



ENERGY GUIDE FOR:

# BEHLEN RIGID FRAME STEEL BUILDINGS

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Building name: Air Bravo Hangar, Barrie, Ont.  
Builder: Mike Moore Construction Ltd.

## Disclaimer

BEHLEN Industries LP; Energy Guide for BEHLEN Rigid Frame Steel Buildings, contains information to assist professional designers, engineers, architects and other interested parties in the thermal analysis of typical wall and roof systems used in steel building systems (SBS) utilizing steel supports. BEHLEN and our subsidiary companies are constantly improving products and technical information and therefore, the information in this guide document is subject to change without notice. Always ensure you have the current information by contacting BEHLEN direct.

This guide document is not to replace advise or guidance from any professionals in regards to building design, including building envelopes, structural or code conformance.

BEHLEN Industries LP does not assume any responsibility or liability for use of information in this guide document and will not be bound by project specifications, purchase orders terms and conditions, or contract documents, for the conformance to thermal design, code conformance or project requirements.

BEHLEN Industries LP would like to acknowledge the exceptional work and guidance by; EVOKE Buildings Engineering Inc, QAI Laboratories, ECOSPAN Profiles Inc and ARTSPAN IMP. This guide would not have been possible without their assistance.

## Preface – Introduction

With the evolving energy code changes and the introduction of step codes by municipalities, it is important to understand how insulated rigid frame steel buildings will perform. BEHLEN Industries LP created this document as a guide, to provide data on wall and roof assemblies utilizing steel interior liner, thermal clips and exterior cladding and roof panels typically used in rigid frame steel buildings, including Insulated Metal Panels (IMP).

This guide focuses on insulated walls and roof assemblies and provides thermal values for available insulation options used in steel building systems (SBS). This guide will show insulation R-Values, Nominal R-Values, Effective R-Values, and Clear Field thermal transmittance U-Values for various steel building assemblies. Building envelope requires a continuous air barrier to control air leakage utilizing a site sealed interior liner or properly sealed IMP. Building Envelope specialist should be consulted and construction details and methods reviewed to ensure continuity of air barrier control layers. Testing will be required to validate completeness of the envelope to meet air leakage requirements.

The guide is intended for readers who have an in-depth knowledge and complete understanding of frame type steel building systems and components, current energy codes, local bylaws, energy modeling and specifications. It is developed for Design-build builders, Architects, Engineers and Coordinating Registered Professionals. The data contained presents solutions for the best design decisions on how a building and their assemblies will comply with current energy targets for their projects.

Building energy requirements in most jurisdictions in Canada reference energy efficiency standards and model codes from the National Energy Code for Buildings (NECB). Jurisdictions within Canada such as British Columbia, Ontario and Quebec modify their model energy codes and standards with additional requirements to NECB including under the Ontario Building Code Supplementary Standard SB-10 (OBC SB-10) and ASHRAE 90.1. These codes and standards may differ in specific requirements but all provide three options or paths for compliance; Prescriptive, Trade-off or Performance Path utilizing computer energy modeling. Optimization of the building envelope utilizing computer modeling to include all the equipment inside the building may provide significant savings on the insulation system required versus following the simple prescriptive path.

Designers and Coordinating Registered Professionals, must check and understand the applicable codes and standards for energy compliance requirements and conformance for their project.

While this document provides information on various configurations for BEHLEN assemblies and provides solutions and data required to determine a buildings overall compliance or solutions to the energy codes, it is the responsibility of the Owner, Builder or Coordinating Registered Professional that applies for the final building permit to ensure acceptance for compliance. This guide focuses on opaque wall and roof assemblies and will not address all other factors required for whole building compliance including; HVAC and fan efficiency, lighting/plug loads, window/door thermal efficiency, daylighting or building orientation. The thermal assemblies contained in this guide will only form part of the required building permit compliance as it cannot address the numerous and variable options for the entire building.

Assessing a building for its final compliance level must be done by a knowledgeable Building Energy Science professional and is not the responsibility of BEHLEN Industries LP or associated divisions.

This document will provide a basic understanding of frame type Steel Building Systems (SBS), Metal Building Insulation (MBI), Insulated Metal Panels (IMP), structural supports, and wall and roof systems. It presents various scenarios for thermal transmittance and resistance values based on variable support spacings and assembly systems.

U-Value or factor (Overall Thermal Transmittance): Total rate, expressed in  $W/(m^2 \cdot K)$  of heat flow (transferred) through an entire building assembly [inverse of the effective RSI Value].

R-Value (thermal resistance): The measure of a material's ability to impede heat flow. Based on a measured standard temperature at 75°F using ASTM C518 test method.

The presented Effective Assembly values for insulated roof and wall assembly systems have been provided by EVOKE Building Engineering Inc (Evoke), an independent third-party thermal analysis company with over 19 years of consulting experience related to building science and energy efficiency. Evoke provides guidance to industry practitioners to help make informed design decisions related to constructability, thermal, structural, and energy performance.

Insulated Metal Panels (IMP) Effective Assembly values have been provided by QAI Laboratories who specializes in testing, certification and evaluations for building products with comprehensive testing services. Testing was conducted based on ASTM C518-17 and ASTM C1363-19 test methods.

Additional insulation products and systems can be used on BEHLEN rigid frame steel buildings including; Spray Foam Insulation, faced and un-faced polyisocyanurate rigid foam boards, proprietary banding systems, and mineral wool. These additional products are out of the scope of this document as some of the products have specific building code fire safety requirements for foam insulation and installation methods. For thermal information and guidance on other products, contact the respective manufacturer or reach out to BEHLEN Industries LP.

# Primer on Rigid Frame Steel Building Systems

For over 55 years, BEHLEN Industries LP has grown to be the largest manufacturer of steel building systems in Canada. BEHLEN manufactures both a Frameless and Rigid Frame Steel Building Systems for Industrial, Commercial, Institutional, Recreational and Agricultural markets. This guide will focus on the BEHLEN Rigid Frame Steel Building System. Contact BEHLEN Industries LP direct for information regarding the BEHLEN Frameless System or other insulating methods.

Rigid Frame Steel Building Systems are a custom-engineered steel solution designed to optimize and integrate the primary and secondary structural framing, roofing and wall cladding in order to support and transfer loads in an optimum manner. Rigid frame designs are application specific, fabricated and ready for bolt-together construction. Steel frame design and fabrication maximizes the engineering properties of the steel shape. The integral framing system is efficient in its design and optimizes the use of steel through software programs for estimating, design, detailing and drawings. Structural members are tapered built up sections that are 10% to 20% lighter than conventional hot rolled members. The optimizing of steel frames and tapered columns and beams reduces structural weight, making foundation designs simpler and lighter.

Primary Framing consists of all the structural elements which transfer loads to the foundation. Buildings are available in a variety of shapes and can be customized to meet design requirements. Primary framing systems can include; Clear Span with no intermediate supports, Multi Span with strategically placed columns, Lean-to, supported on one side by a Clear Span or Multi Span framing system, and Mono Slope framing.

Secondary Framing consists of the elements which support the roof and wall sheeting and transfers the design loads to the primary framing. Secondary framing is referred to as purlins on roofs and girts on the walls, and are comprised of light weight cold-formed C and Z sections protected from corrosion with a standard G-90 (Z275) zinc coating.

Secondary Framing can incorporate the use of continuous, draped insulation over secondary framing. Laminated faced or un-faced fibreglass Metal Building Insulation (MBI) can be draped over purlins and girts and compressed between the metal wall or roof panels and the secondary framing. This system can be a single layer or double-layer and will meet most requirements for semi-conditioned or unconditioned buildings. Additional insulation can be used to in-fill the purlins or girts for added thermal performance. Interior steel wall and roof liners can be employed to perform as the air vapour barrier while providing a durable interior finish. Building exterior can be finished with pre-painted, profiled steel cladding in numerous colours and profiled shapes. Roofs can be finished with a thermally responsive standing seam (SSR) metal roof system or a through-fastened roof system.

For higher performing values, THERMALGUARD Systems or Insulated Metal Panels are used in conditioned buildings when interior finishes are utilized. For THERMALGUARD System, steel interior liners, steel chairs/Z-clips, hat bars and thermal blocks are incorporated on the outside face of purlins and girts. This allows for continuous insulation in various depths while reducing thermal bridging.

Insulated Metal Panels (IMP) for both walls and roofs are installed direct to girts and purlins secondary framing, utilizing IMP clips that are concealed within the off-set panel tongue and groove joint. Sealant is applied to all secondary framing members and in all panel joints to provide a continuous air vapour barrier. Panel thickness ranges from 2" (50mm) to 6" (152mm) for both walls and roof panels and come in a variety of colours and profile options. IMP roof panels have a mechanically folded 2" (50mm) standing seam.

## **Note on interior steel liner panels:**

Interior steel liner panels, when used as part of roof thermal system, provide a solid working surface during installation while providing options for interior colour finishes. Steel liners provide mechanical protection to installed insulation systems and act as an air and vapour barrier when properly sealed during installation. Removal of the interior liner will not significantly alter the tabulated thermal values when insulating products include an integral air and vapour barrier and installed with similar inside surface geometry.

**Note on secondary structural framing (support spacing and design loads):**

Secondary framing supports are an integral part of a building as they transfer loads to the primary steel structure. The loads include dead loads as well as live loads for wind and snow. Building safety is paramount when it comes to design loads and support spacing. Roof support spacing will vary across a roof depending on roof loading zones and may not be a consistent spacing. For example, a building may have sufficient purlin spacing in the field area, but requires closer spacing at the corners, or a high wall to roof condition. This could result in purlin spacing varying from 48" to 24" depending on loading locations across a roof. This variable support spacing can make determining thermal values for an entire roof challenging. For wall applications, girt support spacing may also vary based on large overhead door supports.

To help with variable secondary support spacing, BEHLEN had EVOKE analyze various spacing and how it effects thermal performance values. This represents accurate thermal values under real support spacing conditions for roof and wall designs in Canada.

Third party proprietary software programs used to assist designers to determine thermal values for roof assemblies are typically based on support spacing at 60" (5 feet). This includes some manufacturers and insulation suppliers published thermal results. This can lead to underperforming results for permit applications, when support spacing is required to be closer together for loading conditions. This document and tables take into account the variable secondary supports required for life safety and their thermal value variations.

**Note on gauge thickness variation and non-effects:**

Prior to completing the analysis for numerous assemblies, various steel gauges were analyzed and it was determined that varying the gauge of steel for supports, cladding or roofing panels, did not offer a noticeable degree of change in the thermal values of each assembly. Changes in thermal values was more noticeable in the variable support spacing and insulation thickness than with gauge of materials.

**Note on Thermal Blocks (Spacers):**

Thermal blocks, sometimes referred to as Thermal Spacers; improve thermal performance by reducing the conduction or cold bridging through the purlin and girts. Thermal Blocks for standing seam roof panels are typically 1" (25mm) thick by 3" (76mm) wide by 23.5" (597mm) with an average R-5/inch and can be extruded polystyrene or polyisocyanurate rigid foam. Thermal blocks are installed under the roof panels above the primary bottom insulation layer. The Thermal blocks can be placed either between roof clips, under the clips or in combination, and are installed in line with purlins. The blocks provide additional benefit of supporting the panels between the standoff SSR roof clips. For wall applications, 1" (25mm) Thermal Blocks are installed on the outside face of girts behind wall cladding or covered with continuous draped insulation.

**Note on through-beam penetrations:**

Through-beam penetrations for canopy's, overhangs or other architectural features that are tied back into the primary steel structure, can be a source of thermal bridging from unconditioned space to conditioned space and vice versa. Thermal bridging by through-beam penetrations can be reduced by utilizing proprietary high strength polyurethane structural thermal breaks, with thermal resistance values based on individual manufacturers published data.



# BEHLEN Rigid Frame Thermal Systems

Evolve evaluated the roof and wall assemblies to determine the clear field thermal transmittances (U-Values) and the assemblies effective R-Values. Thermal evaluation of the THERMALGUARD Roof and Wall Systems as well as common wall assemblies used in rigid frame steel building systems are provided. Parts of the information contained in this document have been extracted from Evolve's evaluation reports with originals available upon request.

The evaluated roof assemblies include the purlins, steel liner, thermal chairs, hat bar with thermal block and BEHLEN SSR standing seam roof connected with SSR clips. The fiberglass batt insulation ranged from 13.5" to 16.5" (343mm to 419mm) in total thickness and with compressed insulation over the hat bar. The purlins and chairs were modeled at various spacings. Figures 1 and 2 provide more details of the evaluated roof assemblies.

Evaluations were also completed on 4 different common wall assemblies - Full Cavity, Full Cavity Double Layer, and Faced MBI systems. The evaluated wall assemblies include all the components outlined in Figure 3 to 6 in the thermal results section. Scenarios include varying the thickness of the insulation and spacing of the girts.

The geometry of the components and assemblies are based on standard BEHLEN drawing detail sets and attached in Appendix A and B.

## Methodology

The thermal analysis was done using 3D thermal simulation using the Simcenter 3D software package from Siemens, which is a general-purpose computer aided design (CAD) and finite elements analysis (FEA) package. The thermal solver and modeling procedures utilized for this evaluation were extensively calibrated and validated to within +/- 5% of hotbox testing<sup>1,2,3</sup>. The thermal analysis utilized steady-state conditions, published thermal data for materials and information provided by BEHLEN. Additional assumptions for the thermal analysis are provided in Appendix C.

<sup>1</sup> ASHRAE Research Project 1365-RP, Thermal Performance of Building Envelope Details for Mid- and High-Rise Construction, 2011

<sup>2</sup> AISI Research Report RP18-1, Thermal Analysis of Cold-Formed Steel Wall Assemblies, 2018

<sup>3</sup> Building Envelope Thermal Bridging Guide, Version 1.6, 2021



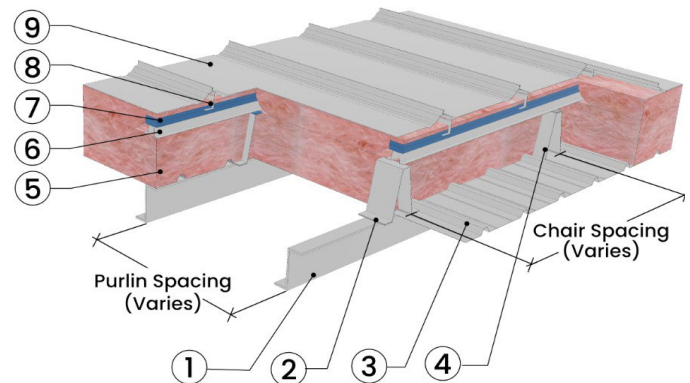
# Thermal Results Roof Systems

## Thermalguard® Roof System

The evaluated THERMALGUARD Roof assemblies include the purlins, steel liner, thermal chair, hat bars with thermal blocks and BEHLEN SSR standing seam roof panels connected with SSR clips. Fiberglass batt insulation ranges from 13.5" to 16.5" (343mm to 419mm) in total thickness and with compressed insulation over the hat bar. The purlins and chairs were modelled at various spacing to represent support spacing for design loads differences. Figures 1 and 2 provide more details of the evaluated roof assemblies.

### Components

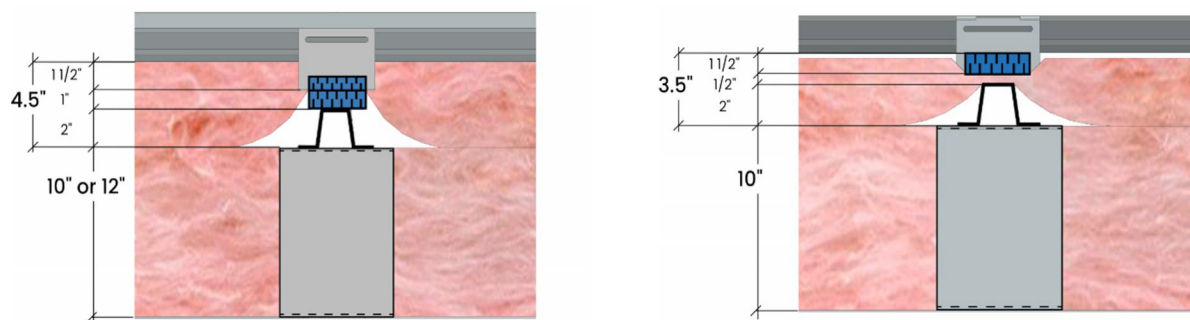
1. Steel purlins
2. 2x#14 steel fasteners
3. 24ga steel liner
4. 10" or 12" steel thermal chairs (12ga)
5. Fiberglass batt insulation
6. 16 gauge 2" Galvanized steel hat
7. Thermal blocks (R-5/inch)
8. 3 1/4" steel SSR clips
9. 24ga BEHLEN SSR standing seam roof panels



**Figure 1: Evaluated BEHLEN Thermalguard Roof System**

Two details for the thermal block and SSR clips were evaluated as illustrated in Figure 2 and described below.

1. **Baseline:** 1-inch thermal block under the SSR clips, 3/4" block between the clips and batt insulation compressed to 3/4" over the hat bar and thermal blocks.
2. **Alternative:** Batt insulation compressed to 1/2" over the hat bar and 1" thermal block over the batt between the SSR clips.



**Figure 2: Detailing of the Thermal Block and SSR clips (Baseline Left, Alternative Right)**

Geometry of the components and assemblies are attached in Appendix A.

The clear field assembly effective R-Values and the thermal transmittances of the BEHLEN Thermalguard Roof System is presented in Table 1 for the scenarios with the thermal block under the SSR clips and Table 2 for the scenarios with the thermal block between the SSR clips. Example temperature profiles are provided in Appendix D.

**Table 1.** Effective R-Value and Thermal Transmittance of the BEHLEN Thermalguard Roof System with Thermal Block under the SSR Clips (Figure 2 Baseline detail)

Purlin Spacing (inches)	Chair Spacing (inches)	Chair Height (inches)	Bottom Layer Insulation Nominal R-Value <sup>4</sup>	Top Layer Insulation Nominal R-Value <sup>4</sup>	R <sub>1D</sub>	Effective Assembly	
			ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)		R <sub>0</sub>	U <sub>0</sub>
24	36	10	R-30	R-20	R-51.3 (9.04)	R-29.4 (5.17)	0.034 (0.193)
		12	R-30 + R-10	R-16	R-57.3 (10.09)	R-31.5 (5.55)	0.032 (0.180)
36	36	10	R-30	R-20	R-51.3 (9.04)	R-33.7 (5.94)	0.030 (0.168)
		12	R-30 + R-10	R-16	R-57.3 (10.09)	R-36.8 (6.48)	0.027 (0.154)
36	48	10	R-30	R-20	R-51.3 (9.04)	R-36.3 (6.40)	0.028 (0.156)
		12	R-30 + R-10	R-16	R-57.3 (10.09)	R-40.0 (7.04)	0.025 (0.142)
48	48	10	R-30	R-20	R-51.3 (9.04)	R-38.9 (6.85)	0.026 (0.146)
		12	R-30 + R-10	R-16	R-57.3 (10.09)	R-42.8 (7.54)	0.023 (0.133)

**Table 2.** Effective R-Value and Thermal Transmittance of the BEHLEN Thermalguard Roof System with Thermal Block between the SSR Clips (Figure 2 Alternative detail)

Thermal Block Scenario	Purlin Spacing (inches)	Chair Spacing (inches)	Chair Height (inches)	Insulation Layers	R <sub>1D</sub>	R <sub>0</sub>	U <sub>0</sub>	
				Nominal R-Value <sup>4</sup>				
				ft <sup>2</sup> ·hr·°F/Btu ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	Btu/ft <sup>2</sup> ·hr·°F (W/m <sup>2</sup> K)	
Baseline				R-30 + R-20	R-51.3 (9.04)	R-38.9 (6.85)	0.026 (0.146)	
Thermal Block between Clips	5	48	48	10	R-30 + R-13	R-44.3 (7.80)	R-35.8 (6.30)	0.028 (0.159)

<sup>4</sup> This nominal R-value is the insulation only. Additional components such as the air films add R-1.3 nominal thermal resistance to the assembly.

