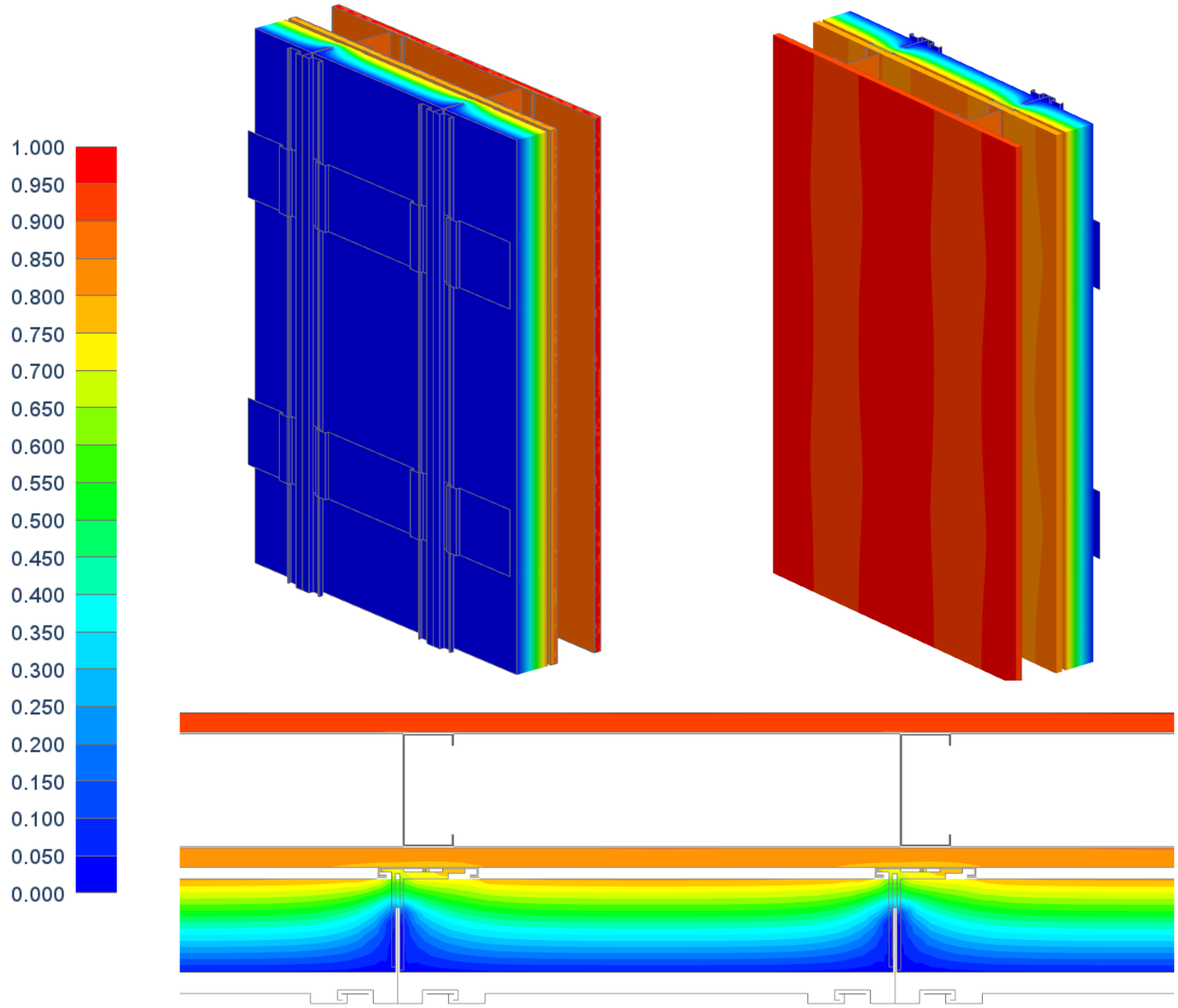

Figure C1.2: Temperature Profile of CL-300 Cladding Support System: 3in. Exterior Insulation isometric view from exterior, interior and plan view through clip