Detailing and Dimensional Stability Considerations in Spray Polyurethane Foam Air Barriers

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Introduction

- Spray Polyurethane Foam (SPF) has become a popular choice among design professionals and contractors alike for use as an air and water barrier in new construction. It is versatile material that can be applied to either interior or exterior wall systems providing a useful combination of water and air penetration resistance.

Learning Objectives

- Understand the materials and mechanics of sprayed polyurethane foam systems used in exterior applications
- Recognize the extent and the cause of dimensional changes in foam systems
- Learn the detailing considerations necessary to reduce the severity of these dimensional changes and prevent damage to adjoining materials
- Develop a general understanding of other design considerations relevant to SPF including flame spread, vapor transmission, UV exposure and air permeance.

Caution

- Because the product is essentially fabricated on site by the installer, differences in mixture proportions, thicknesses, ambient and substrate temperatures, moisture or humidity conditions and other factors can result in dramatic variations in the physical properties of the material as well as the behavior and performance of the system.

History of SPF

- First used as a roofing material in the United States in the 1960's, particularly practical for re-roofing applications over built up roofing when used with a urethane, silicone or acrylic top coat.

History of SPF

- Shortly thereafter material was adapted for wall applications in the 1970's

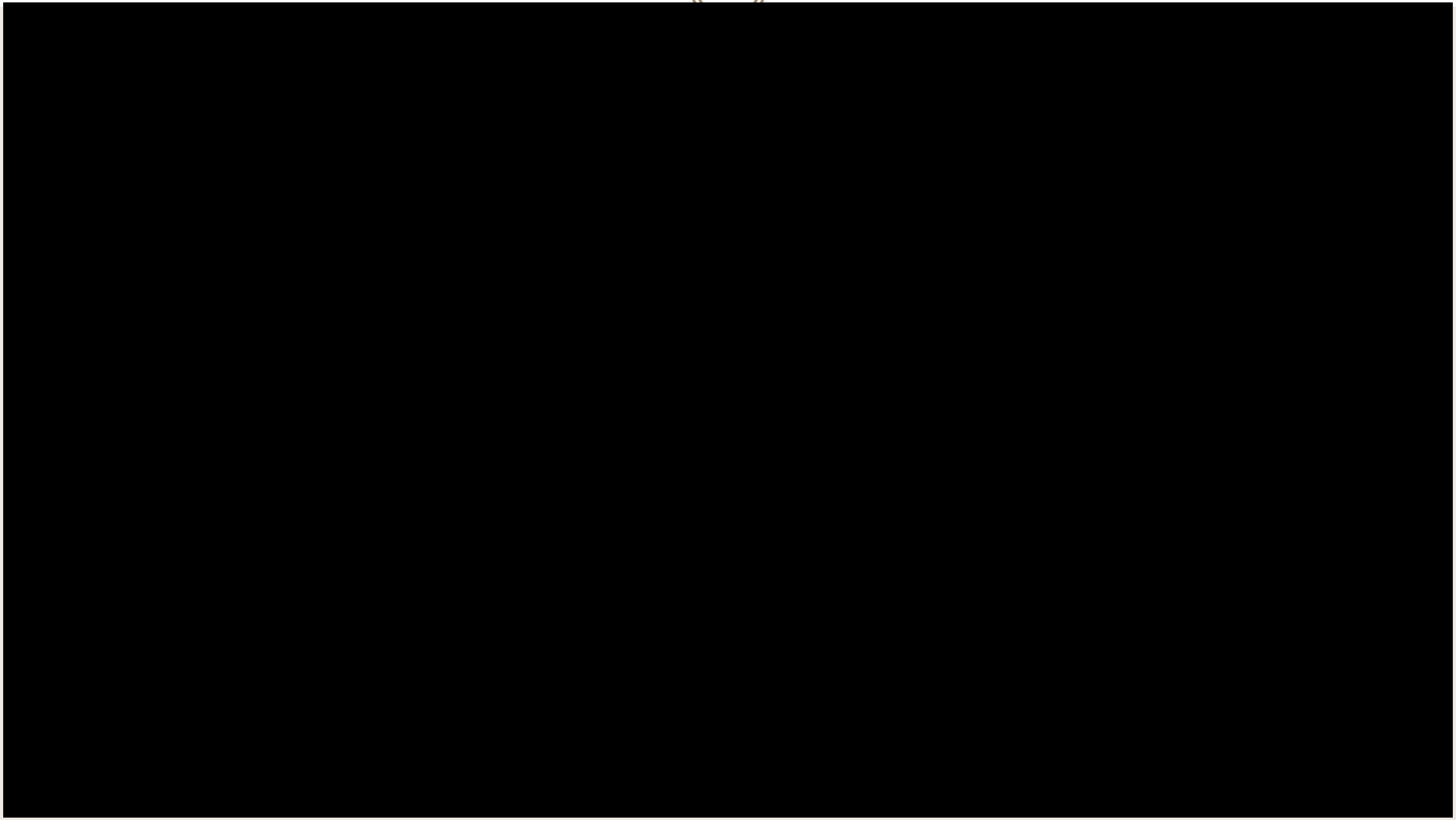
Code Requirements

- Continuous insulation requirements for many climate zones
- Air infiltration limitations for components, systems and buildings.
- Continuous air barrier requirements

What is SPF

- Mixture of Polyisocyanate and Polyhydroxl compounds (may have stabilizers and blowing agents).
- Delivered and mixed at gun nozzle.
- Applies mist of mixed components to surface
- Components react and expand 20-30 times
- Cures to a rigid cellular plastic layer

Installation of SPF



Any Observations?

- Thickness of pass?
- Angle of application?
- Surface Irregularity?
- Surface texture?

SPF Thickness

- Optimum pass thickness is between ½” and 1 ½”