<sup>5</sup> Utilizing 1" Thermal Block between the SSR clip versus Thermal Block under the SSR clips in assemblies composed of similar insulation, clip heights, support size, and spacing, achieve comparable thermal performance results tabulated in Table 1.

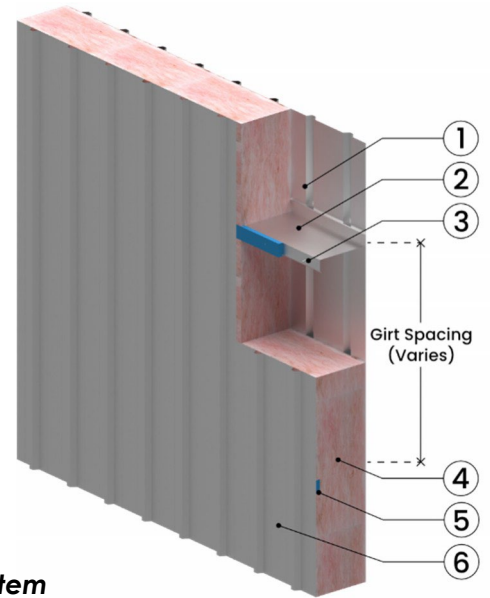
# Thermal Results Wall Systems

The clear field assembly effective R-Values and thermal transmittance of the evaluated wall assemblies follow in tables 3 to 6. Example temperature profiles are provided in Appendix D.

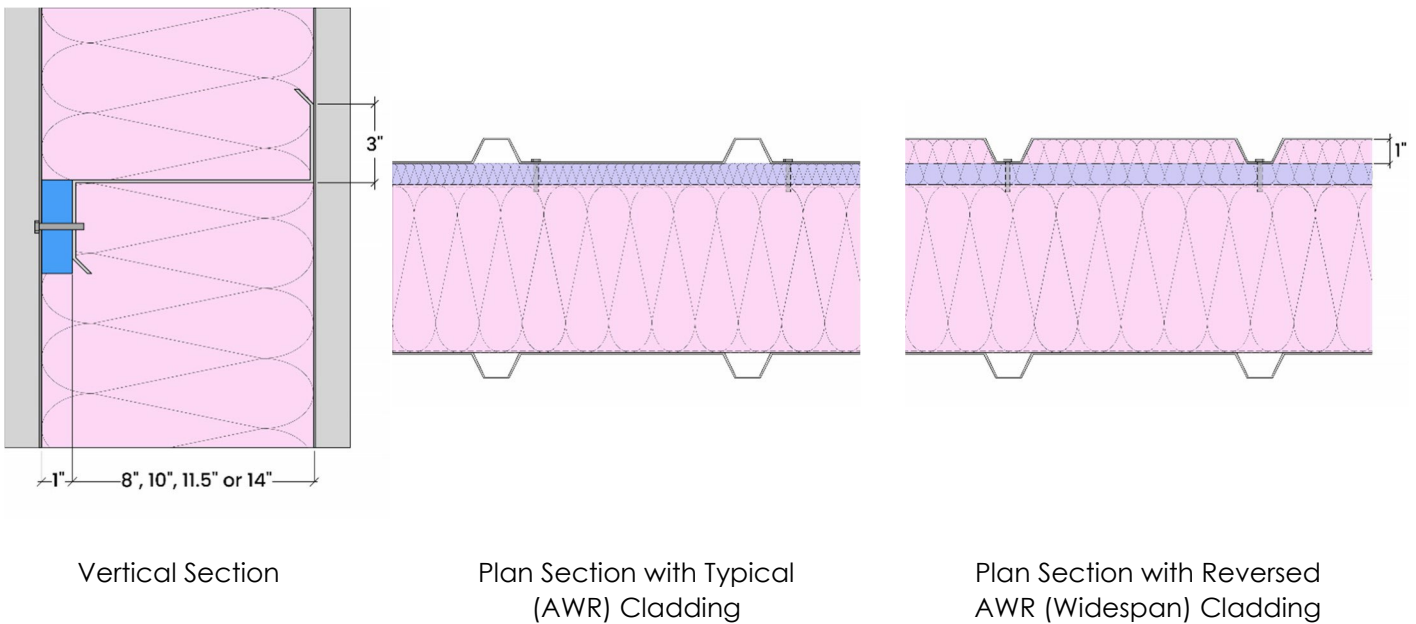
## BEHLEN Full Cavity Wall System

### Components

1. 24ga steel liner (AWR profile)
2. 16ga Galvanized steel girt
3. #14 steel fasteners at 12" (300mm) o.c.
4. Fiberglass batt insulation between girts
5. 1" thermal block (R-5/inch)
6. 24ga exterior steel cladding (AWR profile)



**Figure 3: BEHLEN Full Cavity Wall System**



**Table 3.** Effective R-Value and Thermal Transmittance of the BEHLEN Full Cavity Wall System

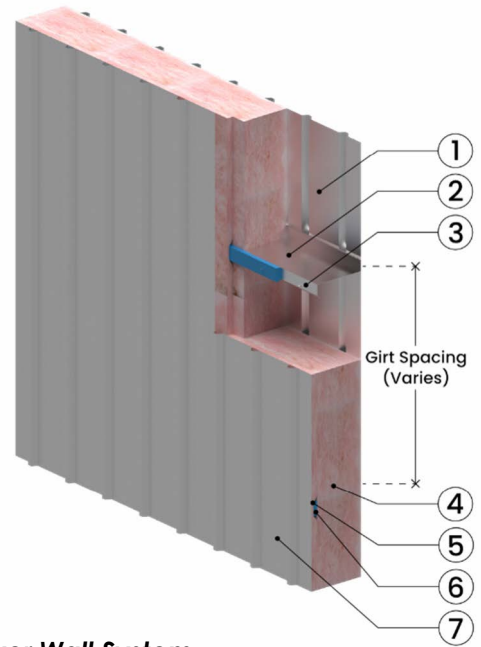
Cladding	Girt Vertical Spacing	Girt Depth	Insulation Thickness	Insulation Layers Nominal R-Value <sup>4</sup>	Effective Assembly	
					R <sub>o</sub>	U <sub>o</sub>
		inches	inches	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	Btu/ft <sup>2</sup> ·hr·°F (W/m <sup>2</sup> K)
Typical AWR Cladding	36" Girt Spacing	8	9	R-30.0 (5.28)	R-19.4 (3.41)	0.052 (0.293)
		10	11	R-36.6 (6.45)	R-21.8 (3.84)	0.046 (0.261)
		11.5	12.5	R-41.6 (7.33)	R-23.7 (4.17)	0.042 (0.240)
		14	15	R-50.0 (8.80)	R-26.7 (4.69)	0.038 (0.213)
	48" Girt Spacing	8	9	R-30.0 (5.28)	R-22.1 (3.89)	0.045 (0.257)
		10	11	R-36.6 (6.45)	R-25.1 (4.43)	0.040 (0.226)
		11.5	12.5	R-41.6 (7.33)	R-27.2 (4.79)	0.037 (0.209)
		14	15	R-50.0 (8.80)	R-31.0 (5.46)	0.032 (0.183)
	60" Girt Spacing	8	9	R-30.0 (5.28)	R-23.6 (4.15)	0.042 (0.241)
		10	11	R-36.6 (6.45)	R-26.9 (4.73)	0.037 (0.211)
		11.5	12.5	R-41.6 (7.33)	R-29.4 (5.18)	0.034 (0.193)
		14	15	R-50.0 (8.80)	R-33.6 (5.93)	0.030 (0.169)
Reversed AWR Cladding	36" Girt Spacing	11.5	13.5	R-45.0 (7.92)	R-30.1 (5.30)	0.033 (0.189)

<sup>4</sup> This nominal R-value is the insulation only. Additional components such as the air films add R-1.3 nominal thermal resistance to the assembly.

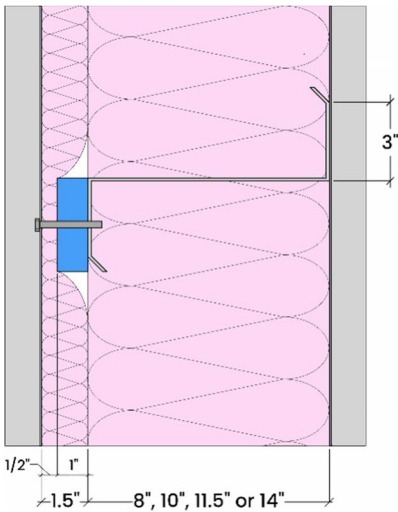
## BEHLEN Full Cavity Double Layer Wall System

### Components

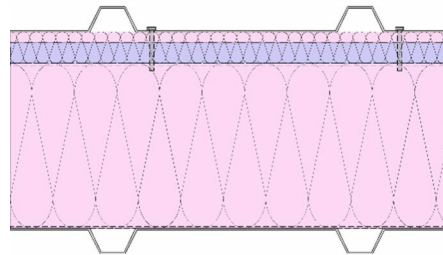
1. 24ga steel liner (AWR profile)
2. 16ga Galvanized steel girt
3. #14 steel fasteners at 12" (300mm) o.c.
4. Fiberglass batt insulation between girts
5. Fiberglass batt insulation compressed over thermal block
6. 1" thermal block (R-5/inch)
7. 24ga exterior steel cladding (AWR profile)



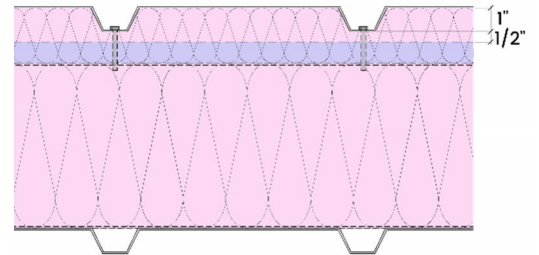
**Figure 4: BEHLEN Full Cavity Double Layer Wall System**



Vertical Section



Plan Section with Typical  
(AWR) Cladding



Plan Section with Reversed  
AWR (Widespan) Cladding

**Table 4.** Effective R-Value and Thermal Transmittance of the BEHLEN Full Cavity Double Layer Wall System

Cladding	Girt Vertical Spacing	Girt Depth & 1 <sup>st</sup> Layer Insulation	2 <sup>nd</sup> Layer Insulation Thickness	Insulation Layers Nominal R-Value <sup>4</sup>	Effective Assembly	
					R <sub>o</sub>	U <sub>o</sub>
		inches	inches	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	Btu/ft <sup>2</sup> ·hr·°F (W/m <sup>2</sup> K)
Typical AWR Cladding	36" Girt Spacing	8	3.5	R-37.0 (6.52)	R-22.6 (3.98)	0.044 (0.252)
		10		R-44.0 (7.75)	R-25.2 (4.45)	0.040 (0.225)
		11.5		R-47.0 (8.28)	R-27.0 (4.76)	0.037 (0.210)
		14		R-56.0 (9.86)	R-29.9 (5.27)	0.033 (0.190)
	48" Girt Spacing	8	3.5	R-37.0 (6.52)	R-24.7 (4.35)	0.040 (0.230)
		10		R-44.0 (7.75)	R-27.9 (4.91)	0.036 (0.204)
		11.5		R-47.0 (8.28)	R-30.1 (5.30)	0.033 (0.189)
		14		R-56.0 (9.86)	R-33.6 (5.92)	0.030 (0.169)
	60" Girt Spacing	8	3.5	R-37.0 (6.52)	R-25.7 (4.53)	0.039 (0.221)
		10		R-44.0 (7.75)	R-29.3 (5.16)	0.034 (0.194)
		11.5		R-47.0 (8.28)	R-31.9 (5.62)	0.031 (0.178)
		14		R-56.0 (9.86)	R-35.8 (6.31)	0.028 (0.158)
Reversed AWR Cladding	36" Girt Spacing	11.5	4.5	R-50.3 (8.86)	R-33.0 (5.81)	0.030 (0.172)

<sup>4</sup> This nominal R-value is the insulation only. Additional components such as the air films add R-1.3 nominal thermal resistance to the assembly.

## BEHLEN Faced MBI System

### Components

1. 16ga Galvanized steel girt
2. #14 steel fasteners at 12" (300mm) o.c.
3. Polypropylene insulation facer
4. Fiberglass batt insulation compressed over girts
5. 24ga exterior steel cladding (AWR profile)



**Figure 5: BEHLEN Faced MBI System**

**Table 5.** Effective R-Value and Thermal Transmittance of the BEHLEN Faced MBI Wall System

Girt Vertical Spacing	Insulation Thickness  inches	Insulation Layers Nominal R-Value <sup>4</sup>  ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	Effective Assembly	
			R <sub>o</sub>  ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	U <sub>o</sub>  Btu/ft <sup>2</sup> ·hr·°F (W/m <sup>2</sup> K)
36" Girt Spacing	6	R-19.0 (3.35)	R-11.8 (2.07)	0.085 (0.482)
48" Girt Spacing			R-13.4 (2.36)	0.075 (0.424)
60" Girt Spacing			R-14.6 (2.56)	0.069 (0.390)

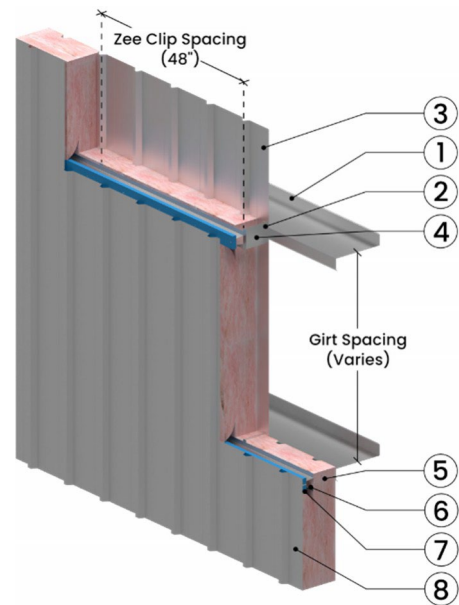
<sup>4</sup> This nominal R-value is the insulation only. Additional components such as the air films add R-1.3 nominal thermal resistance to the assembly.



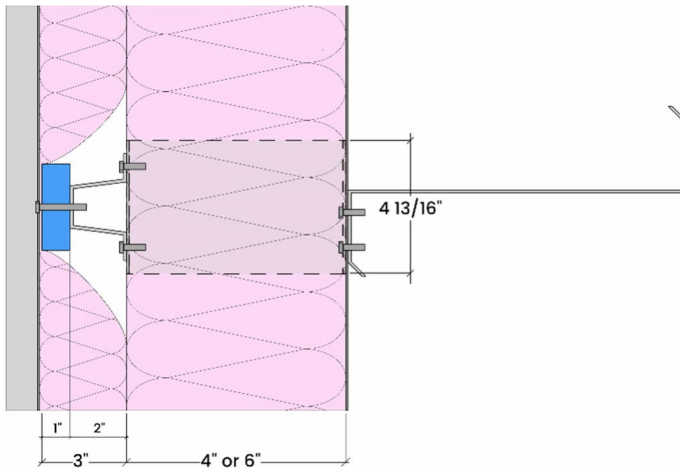
## BEHLEN Thermalguard® Wall System

### Components

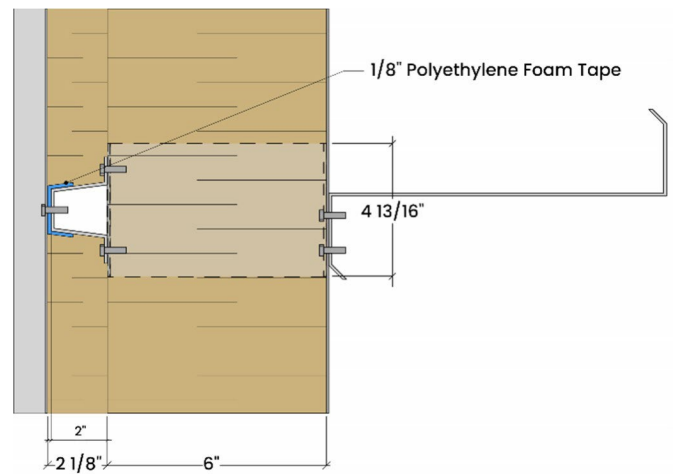
1. 16ga Galvanized steel girt
2. 2x#14 steel fasteners at 12" (300mm) o.c.
3. 24ga steel liner (AWR Profile)
4. Steel Zee clip 16ga at 48" (1219mm) Horizontal and 36" (914mm) to 60" (1524mm) vertical spacing
5. 1<sup>st</sup> layer fiberglass batt or mineral wool insulation
6. 2<sup>nd</sup> layer fiberglass batt insulation compressed over hat bar
7. 16ga 2" galvanized steel hat bars
8. 1" thermal block (R-5/ich) or 1/8" thermal tape (for mineral wool scenario)
9. 24ga exterior steel cladding (AWR profile)



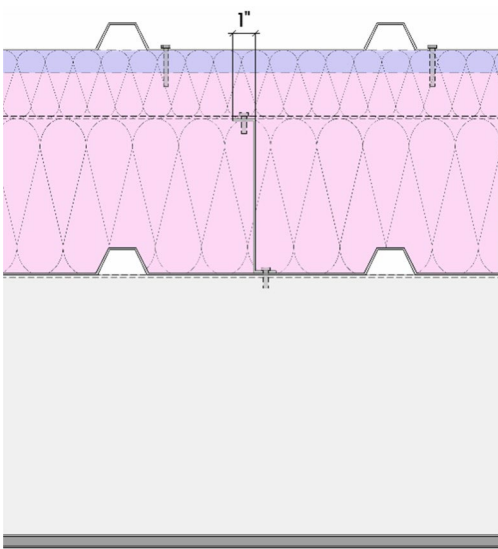
**Figure 6: BEHLEN Thermalguard Wall System**



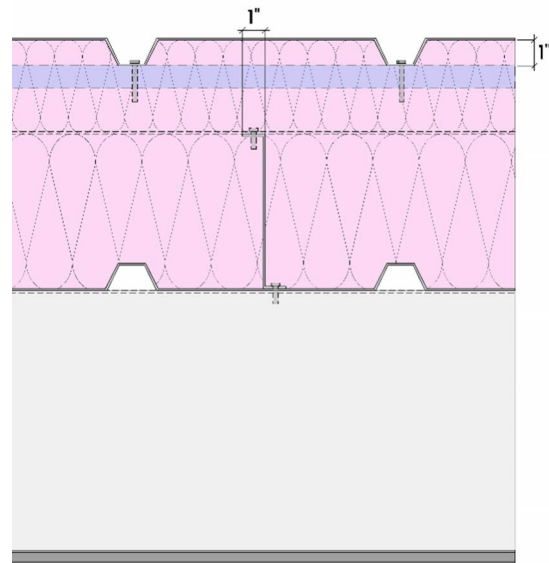
**Vertical Section**



**Vertical Section with Mineral Wool Insulation**



**Plan Section with Typical Cladding**



**Plan Section with Reversed AWR (Widespan) Cladding**

**Table 6.** Effective R-Value and Thermal Transmittance of the BEHLEN Thermalguard System

Scenario	Girt Vertical Spacing	Zee Clip Horizontal Spacing	Zee Clip Height & 1 <sup>st</sup> Layer Insulation	2 <sup>nd</sup> Layer Insulation Thickness	Insulation Layers Nominal R-Value <sup>4</sup>	Effective Assembly	
						R <sub>0</sub>	U <sub>0</sub>
	inches	inches	inches	inches	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	Btu/ft <sup>2</sup> ·hr·°F (W/m <sup>2</sup> K)
Typical AWR Cladding with Fiberglass Batt Insulation	36	48	4	3"	R-23.3 (4.11)	R-19.9 (3.51)	0.050 (0.285)
			6		R-30.0 (5.28)	R-25.6 (4.50)	0.039 (0.222)
	48	48	4	3"	R-23.3 (4.11)	R-20.8 (3.66)	0.048 (0.273)
			6		R-30.0 (5.28)	R-26.6 (4.69)	0.038 (0.213)
	60	48	4	3"	R-23.3 (4.11)	R-21.3 (3.75)	0.047 (0.266)
			6		R-30.0 (5.28)	R-27.3 (4.81)	0.037 (0.208)
Reversed AWR Cladding with Fiberglass	48	48	6	4"	R-33.3 (5.86)	R-29.5 (5.20)	0.034 (0.192)
Typical AWR Cladding with Mineral Wool <sup>6</sup> Insulation	48	48	6	2"	R-33.6 (5.92)	R-28.8 (5.07)	0.035 (0.197)

<sup>4</sup> This nominal R-value is the insulation only. Additional components such as the air films add R-1.3 nominal thermal resistance to the assembly.

<sup>6</sup>BEHLEN FIREGUARD wall system is an ULC designated non-load bearing fire rated wall assembly to ULC W605 (1-hour) & ULC W606 (2-hour) Fire Rated Wall Assemblies. Consult BEHLEN FIREGUARD tech sheet for assembly and components required for fire rated walls. Thermal Effective U-Value performance for fire rated wall assemblies based on published data by mineral wool suppliers; W605 (1-hour/6") 0.052 (0.298) & W606 (2-hour/8") 0.043 (0.245). See suppliers current thermal report for Effective Assembly U-Values for fire rated wall systems.

## Thermal Results Insulated Metal Panels

Insulated Metal Panels (IMP) Effective Assembly values have been provided by QAI Laboratories with testing based on ASTM C518-17 and ASTM C1363-19 test methods. Clear field assembly effective R-Values and thermal transmittances of the ARTSPAN IMP panels is presented in Table 7. Figures 7 and 8 provide more details of the evaluated roof and wall assemblies.

Thermal Transmission Properties testing for IMP foam core are in accordance with; ASTM C518-17 Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus. Test procedures for ASTM C518-17 is based on 1 inch (25mm) thick foam core samples individually tested in a LaserComp FOX314 Heat Flow Meter under a controlled environment.

Thermal Resistance Properties testing for IMP are in accordance with; ASTM C1363-19 Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus. Test procedures for ASTM C1363-19 is based on Hot Box Apparatus; 8' x 8' assembly with 6" thick (2.43m x 2.43m x 152mm) IMP panels manufactured with prefinished 26ga exterior and interior steel liner and a polyisocyanurate (PIR) foam core with a density of 2.5 lbs./ft<sup>3</sup>.

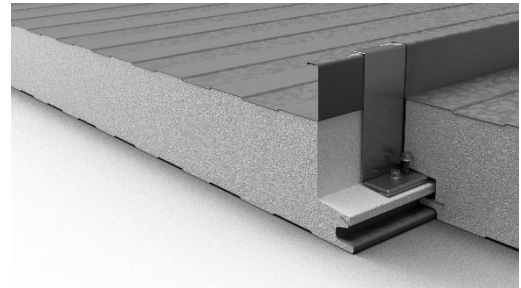
### Note on support spacing for IMP:

Hot Box Apparatus testing has shown purlin and girt support spacing does not change clear field thermal resistance properties with IMP.

### Artspan Insulated Metal Panels (IMP) Roof System

#### Components

1. 16ga Galvanized steel girt
2. 26ga interior steel liner (Mesa Profile)
3. 2x#14 steel fasteners at clip location
4. IMP steel roof clip 20ga c/w 14ga base at 42" (1067mm) Horizontal and 48" (1219mm) purlin spacing
5. 6" (152mm) Polyisocyanurate (PIR) foam core insulation
6. 26ga exterior standing seam steel face (Mesa profile)

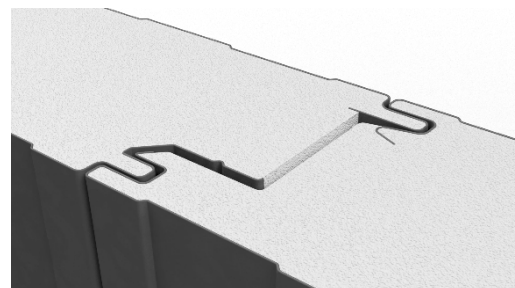


**Figure 7: Artspan IMP Roof System**

### Artspan Insulated Metal Panels (IMP) Wall System

#### Components

1. 16ga Galvanized steel girt
2. 26ga interior steel liner (Mesa Profile)
3. 2x#14 steel fasteners at clip location
4. IMP steel wall clip 16ga at 42" (1067mm) Horizontal and 48" (1219mm) purlin spacing
5. 6" (152mm) Polyisocyanurate (PIR) foam core insulation
6. 26ga exterior steel cladding (Mesa profile)



**Figure 8: Artspan IMP Wall System**

**Table 7.** Effective R-Value and Thermal Transmittance of the Artspan IMP Roof and Wall Systems

IMP Roof & Wall	Purlin or Girt (Vertical) Spacing	Panel Depth	Insulation Thickness	Insulation Layers Nominal R-Value <sup>4</sup>	Effective Assembly	
					R <sub>o</sub>	U <sub>o</sub>
		inches	inches	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	ft <sup>2</sup> ·hr·°F/Btu (m <sup>2</sup> K/W)	Btu/ft <sup>2</sup> ·hr·°F (W/m <sup>2</sup> K)
Typical IMP Roof & Wall Cladding	48" Spacing	2	2	R-15.2 (2.67)	R-16.7 (2.93)	0.060 (0.341)
		3	3	R-22.7 (4.00)	R-25.0 (4.41)	0.040 (0.227)
		4	4	R-30.4 (5.35)	R-33.3 (5.88)	0.030 (0.170)
		5	5	R-37.9 (6.67)	R-41.7 (7.35)	0.024 (0.136)
		6	6	R-45.4 (8.00)	R-50.0 (8.77)	0.020 (0.114)

<sup>4</sup> This nominal R-value is the insulation only. Additional components such as the air films add R-1.3 nominal thermal resistance to the assembly.

## Conclusion

The assemblies presented in this guide, provided numerous options for use in steel building systems (SBS) and presents data for variable insulation cavity depths and support spacing. Secondary support spacing may vary across roof and walls based on design loads, framed openings and additional loading supports. This guide provides tables based on constructable systems and assemblies.

This guide provides information when support spacing is known and Nominal R-Values or Thermal Transmittance values are required. It can also be used when specific clear field thermal values are being analyzed and support spacing requires confirmation.

Comparing information in this guide to third-party proprietary compliance software tools may produce different results when pre-programed or set support spacing is different than what is shown in our tables.

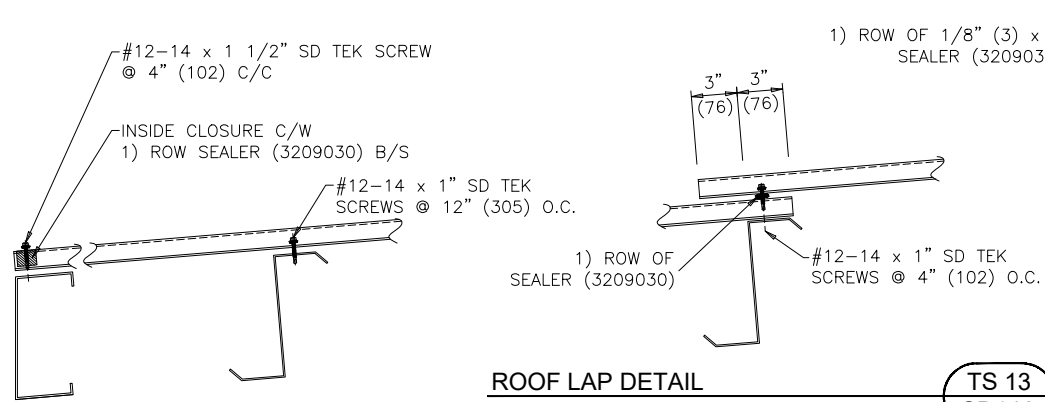
Analysis of various steel thickness in each assembly determined that increasing the gauge thickness did not impact or offer a noticeable degree of change in the thermal values. Changing the support spacing made the biggest impact to the overall Effective R-Values and Thermal Transmittance, with the exception of Insulated Metal Panels (IMP) which saw no impact with or without support spacing in the test results.

This guide should not be used on its own for permit application or code conformance and should accompany additional support material provided by Coordinating Registered Professionals. BEHLEN recommends full building energy modeling including air leakage testing, to provide whole building energy efficiency for lighting, HVAC, service water and electrical systems.

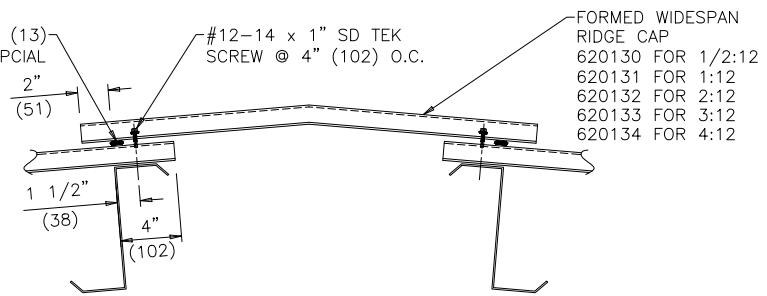
Overall Thermal Transmittance (U-Value) in  $W/(m^2 \cdot K)$ , is the inverse of Effective RSI in  $m^2 \cdot K/W$ . To convert RSI to imperial R-Value, use  $1 \text{ } m^2 \cdot K/W = 5.678263 \text{ } ft^2 \cdot h \cdot ^\circ F/Btu$ . To convert  $ft^2 \cdot h \cdot ^\circ F/Btu$  to  $m^2 \cdot K/W$  divide by 5.678263

## **Appendix A: Detail Drawings and Data Sheets – Roof**

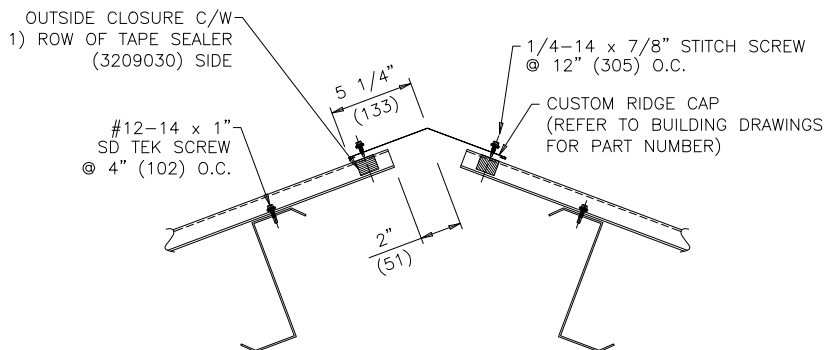
The following details illustrate the general evaluated assemblies. Not all the details are presented and full detail sets should be reviewed based on final design review.



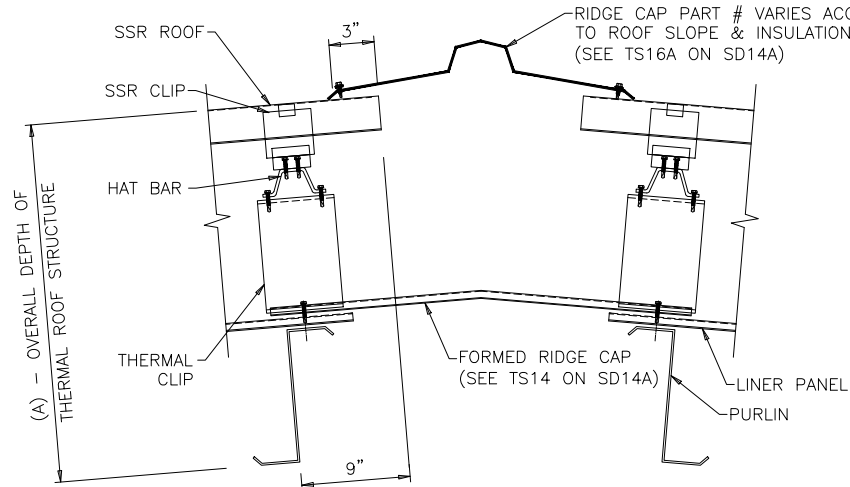
**ROOF LAP DETAIL** **TS 13**  
**SD14A**  
ORIENTATION OF PURLIN COULD BE REVERSED.  
SEE ERECTION DRAWINGS FOR PURLIN ORIENTATION.



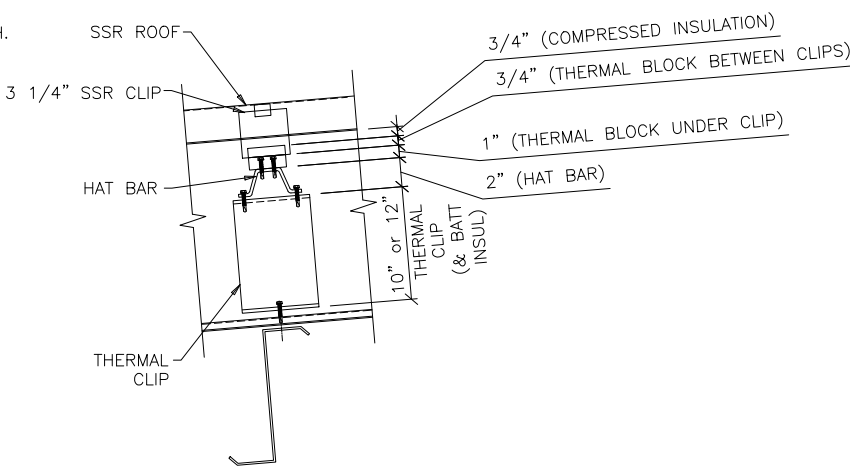
**PEAK DETAIL - FORMED RIDGE CAP** **TS 14**  
**SD14A**  
FOR WIDESPAN PROFILE



**PEAK DETAIL - FLAT RIDGE CAP** **TS 15**  
**SD14A**  
FOR WIDESPAN PROFILE WITH  
ROOF SLOPES GREATER THAN 4:12



**PEAK DETAIL - RIDGE CAP (SSR ROOF)** **TS 16**  
**SD14A**  
FOR VARYING SLOPES (SEE TS16A ON SD14A)  
FOR RIDGE DETAIL (SEE SSR17 ON SD8G)



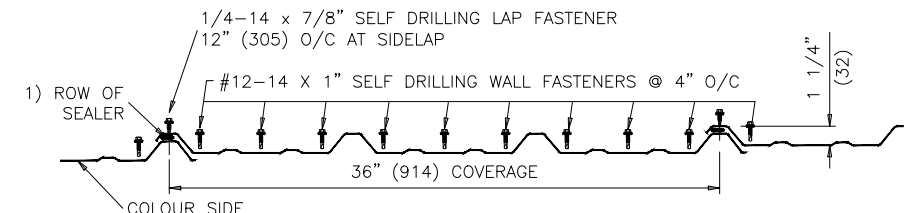
**Thermal Roof Components** **TS 16B**  
**SD14A**  
-SSR ROOF PANEL.  
-3 1/4" SSR CLIPS.  
-3/4" COMPRESSED INSULATION.  
-3/4" THERMAL BLOCK BETWEEN SSR CLIPS.  
-1" THERMAL BLOCKS CONTINUOUS UNDER SSR CLIPS.  
-2" HAT BARS.  
-10" OR 12" THERMAL CLIPS & BATT INSULATION.  
-ROOF LINER PANEL.  
-ROOF FRAMING.

**RIDGE CAPS (SSR ROOF)** **TS 16A**  
**SD14A**  
RIDGE CAP PART NUMBER, ROOF SLOPE & TOTAL THERMAL SYSTEM DEPTH

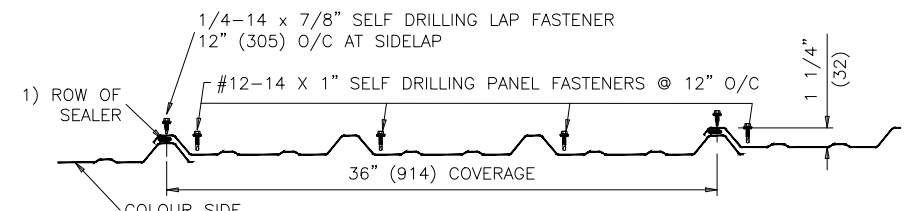
ROOF SLOPE	(A) - OVERALL DEPTH OF ROOF (FROM T.O. RAFTER TO U.S. OF SSR PANEL)	SUITABLE RIDGE CAP PART #
1:12	(A) <= 30"	554426
2:12	(A) <= 14" 14" < (A) <= 33"	554426 554436
3:12	(A) <= 21" 21" < (A) <= 29" (A) >= 29"	554436 554435 CUSTOM
4:12	(A) <= 21" (A) >= 21"	554435 CUSTOM

NOTE: (A) INCLUDES THE DEPTH OF PURLIN. THERMAL CLIP, HAT BAR & THERMAL BLOCK.