- Thicknesses of less than an ½” are not recommended
- Greater single lift thicknesses may require different foam formulation
- Passes should be tack free before next lift
- Variations in thickness can affect heat, density and strength

Surface texture

- Surface texture provides indication of foam quality
- Roughness (orange peel, popcorn, tree bark, etc.) can be indicative of problems
  - Equipment adjustment
  - Temperature
  - Moisture
  - Applicator Technique
- Can lead to pinholes, blowholes, blisters,

Foam Surface Texture

Uses of SPF

- Serves as:
  - Insulation
  - Air barrier
  - Gap filler
  - Water barrier
  - Vapor retarder

Material Properties

- Thermal Barrier
  - Typical R value for 1 inch of SPF is between 6 and 8 ft^2 hr. °F / Btu
  - Comparable or better than fiber blankets or batts, extruded polystyrene (XPS), and polyisocyanate insulation
  - Seamless unlike blanket or board products
  - Moisture adversely affects the thermal properties of SPF less than other products

Material Properties

- Air Barrier
  - Typical air permeance of material <.0005 cfm/ft^2 at 1.57 lbs./ft^2
  - Readily integrated into other air barrier components
  - Ideal for sealing penetrations and gaps

Material Properties

- Vapor Barrier
  - Class II vapor barrier as defined by 2009 IBC
  - Typical vapor permeance between 0.1 and 1.0 perms depending on thickness

Material Properties

- Water Resistive Barrier
  - Meets code criteria for water resistance
  - Very low water absorption (<5%)

ASTM 1029

ASTM 1029 - Standard Specification for Spray-Applied Rigid Cellular Polyurethane Thermal Insulation

TABLE 1 Physical Properties

Property	Requirements			
	Type I	Type II	Type III	Type IV
Thermal resistance of 1.0 in. (25 mm) thickness, min, °F·ft²·h/Btu (K·m²/W) at mean temperature 75°F (24°C)	6.2	6.2	6.2	6.2
Compressive strength, at yield or 10 % deformation, whichever comes first, min, psi (kPa)	15 (104)	25 (173)	40 (276)	60 (414)
Water vapor permeability, max, perm-inches (ng/Pa·s·m)	3.0 (4.4)	3.0 (4.4)	3.0 (4.4)	3.0 (4.4)
Water absorption, max, volume %	5	5	5	5
Tensile strength, min, psi (kPa)	20 (138)	32 (221)	42 (290)	56 (386)
Response to thermal and humid aging, max, linear change %	12	9	6	5
Closed cell content, min, %	90	90	90	90
Surface burning characteristics, report value	...	...	...	...