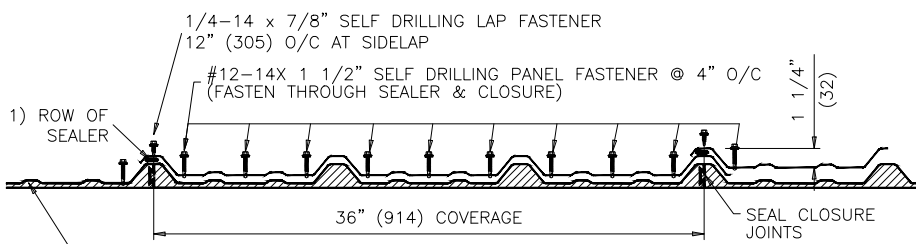
**FASTENER LAYOUT (ROOF)** **TS 11**  
**SD14A**  
WIDESPAN LINER PANEL



**AT RIDGE AND PANEL ENDLAPS**



**AT INTERMEDIATE PURLINS**



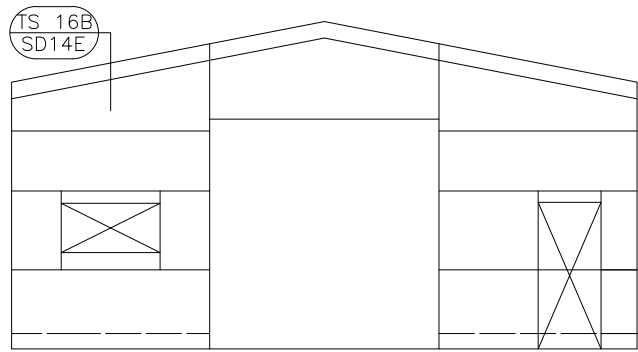
**AT EAVES AND ROOF OPENING HEADERS**

**NOTES:**

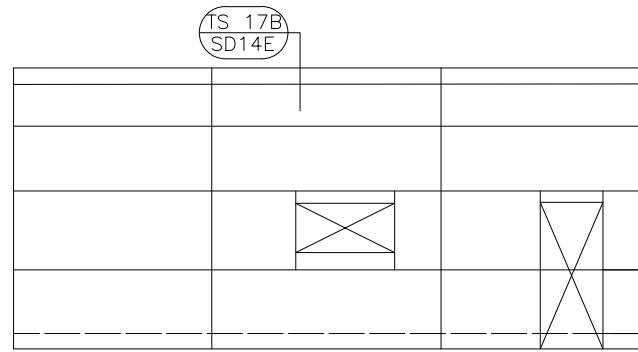
- REFERENCES TO "SEALER" INDICATE 1/8" X 1/2" (3 X 13) SEALER (3209030) UNLESS NOTED OTHERWISE.
- SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.
- HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX: 36" (914) BECOMES 28 3/4" (732).
- PART NUMBERS, SIZES AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.
- THERMAL CLIP AND LINER PANEL SCREW SHANKS ARE EXPOSED TO THE INTERIOR OF THE BUILDING. CORROSIVE INTERIOR CONDITIONS REQUIRE CORROSION-RESISTANT SHANKS.
- FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS SD6 THROUGH SD8J.

E1	DETAIL TS16 REVISED, DETAIL TS16A ADDED, FOR THERMAL EVALUATION.	GD	24/07/02	THERMAL SYSTEM ON ROOF RIDGE CAP & LINER DETAILS (C/W VAPOUR BARRIER)	05-EN-S1000	SD14A	E1
E	NOTE #2 REVISED, ADDED RIDGE CAP DETAIL FOR THERMAL SYSTEM & ASSOCIATED RIDGE CAP CHART, REVISED ROOF LAP DETAIL.	SH	21/11/01				
D	GENERAL REVISIONS.	SH	17/02/16				
C	GENERAL REV. - DRAWING RE NUMBERED (OLD SD14A IS NOW SD14B)	QZ/JC	14/07/04				
B	WALL AND ROOF DETAILS SEPARATED.	GD	01/11/21	DRAWN BY GD	DATE 01/07/12		
A	DETAILS REDRAWN. STD. AND VAPOUR BARRIER DETAILS COMBINED.	GD	01/07/12				
LETTER	DESCRIPTIONS REVISIONS	BY	DATE	SCALE N.T.S.			

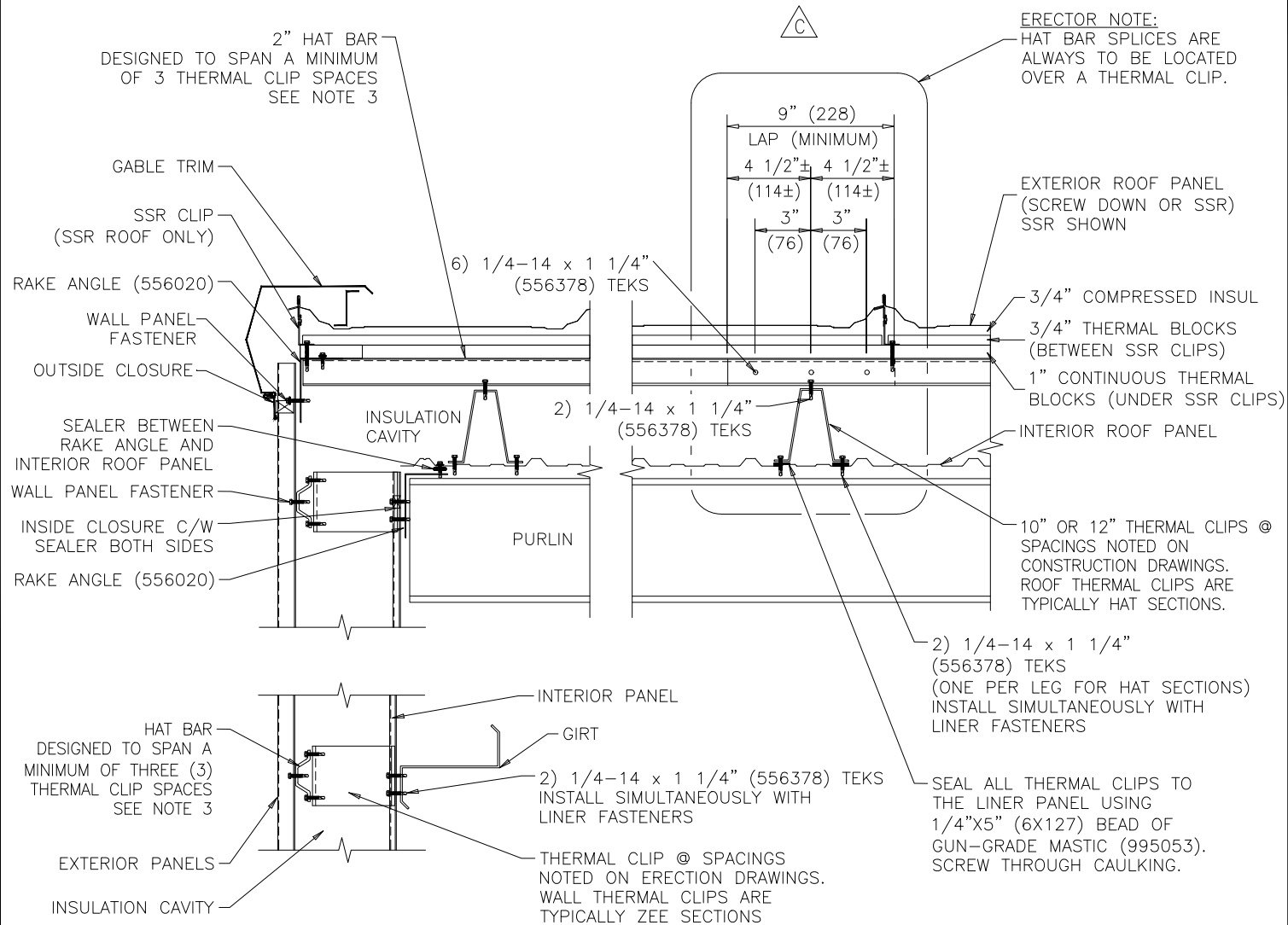




ENDWALL ELEVATION



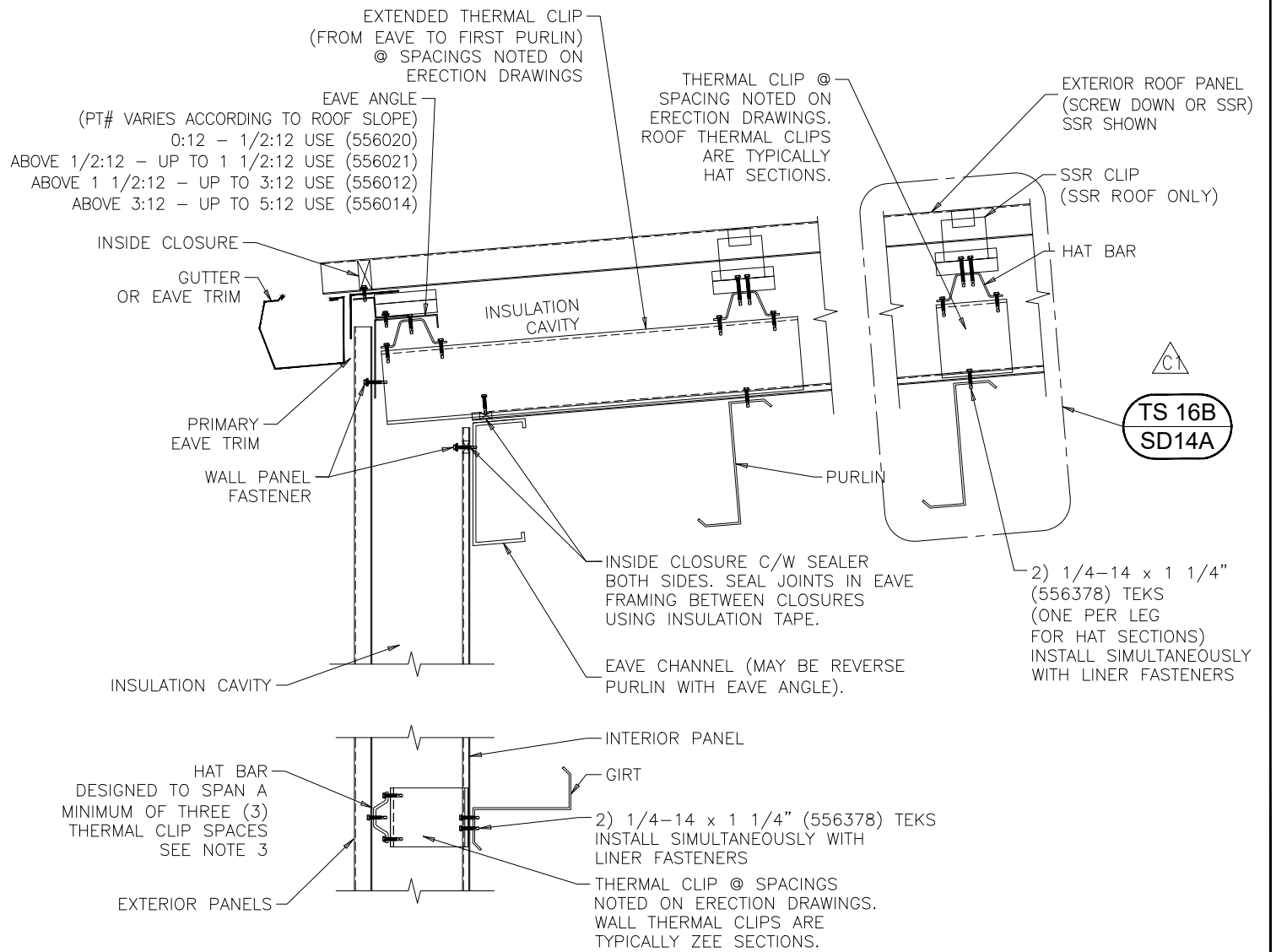
SIDEWALL ELEVATION



SECTION

DETAIL AT GABLE SHOWING THERMAL SYSTEM AT ROOF AND WALL.  
-FOR VAPOUR BARRIER: SEAL ALL THERMAL CLIPS TO THE LINER PANEL .

TS 16B  
SD14E



SECTION

DETAIL AT EAVE SHOWING THERMAL SYSTEM AT ROOF AND WALL.  
SEAL ALL THERMAL CLIPS TO THE LINER PANEL (SEE TS 24/SD14E).

TS 17B  
SD14E

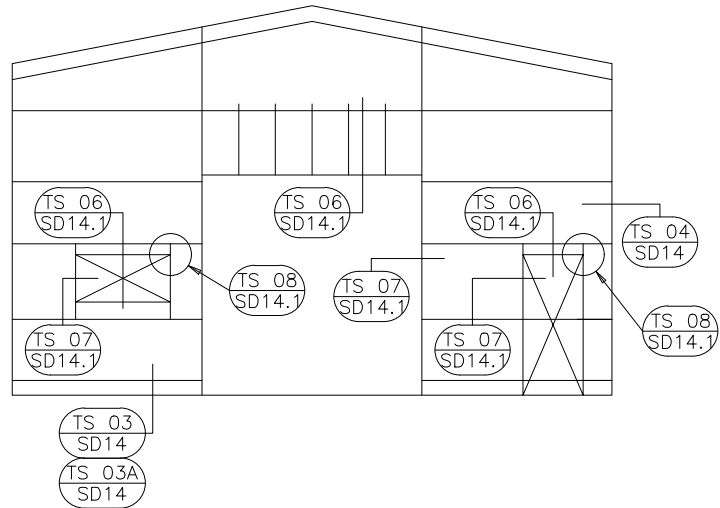
NOTES:

1. REFERENCES TO "SEALER" INDICATE 1/8" X 1/2" (3 X 13) SEALER (3209030) UNLESS NOTED OTHERWISE.
2. SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS FROM INSULATION CAVITY TO BUILDING INTERIOR ARE COLOURED.
3. HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX: 36" (914) BECOMES 28 3/4" (732).
4. PART NUMBERS, SIZES AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING ERECTION DRAWINGS.
5. FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE SD DRAWINGS SD6 THROUGH SD8H.

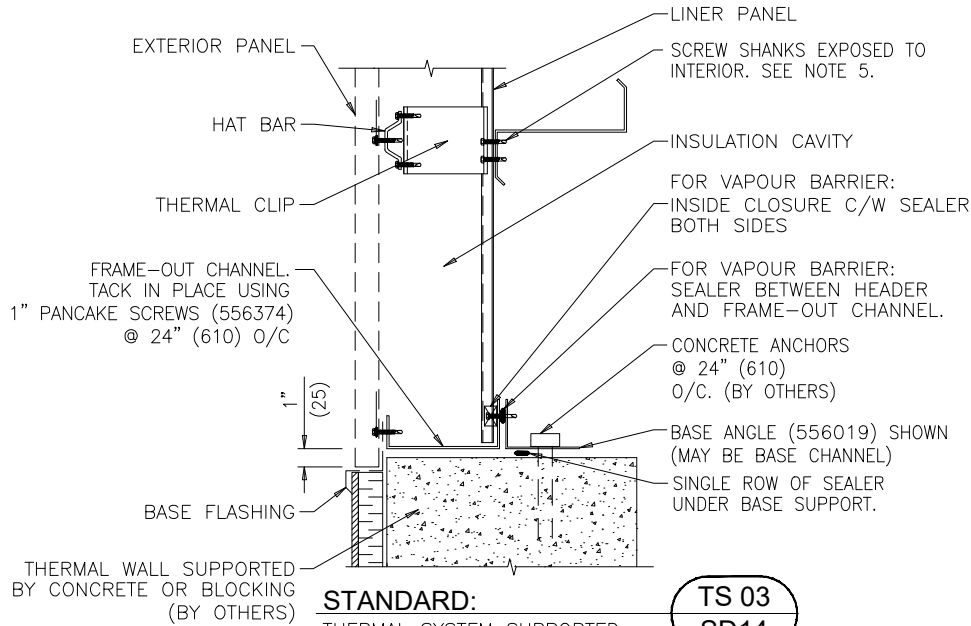
				THERMAL SYSTEM ON ROOF AND WALLS STANDARD EAVE AND GABLE DETAILS (C/W VAPOUR BARRIER)		05-EN-S1000	SD14E	C1
C1	DETAILS REVISED FOR THERMAL EVALUATION.	GD	24/07/02	DRAWN BY	DATE			
C	REVISION TO EAVE ANGLE CALL-OUT: ADDED PT#'s RELATIVE TO VARYING -	SH	21/11/01	GD	01/07/12			
	ROOF SLOPES. HAT BAR SPLICE LOCATIONS NOTED.							
B	GENERAL REVISIONS	SH	17/02/16					
LETTER	DESCRIPTIONS	BY	DATE	SCALE				
	REVISIONS			N.T.S.				

## **Appendix B: Detail Drawings and Data Sheets – Walls**

The following details illustrate the general evaluated assemblies. Not all the details are presented and full detail sets should be reviewed based on final design review.



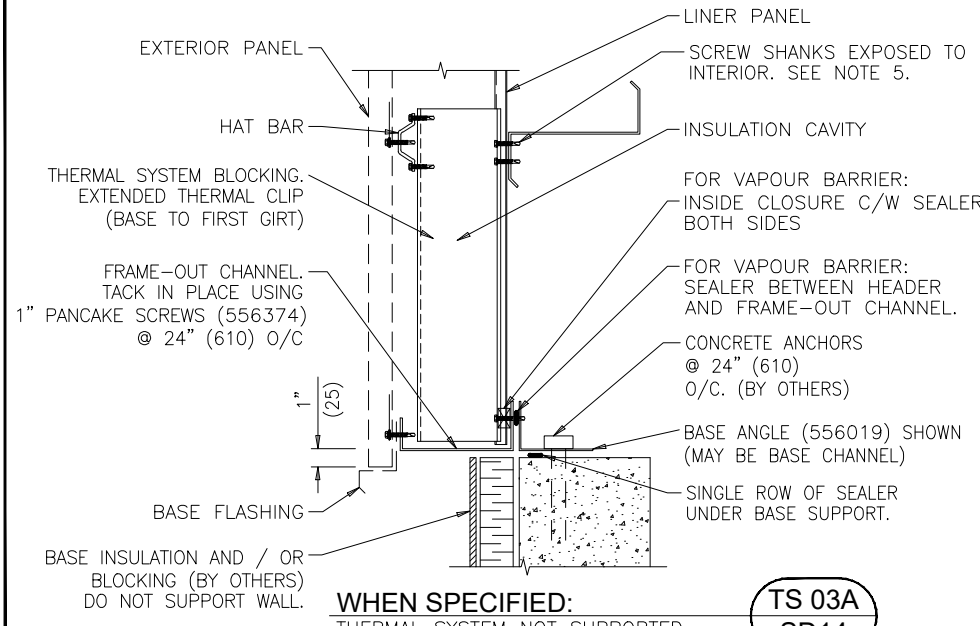
ENDWALL ELEVATION



STANDARD:

THERMAL SYSTEM SUPPORTED BY FOUNDATION (BY OTHERS).  
NOTE: EXTERIOR PANEL & TRIMS VARY. REFER TO SPECIFIC DETAILS FOR CLADDING TYPE USED.

TS 03  
SD14



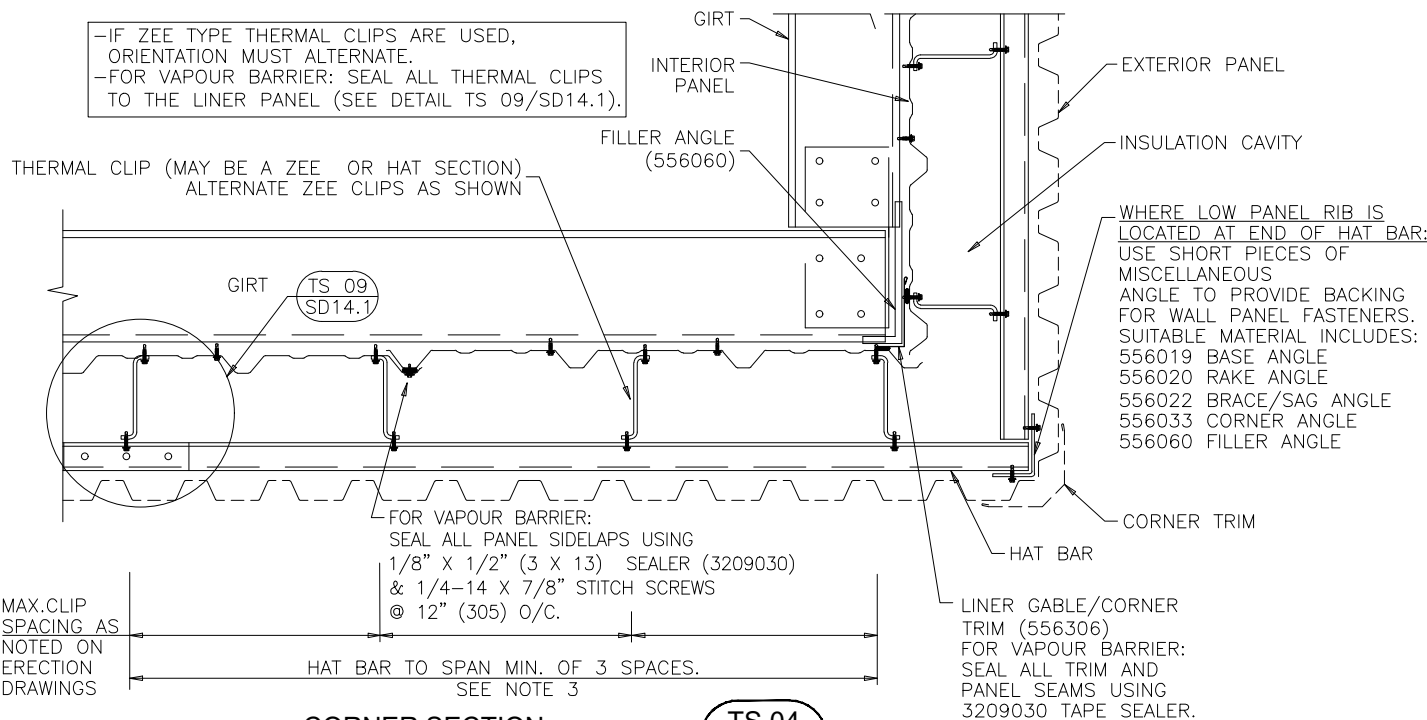
WHEN SPECIFIED:

THERMAL SYSTEM NOT SUPPORTED BY FOUNDATION.  
(BLOCKING BY BUILDING MANUFACTURER)  
NOTE: EXTERIOR PANEL & TRIMS VARY. REFER TO SPECIFIC DETAILS FOR CLADDING TYPE USED.

TS 03A  
SD14

BASE SECTIONS

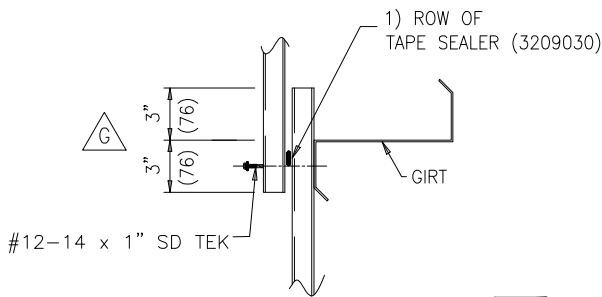
BASE OF THERMAL WALL SYSTEM  
-NOTE THAT STANDARD CONDITION ASSUMES SUPPORT FOR THERMAL WALL SYSTEM BY FOUNDATION.  
-FOR VAPOUR BARRIER: SEAL ALL THERMAL CLIPS TO THE LINER PANEL (SEE DETAIL TS 09/SD14.1).



CORNER SECTION

PLAN VIEW AT GIRT  
NOTE: EXTERIOR PANEL & TRIMS VARY. REFER TO SPECIFIC DETAILS FOR CLADDING TYPE USED.

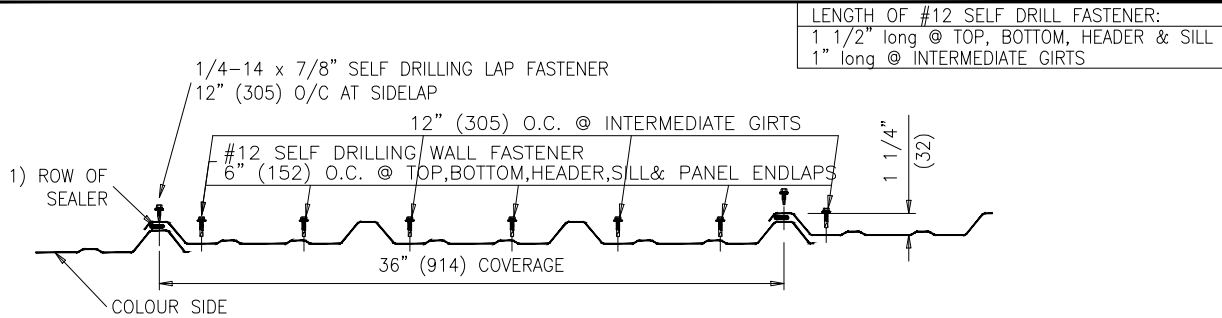
TS 04  
SD14



WALL LINER LAP DETAIL

ORIENTATION OF GIRT COULD BE REVERSED. SEE ERECTION DRAWINGS FOR GIRT ORIENTATION.

TS 05  
SD14



FASTENER LAYOUT (THERMAL WALL)

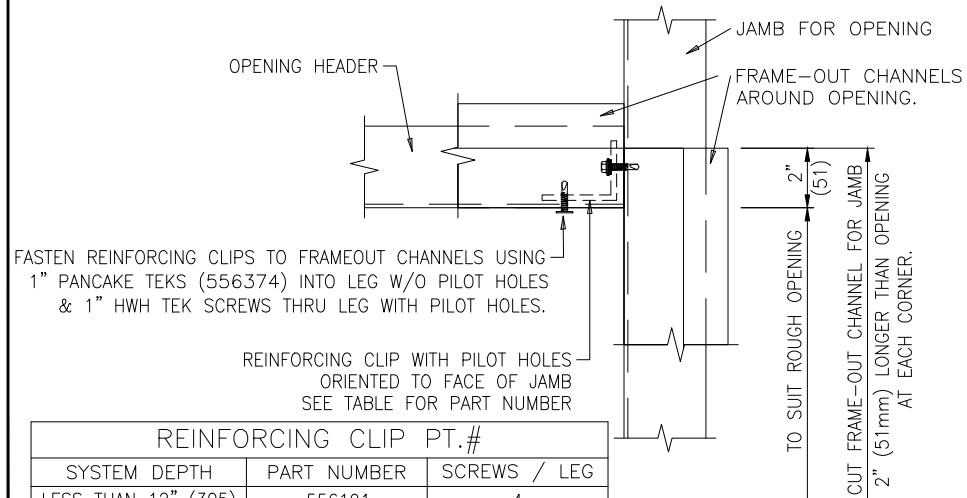
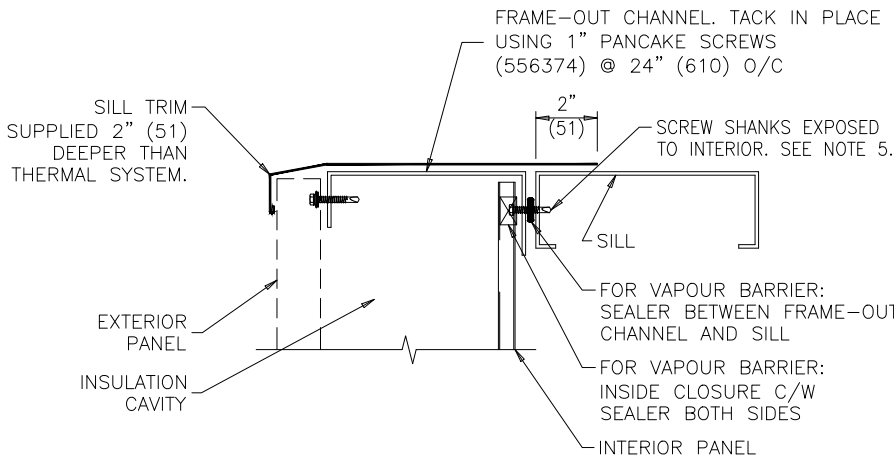
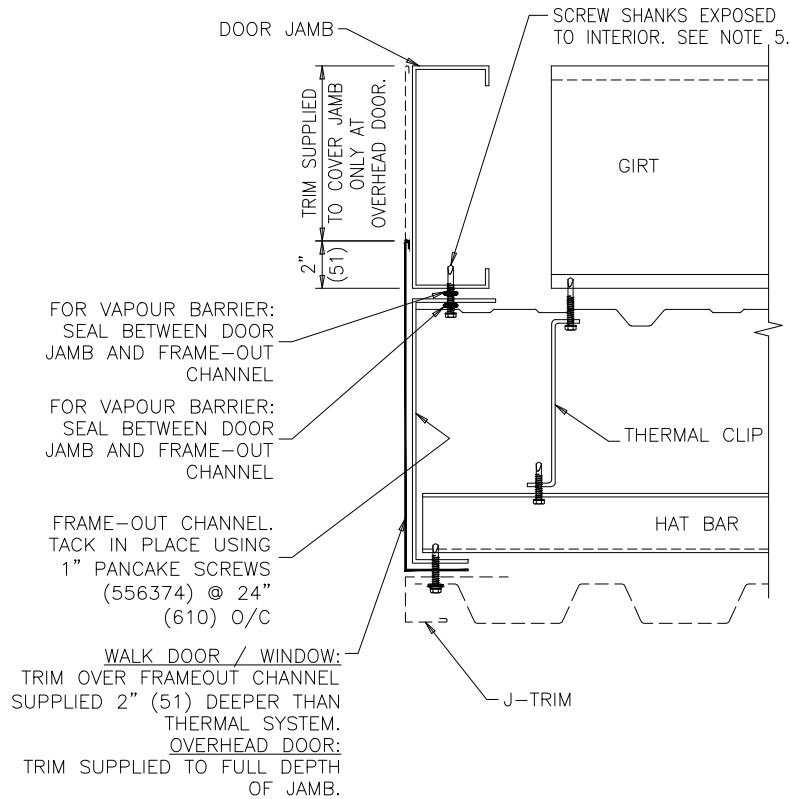
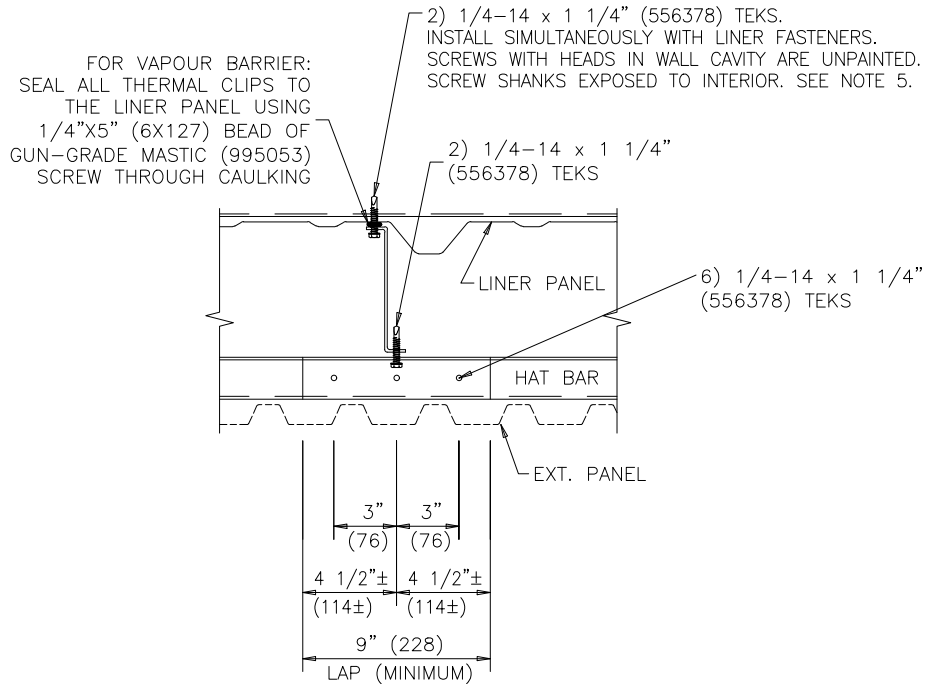
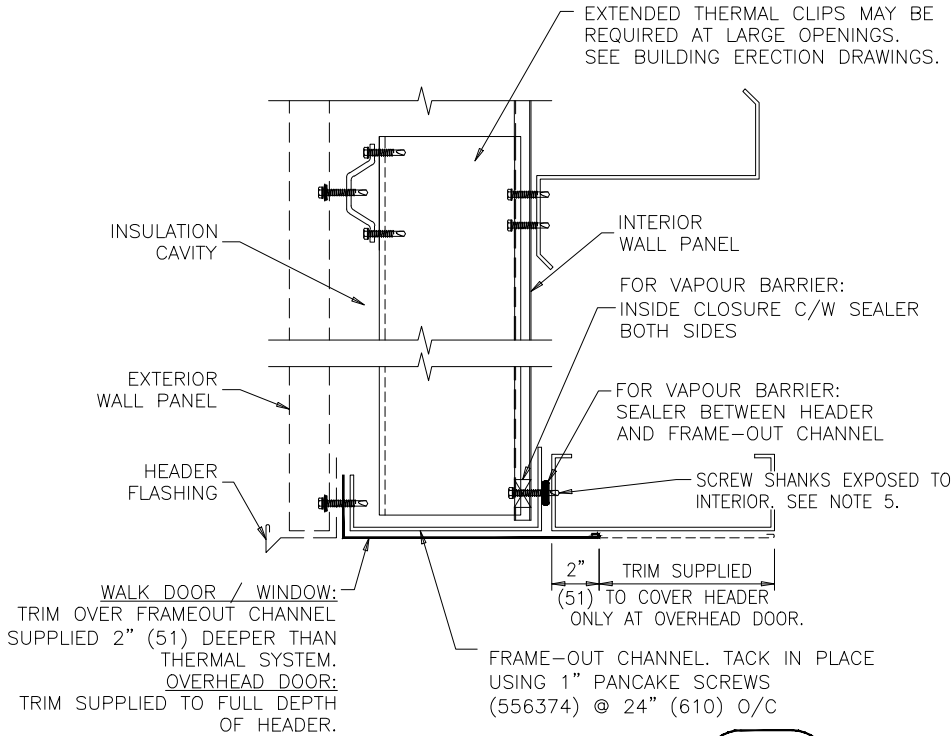
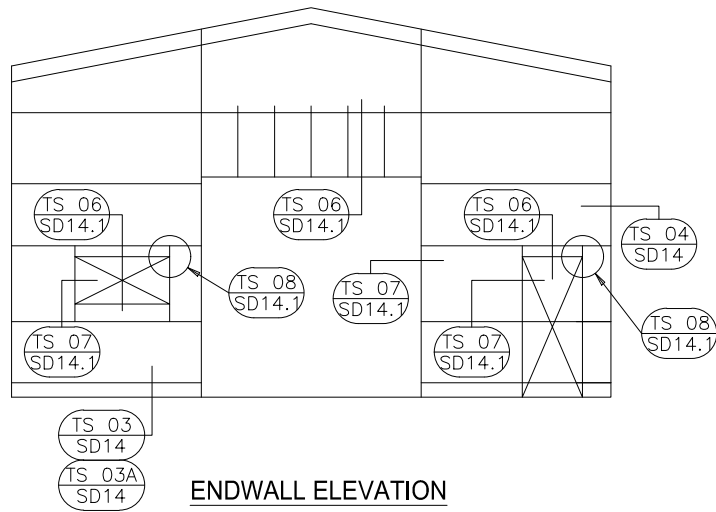
WIDESPAN LINER PANEL

TS 01  
SD14

NOTES:

- REFERENCES TO "SEALER" INDICATE 1/8" X 1/2" (3 X 13) SEALER (3209030) UNLESS NOTED OTHERWISE.
- SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.
- HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX: 36" (914) BECOMES 28 3/4" (732).
- PART NUMBERS, SIZES AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.
- THERMAL CLIP AND LINER PANEL SCREW SHANKS ARE EXPOSED TO THE INTERIOR OF THE BUILDING. CORROSIVE INTERIOR CONDITIONS REQUIRE CORROSION-RESISTANT SHANKS.
- FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS SD6 THROUGH SD8J.

				THERMAL SYSTEM STANDARD WALL DETAILS (C/W VAPOUR BARRIER LINER)		05-EN-S1000	SD14	H
H	NOTES ADDED DEFINING EXTERIOR PANEL & TRIMS SHOWN IN THESE	GD	23/05/17					
	DETAILS AS GENERIC ONLY. REFER TO APPROPRIATE DETAILS FOR THESE			DRAWN BY	DATE	BEHLEN		
G	REVISED: TEXT TO DETAIL TS05, TS01 & NOTES ITEM #2, REV. LAP	SH	21/11/01	GD	01/07/12			
F	GENERAL REVISIONS	SH	17/02/16					
LETTER	DESCRIPTIONS	BY	DATE	SCALE				
	REVISIONS			N.T.S.		927 DOUGLAS STREET, BRANDON, MANITOBA, R7A 7B3, 204-728-1188 605 SHELDON DRIVE, CAMBRIDGE, ONTARIO, N1T 2K1, 519-620-6003		



#### NOTES:

- REFERENCES TO "SEALER" INDICATE 1/8" X 1/2" (3 X 13) SEALER (3209030) UNLESS NOTED OTHERWISE.
- SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.
- HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX: 36" (914) BECOMES 28 3/4" (732).
- PART NUMBERS, SIZES AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.
- THERMAL CLIP AND LINER PANEL SCREW SHANKS ARE EXPOSED TO THE INTERIOR OF THE BUILDING. CORROSIVE INTERIOR CONDITIONS REQUIRE CORROSION-RESISTANT SHANKS.
- FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS SD6 THROUGH SD8J.

H	NOTES ADDED DEFINING EXTERIOR PANEL & TRIMS SHOWN IN THESE	GD	22/05/17	THERMAL SYSTEM STANDARD WALL DETAILS (C/W VAPOUR BARRIER LINER)	DRAWN BY GD	DATE 01/07/12
	DETAILS AS GENERIC ONLY. REFER TO APPROPRIATE DETAILS FOR THESE					
G	REVISED NOTES: ITEM #2/ ADDED TS06A MARK	SH/JD	21/11/01			
F	GENERAL REVISIONS.	SH	17/02/16			
E	GENERAL REV.-SECTIONS UPDATED AND MOVED, DETAIL RE-NUMBERED.	QZ/JC	14/07/04			
D	DETAIL 3 ADDED. REINFORCEMET OF FRAME-OUT CHANNELS AT	GD	10/06/29			
	CORNERS OF OPENINGS.					
LETTER	DESCRIPTIONS	BY	DATE	SCALE		
	REVISIONS			N.T.S.		

05-EN-S1000	SD14.1	H
<b>BEHLEN</b>		
927 DOUGLAS STREET, BRANDON, MANITOBA, R7A 7B3, 204-728-1188 605 SHELDON DRIVE, CAMBRIDGE, ONTARIO, N1T 2K1, 519-620-6003		

## Appendix C: Simulation General Assumptions and Material Properties

### General Assumptions

Steady-state simulations were utilized for the thermal evaluation outlined in this report with the following assumptions:

1. Material properties were taken from the 2017 ASHRAE Handbook – Fundamentals for common materials, information provided by BEHLEN for the system components, and datasheets for proprietary products.
2. Interior and exterior heat transfer coefficients were taken from table 10 on page 26.21 of the 2017 ASHRAE Handbook – Fundamentals depending on surface orientation.
3. Insulation is assumed to be installed tight to the steel liner and roof panel.
4. Enclosed air spaces were modelled with an equivalent thermal conductivity of the air that includes the impacts of convection and radiation within the enclosure. Calculations for this equivalent conductivity are based on ISO 10077.
5. Insulation and other components were considered tight to adjacent interfaces except for the sag of the top layer of insulation that is over the hat bars.
6. Section A9.4.6 from ASHRAE 90.1 2016 was used to calculate the compressed insulation thermal conductivity values and related research.<sup>5</sup>
7. 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 per the following equation:

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

This formula can be rearranged for  $T_{surface}$  to determine the surface temperatures for any climate once the temperature index is known for a critical location to evaluate the condensation risk.

The temperature indices shown in the temperature profiles in Appendix C, are for general information and not intended to predict in-service temperatures subject to transient conditions, variable heating systems, and/or obstructions that restrict heat getting to the wall system.

<sup>5</sup> McBride, Gavin. ASHRAE Standard 90.1 Metal Building U-Factors – Part 3: Equations for Double Layers of Fiberglass Batt Insulation in Roof and Wall Assemblies. 2010 ASHRAE Winter Conference Proceedings.

## Boundary Conditions Roof

Boundary Condition	Combined Convective and Radiative Heat Transfer Coefficient
	Btu/ft <sup>2</sup> · hr·°F (W/m <sup>2</sup> K)
Exterior wall surface (roof)	6.0 (34)
Interior surface (ceiling)	0.9 (5.2)

## Material Properties

Component	Material	Thermal Conductivity Btu · in/ft <sup>2</sup> · hr·°F (W/m K)
Insulation	Fiberglass batt (uncompressed)	0.30 (0.043) <sup>6</sup>
Thermal Block	Extruded polystyrene (XPS)	0.20 (0.029)
Girts, liner, chair, hat bar, roof panel and fasteners	Galvanized Steel	416 (62)

## Boundary Conditions Walls

Boundary Condition	Combined Convective and Radiative Heat Transfer Coefficient
	Btu/ft <sup>2</sup> · hr·°F (W/m <sup>2</sup> K)
Exterior wall surface	6.0 (34)
Interior surface	0.7 (4.2)

## Material Properties

Component	Material	Thermal Conductivity Btu · in/ft <sup>2</sup> · hr·°F (W/m K)
Insulation <sup>6</sup>	Fiberglass batt (uncompressed)	0.30 (0.043)
	Mineral Wool	0.24 (0.034)
Thermal block	Extruded polystyrene (XPS)	0.20 (0.029)
Thermal tape	Polyethylene Foam	0.35 (0.050)
Insulation facer	Polypropylene	0.35 (0.050)
Girts, liner, chair, hat bar, cladding and fasteners	Galvanized Steel	430 (62)

<sup>6</sup> For uncompressed batt Insulation.

## Appendix D: Simulated Temperature Profiles

The following figures illustrate the temperature distribution for the evaluated assemblies. Not all the scenarios are presented as the temperature distribution is similar across the evaluated scenarios. The profiles are presented as a temperature index (between 0 and 1). See Appendix C for more discussion on Temperature Index.

### BEHLEN Thermalguard® Roof System

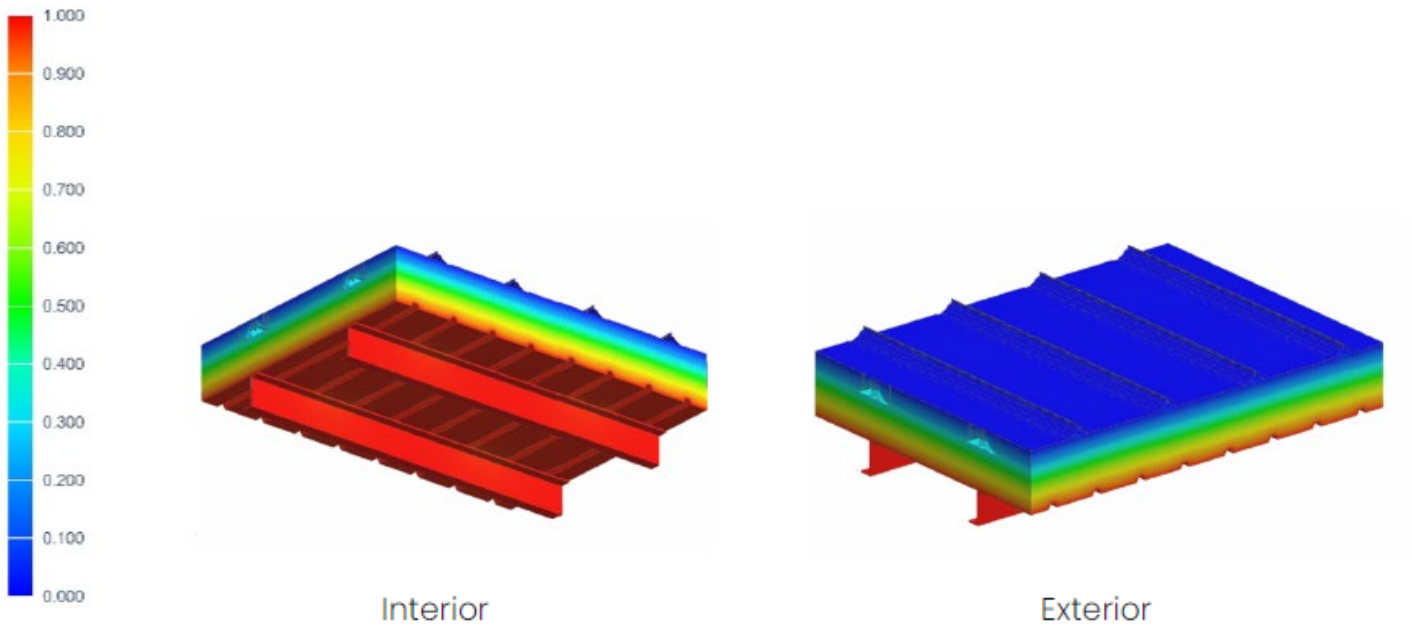


Figure D1. Temperature Profile of the BEHLEN Thermalguard Roof System with Galvanized Steel Purlin at 48" o.c. and chair spacing at 48" with 10" Chair Height with Batt Insulation



**BEHLEN Thermal Wall Systems**

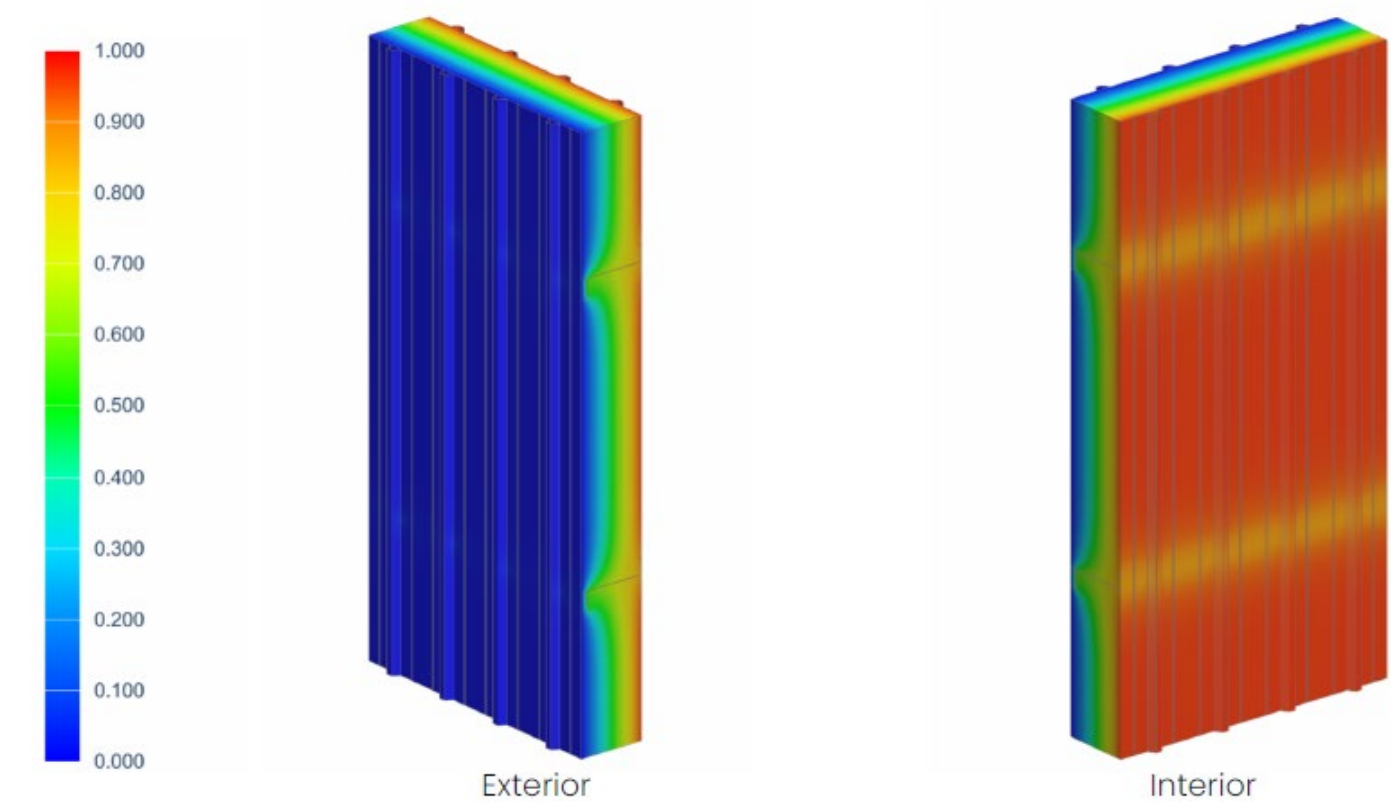


Figure D2. Temperature Profile of the Behlen Full Cavity System with 10" Galvanized Steel Girts at 48" o.c. and 11" Batt Insulation

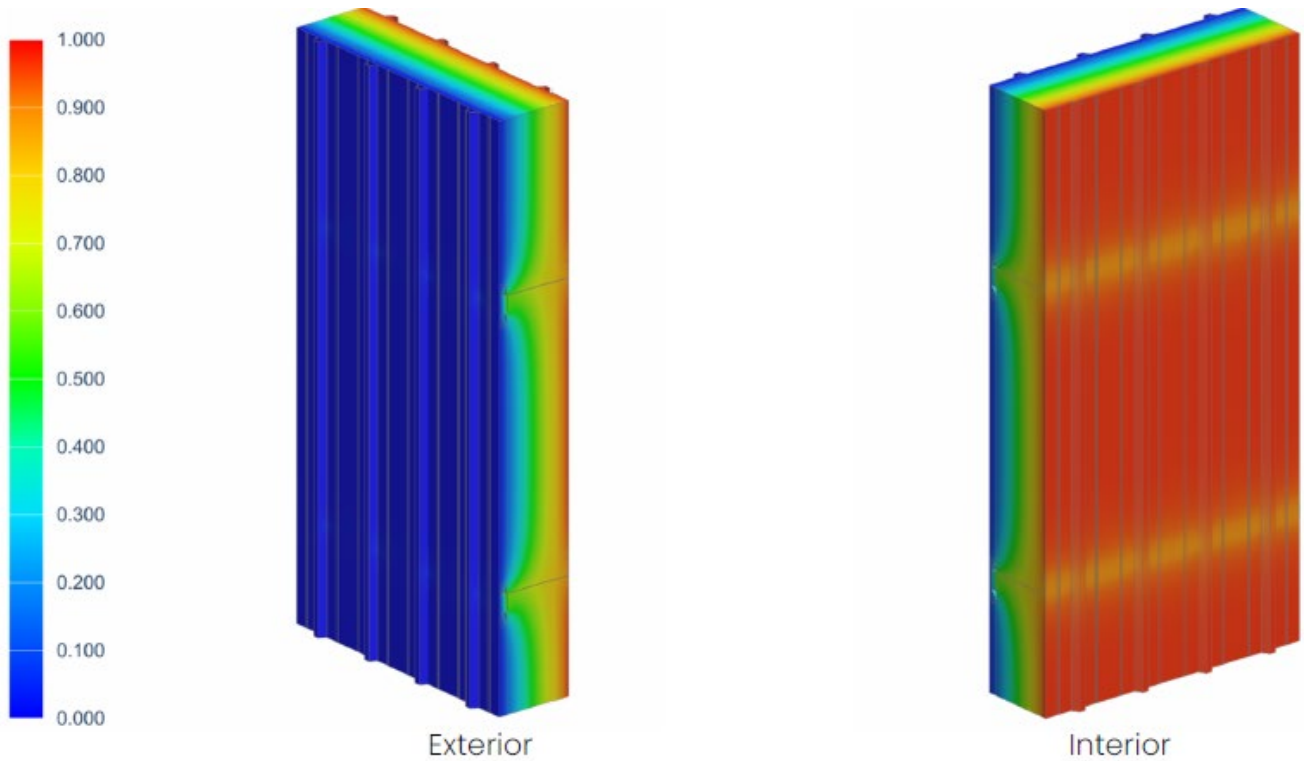


Figure D3. Temperature Profile of the Behlen Full Cavity Double Layer System with 11.5" Galvanized Steel Girts at 48" o.c. and 15" Batt Insulation (Uncompressed)

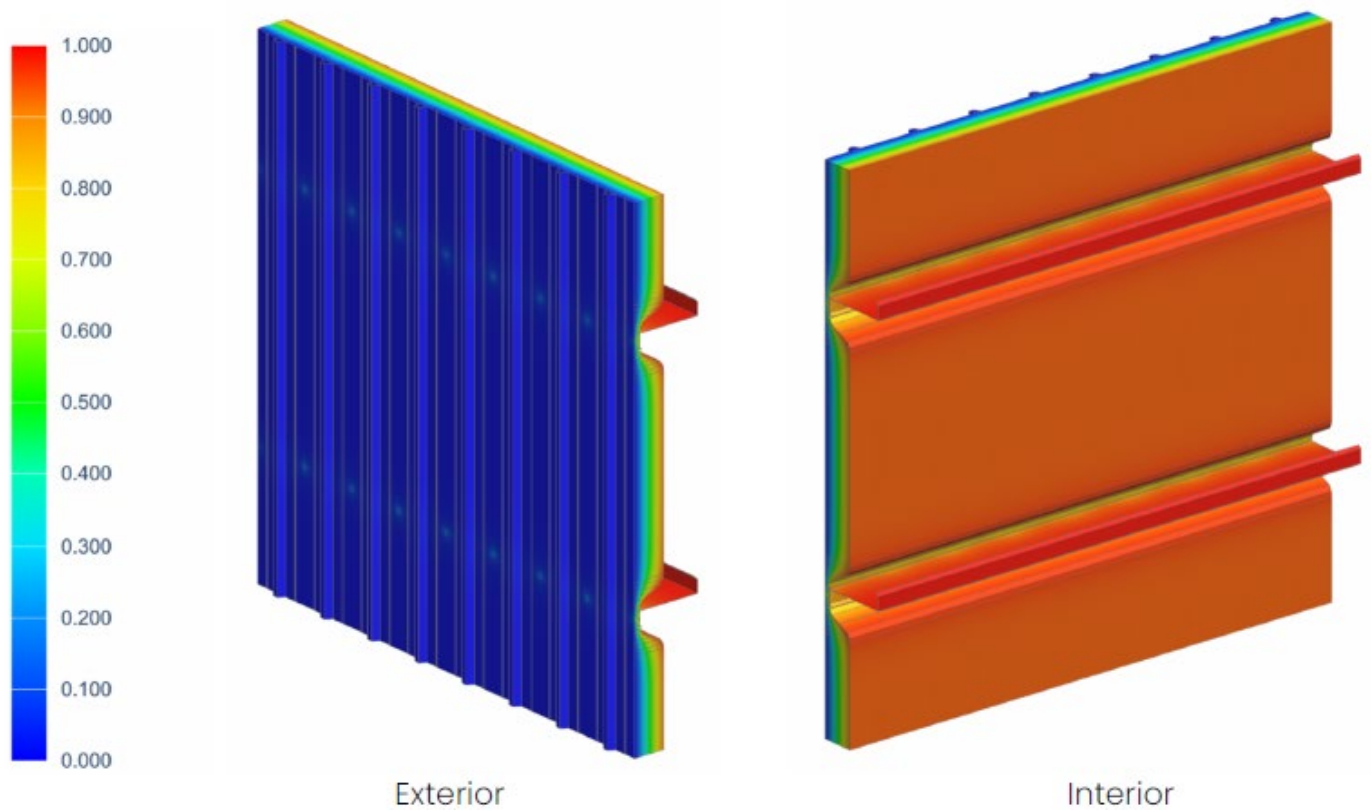


Figure D4. Temperature Profile of the Behlen Faced MBI System with Galvanized Steel Girts at 48" o.c. and 6" Batt Insulation (Uncompressed)

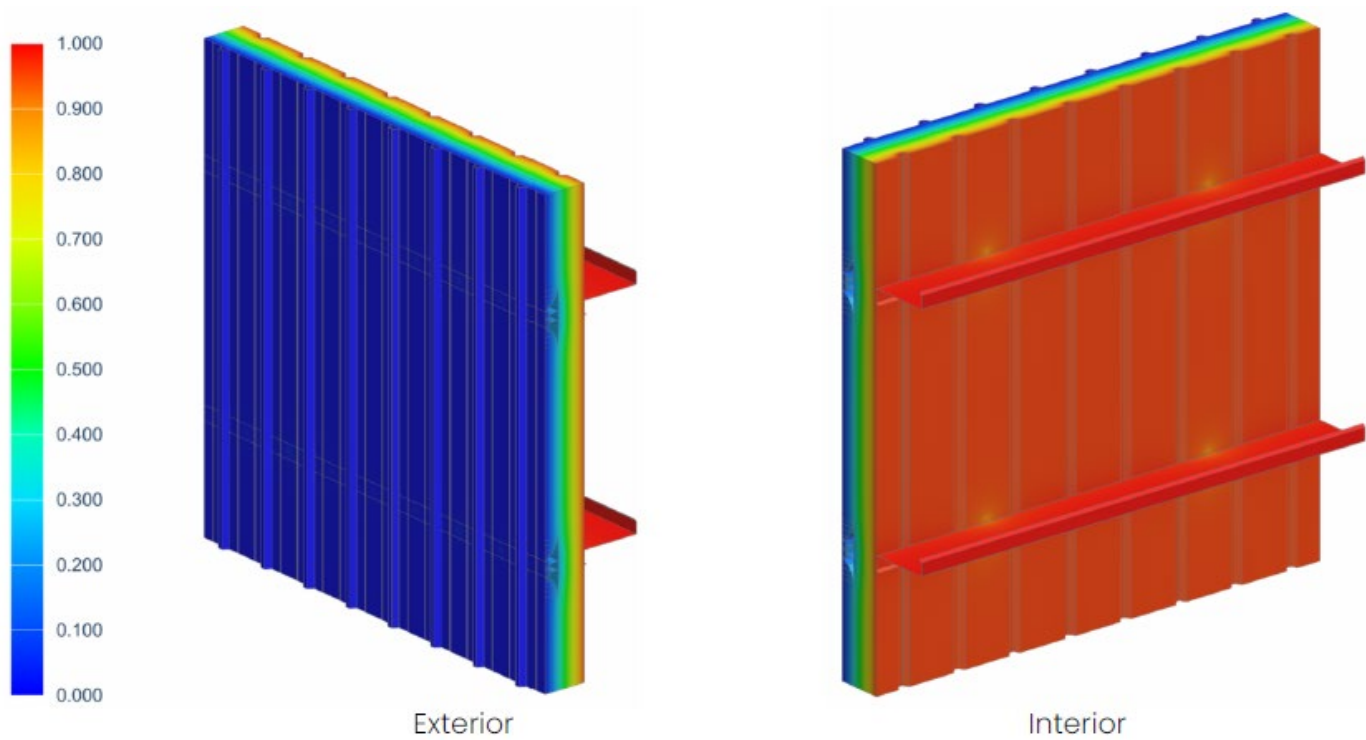
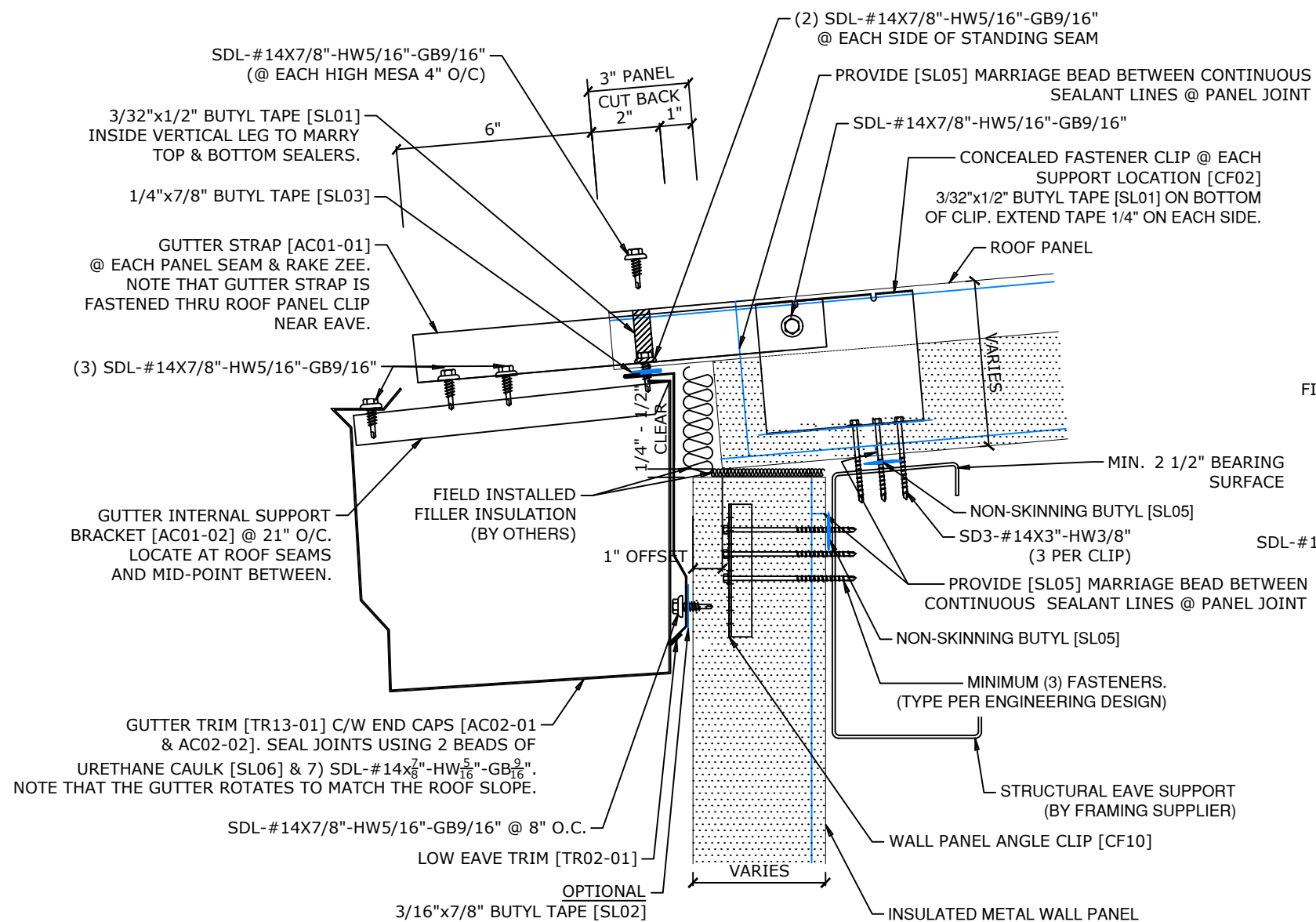


Figure D5. Temperature Profile of the Behlen Thermal Wall System with Galvanized Steel Girts at 48" o.c. and 6" Zee Clip with Batt Insulation

## **Appendix E: Detail Drawings and Data Sheets – ARTSPAN IMP Roof**

The following details illustrate the general evaluated assemblies. Not all the details are presented and full detail sets should be reviewed based on final design review.



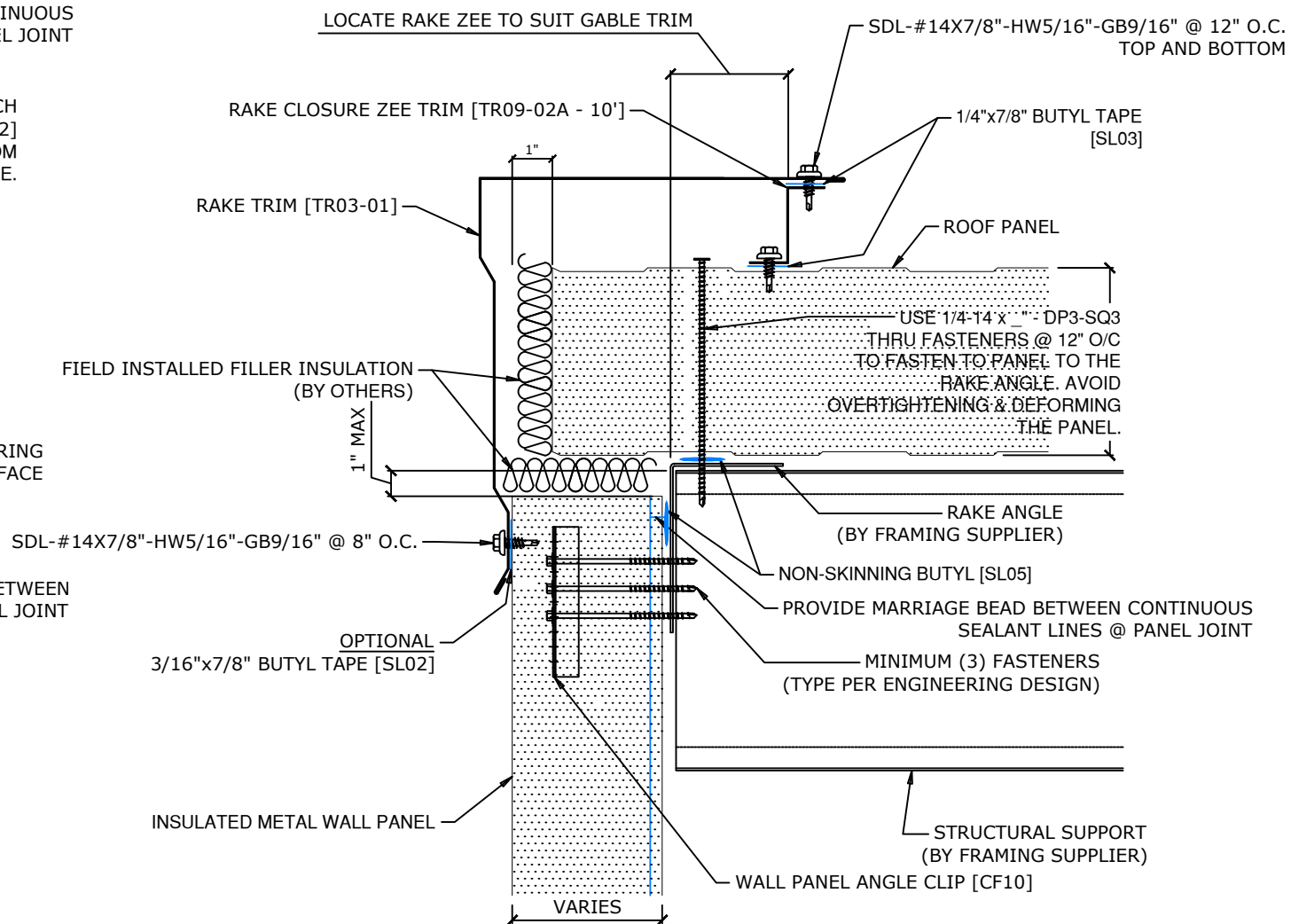
## EAVE DETAIL

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### TYPICAL WITH GUTTER

NOTE:

- FIELD REMOVE LINER AND INSULATION AT CUTBACK PANEL.
- FILLER INSULATION MATERIAL AND APPLICATION IS SPECIFIED BY THE PROJECT DESIGNER.
- TOP OF WALL PANEL TO BE PROTECTED FROM WEATHER DURING CONSTRUCTION.



GABLE DETAIL  
TYPICAL

NOTE:

- FILLER INSULATION MATERIAL AND APPLICATION IS SPECIFIED BY THE PROJECT DESIGNER.
- TOP OF WALL PANEL TO BE PROTECTED FROM WEATHER DURING CONSTRUCTION.

GENERAL NOTES:

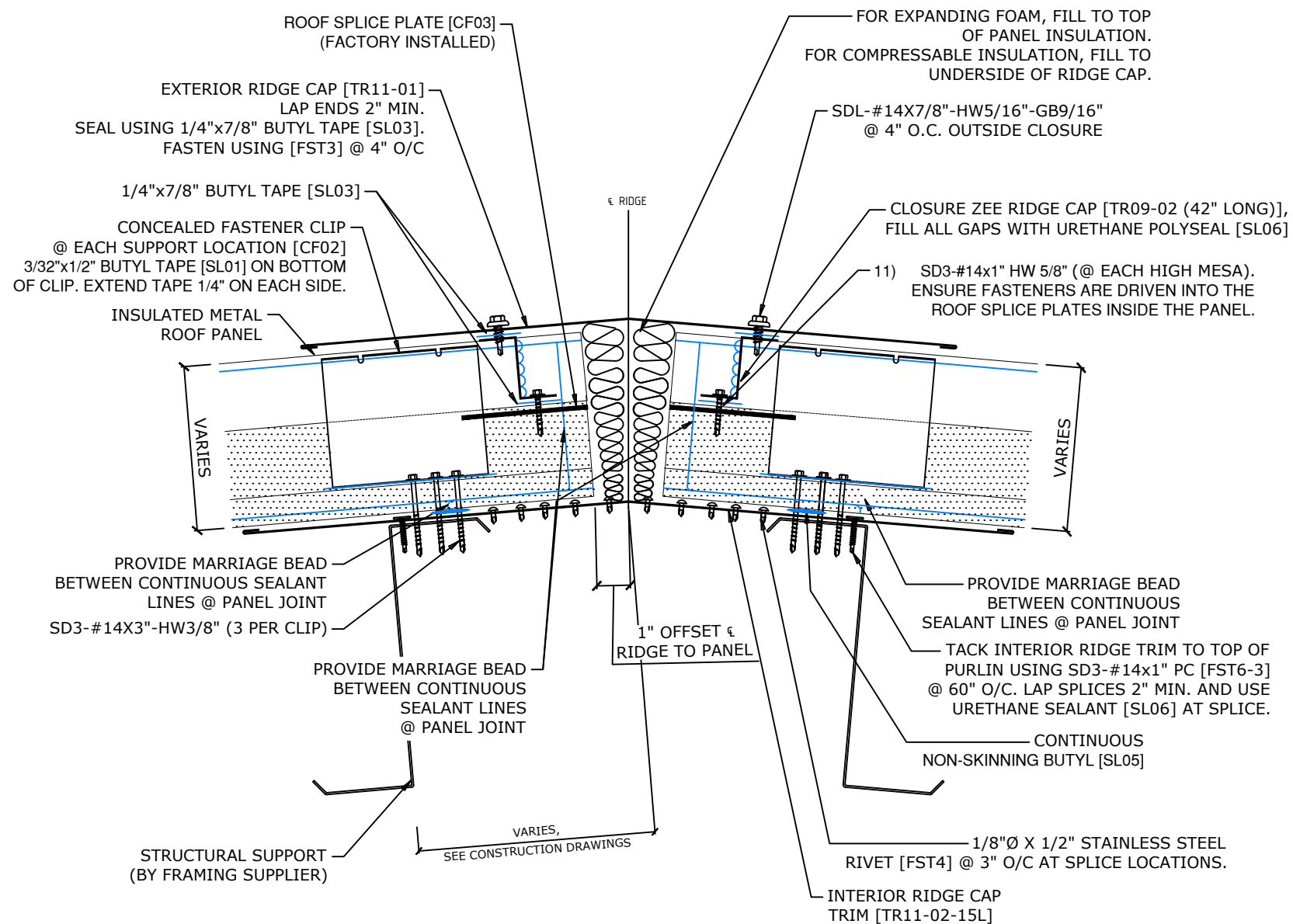
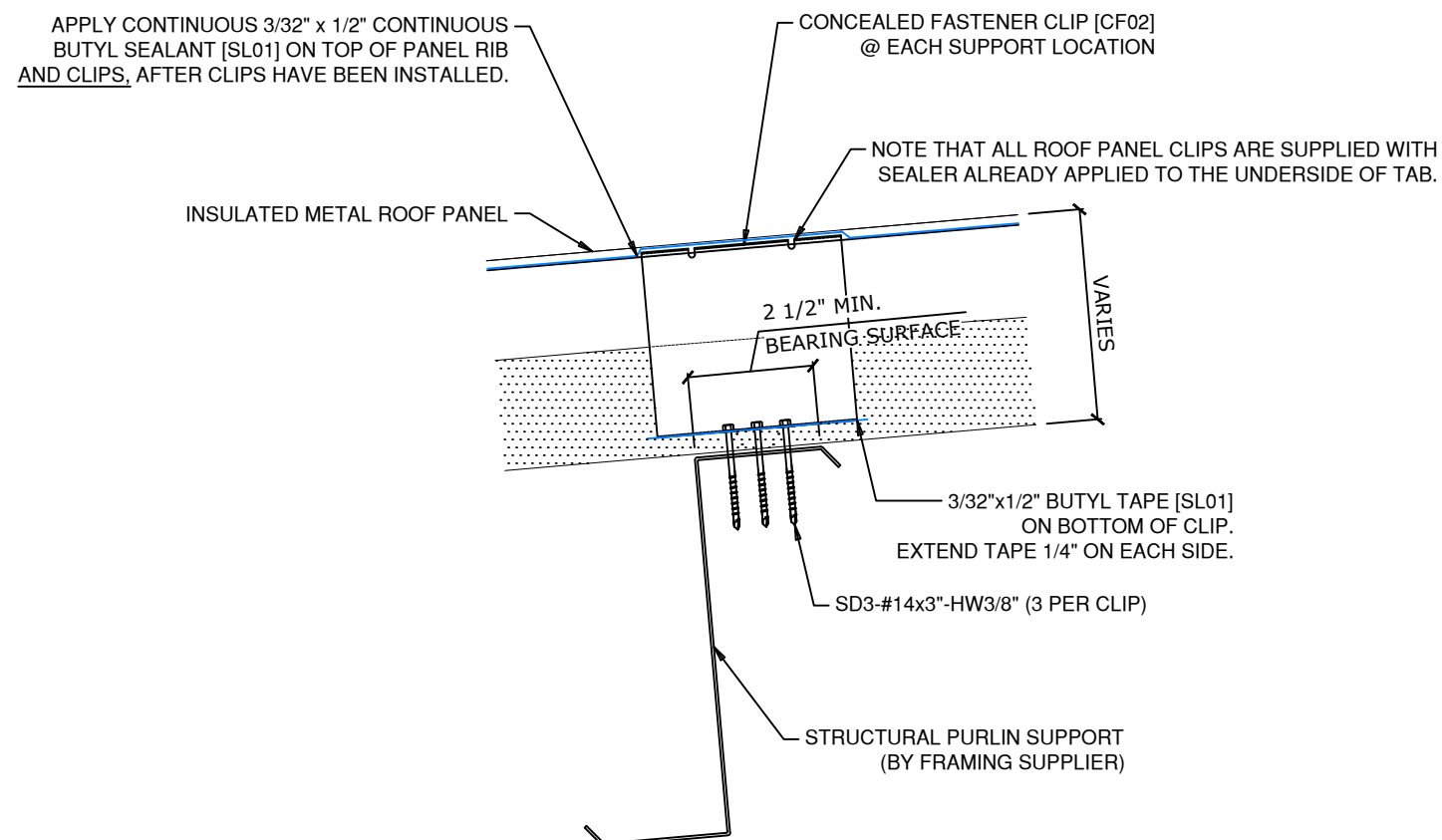
1. REFERENCES TO "SEALER" INDICATE  $\frac{3}{8}$ " X  $\frac{1}{2}$ " SEALER (32090300) UNLESS NOTED OTHERWISE.
2. SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.
3. HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX. 36" BECOMES 28  $\frac{3}{4}$ ".
4. PART NUMBERS, SIZES, AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.
5. THERMAL CLIP AND LINER PANEL SCREW SHANKS ARE EXPOSED TO THE INTERIOR OF THE BUILDING. CORROSIVE INTERIOR CONDITIONS REQUIRE CORROSION-RESISTANT SHANKS.
6. FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS.

A	INITIAL DRAWINGS	GG	DEC 9/2
ISSUE	DESCRIPTION	DRAWN BY	DATE

IMP ROOF DETAILS

SHEET
1
ISSUE
A





**NOTE:**  
- FILLER INSULATION MATERIAL AND APPLICATION IS SPECIFIED BY THE PROJECT DESIGNER.  
- REDUCE PANEL EXTENSION IN SNOW DRIFT CONDITIONS.

GENERAL NOTES:

1. REFERENCES TO "SEALER" INDICATE  $\frac{3}{8}$ " X  $\frac{1}{2}$ " SEALER (32090300) UNLESS NOTED OTHERWISE.
2. SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.
3. HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX. 36" BECOMES 28  $\frac{3}{4}$ ".
4. PART NUMBERS, SIZES, AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.
5. THERMAL CLIP AND LINER PANEL SCREW SHANKS ARE EXPOSED TO THE INTERIOR OF THE BUILDING. CORROSIVE INTERIOR CONDITIONS REQUIRE CORROSION-RESISTANT SHANKS.
6. FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS.

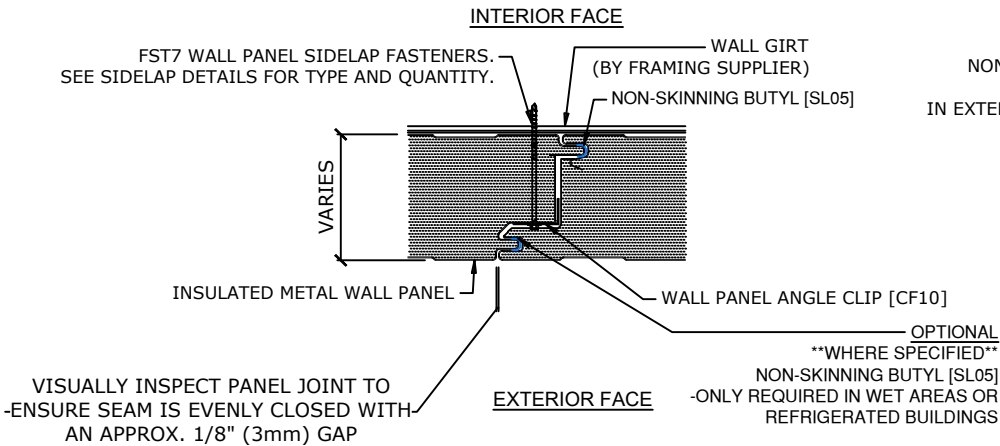
A	INITIAL DRAWINGS	GG	DEC 9/2
ISSUE	DESCRIPTION	DRAWN BY	DATE

## **Appendix F: Detail Drawings and Data Sheets – ARTSPAN IMP Walls**

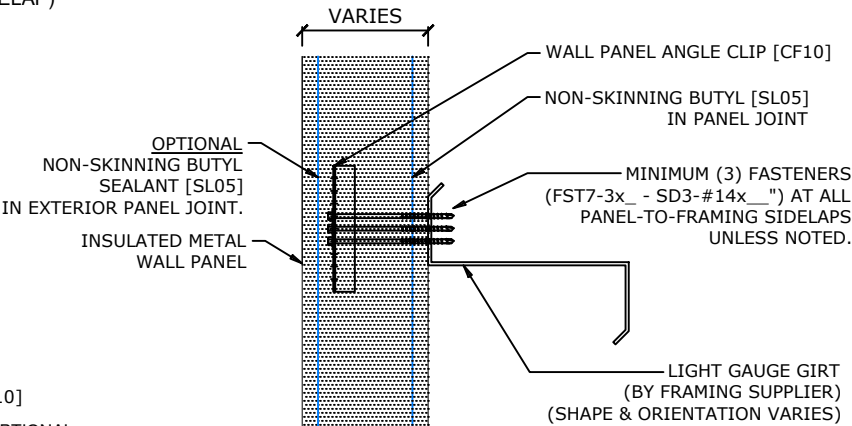
The following details illustrate the general evaluated assemblies. Not all the details are presented and full detail sets should be reviewed based on final design review.



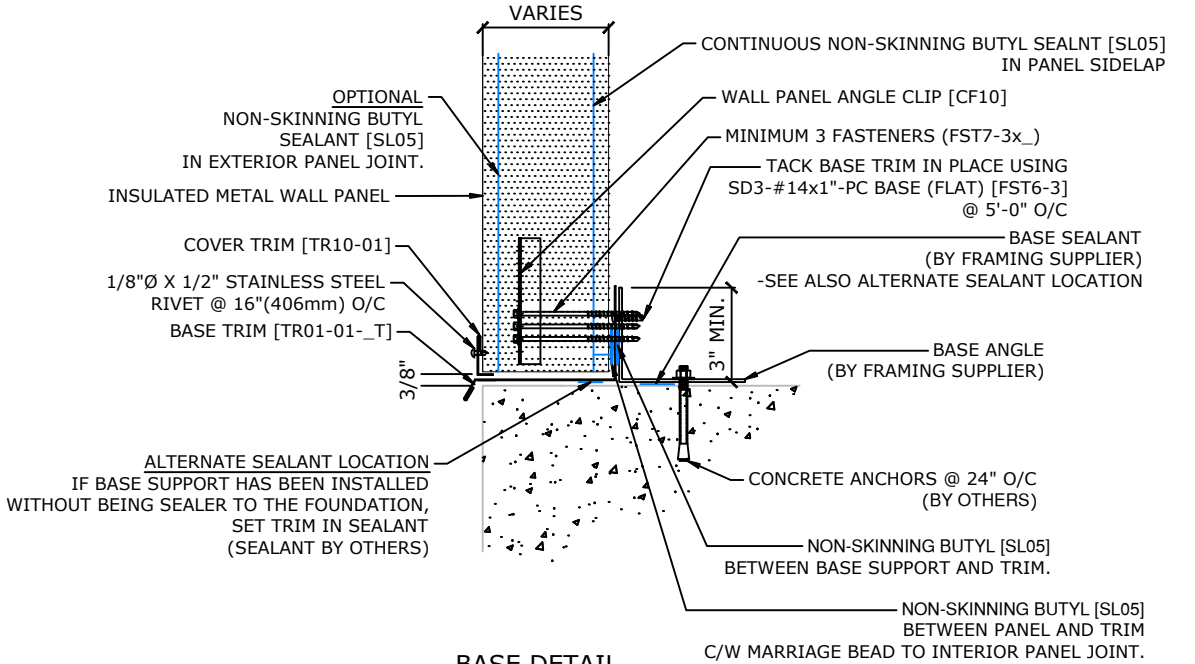
NOTE:  
- AT STRUCTURAL GIRT USE STRUCTURAL FASTENER (FST7-5x\_ - SD5-#14 x \_" HW 3/8" SIDELAP)  
- BEAD OF NON-SKINNING BUTYL [SL05] IS TO BE 3/8" UNLESS NOTED OTHERWISE.  
- IF SEALANT RUNS OUT OF JOINT ENSURE IT IS CLEANED OFF THE PANEL IMMEDIATELY.



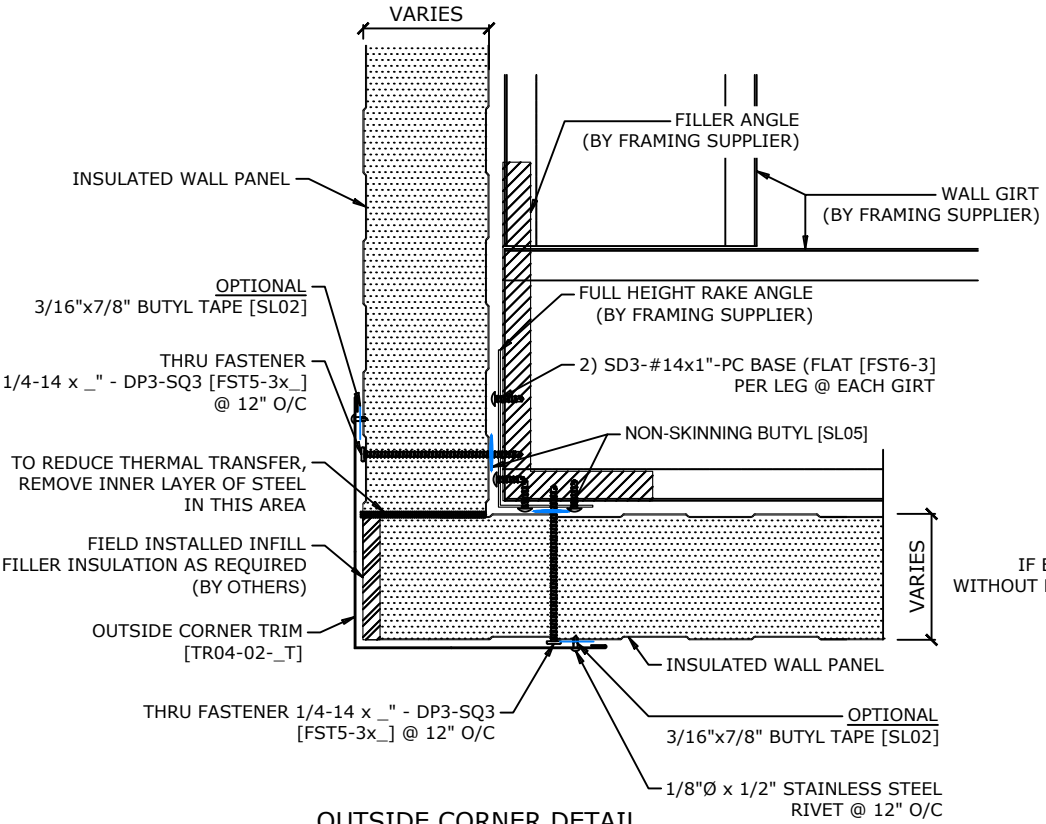
WALL PANEL SIDELAP DETAIL  
TYPICAL



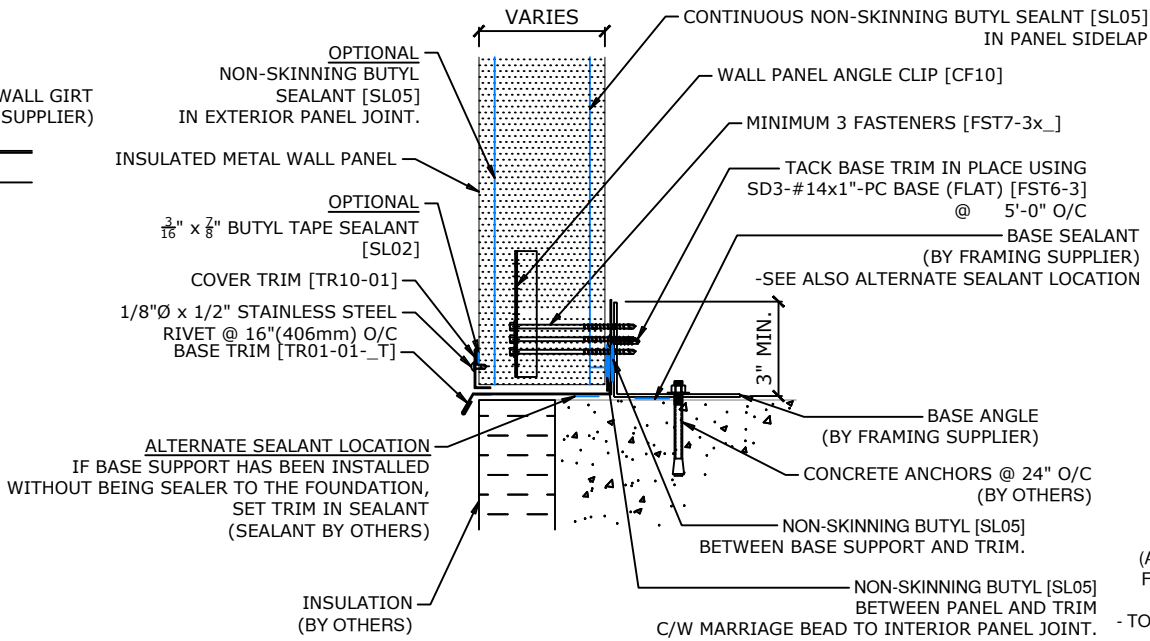
WALL PANEL CLIP DETAIL  
TYPICAL



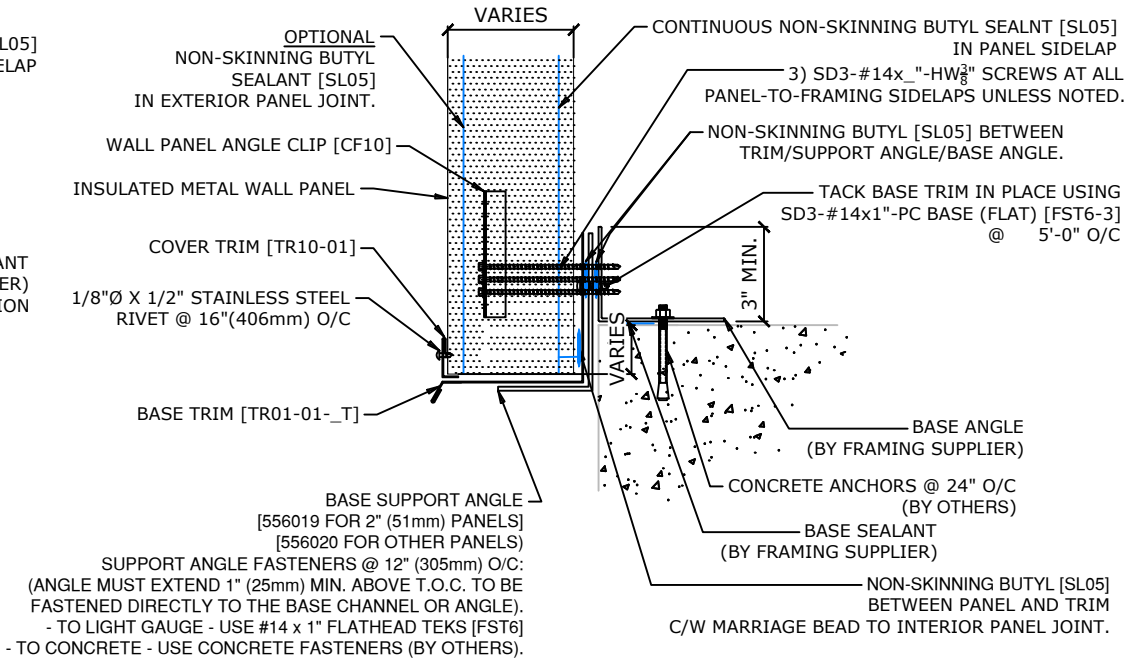
BASE DETAIL  
TYPICAL



OUTSIDE CORNER DETAIL  
TYPICAL



BASE DETAIL  
TYPICAL



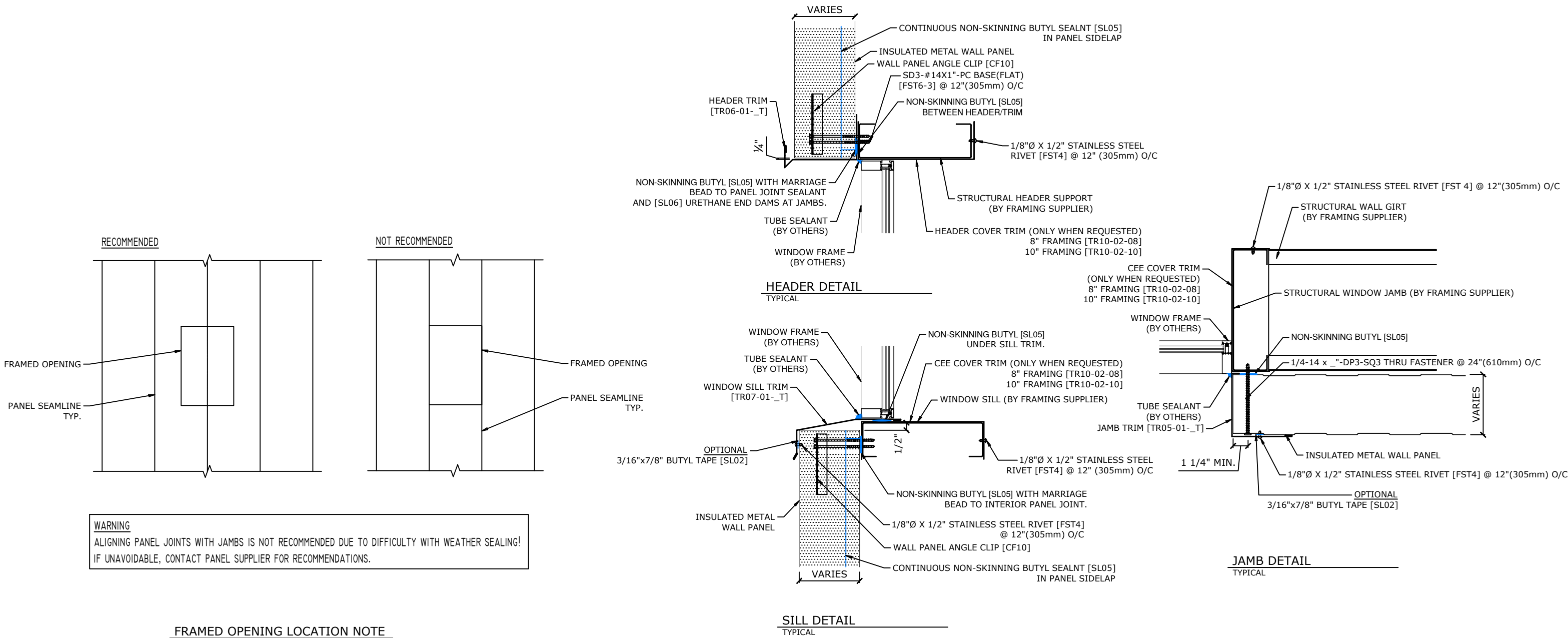
BASE DETAIL  
TYPICAL

GENERAL NOTES:  
1. REFERENCES TO "SEALER" INDICATE 1/8" X 1/8" SEALER (32090300) UNLESS NOTED OTHERWISE.  
2. SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.  
3. HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX. 36" BECOMES 28 3/4".  
4. PART NUMBERS, SIZES, AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.  
5. THERMAL CLIP AND LINER PANEL SCREW SHANKS ARE EXPOSED TO THE INTERIOR OF THE BUILDING. CORROSIVE INTERIOR CONDITIONS REQUIRE CORROSION-RESISTANT SHANKS.  
6. FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS.

				IMP WALL DETAILS	SHEET 2
					ISSUE A
A	INITIAL DRAWINGS	GG	DEC 9/24		
ISSUE	DESCRIPTION	DRAWN BY	DATE		



NOTE:  
- BEAD OF NON-SKINNING BUTYL [SL05] IS TO BE 3/8" UNLESS NOTED OTHERWISE.  
- IF SEALANT RUNS OUT OF JOINT ENSURE IT IS CLEANED OFF THE PANEL IMMEDIATELY.  
- BEAD OF URETHANE POLYSEAL [SL06] IS TO BE 1/4" MINIMUM. A LARGER BEAD MAY BE USED IF REQUIRED.



GENERAL NOTES:

1. REFERENCES TO "SEALER" INDICATE 1/8" X 1/2" SEALER (32090300) UNLESS NOTED OTHERWISE.
2. SCREW COLOUR MATCHES ADJACENT MATERIAL. SCREWS WITH HEADS IN WALL CAVITY ARE COLOURED.
3. HAT BARS ARE DESIGNED AS CONTINUOUSLY SUPPORTED. THEY ARE TO SPAN A MINIMUM OF THREE (3) CLIP SPACES. WHERE 3 SPACES ARE NOT PRACTICAL (AT OPENINGS, ETC.), REDUCE THE THERMAL CLIP SPACING TO 0.8 OF THE SPECIFIED SPACING. EX. 36" BECOMES 28 3/4".
4. PART NUMBERS, SIZES, AND GAUGES FOR THERMAL CLIPS, HAT BARS, FRAMEOUT CHANNELS, BASE SUPPORT, ETC. ARE NOTED ON THE BUILDING CONSTRUCTION DRAWINGS.
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6. FOR EXTERIOR CLADDING DETAILS SEE APPROPRIATE STANDARD DETAIL DRAWINGS.

A	INITIAL DRAWINGS	GG	DEC 9/24
ISSUE	DESCRIPTION	DRAWN BY	DATE

IMP WALL DETAILS

SHEET 2A  
ISSUE A