Key material concepts

- Cellular Foam Insulation
  - Density and compressive strength vary based on formulation
  - Components react with moisture to off gas CO_2
  - Generally good adhesive bond
  - Generally good tensile strength (20 to 60 psi)
  - Subject to long term shrinkage of 5-10%
  - Also subject to short term thermal shrinkage

Testing Considerations

- Dimensional Stability
  - Current specification for SPF references tests for dimensional stability of foam (D2126)
  - Current test methods most appropriate to board stock
  - Do not account for initial dimensional changes immediately following application
  - Data reported by manufacturers outlines performance at limited temperature and relative humidity combinations

Dimensional Stability of SPF

- ASTM D2126-09 “Standard Test Method for Response of Rigid Cellular Plastics to Thermal and Humid Aging”
  - Cut 4 inch by 4 inch samples
  - Condition to a constant mass at 73.4 +/- 4°F and 50+/-10% relative humidity
  - Specimens are exposed to the temperature and humidity conditions specified for the test for a duration of 24 hours +/- 1 hour, 168 hours +/- 2 hours and 336 hours +/- 2 hours
  - Dimensions taken at the end of each test duration

Dimensional Stability of SPF

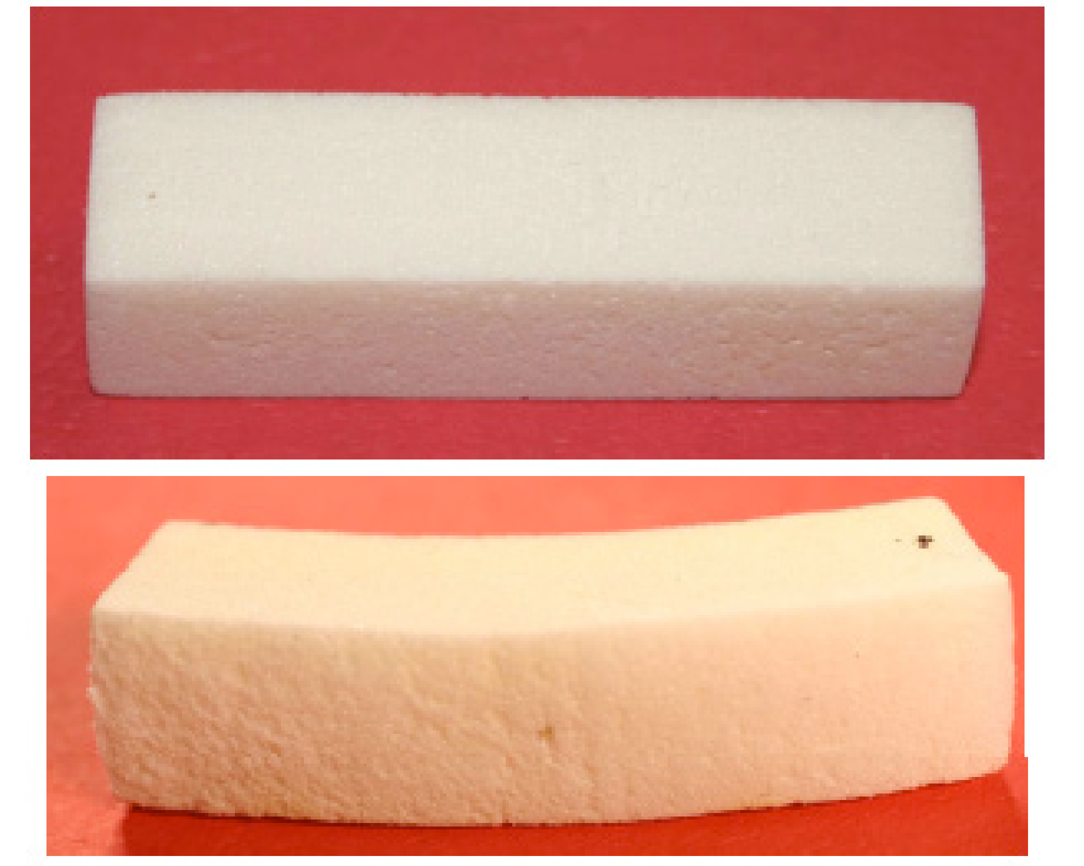
Temperature and Relative Humidity Combinations Outlined in Table 1 of ASTM D2126-09	
Temperature, ºC (ºF)	Relative Humidity, %
-73 ± 3 (-100 ± 6)	Ambient
-40 ± 3 (-40 ± 6)	Ambient
70 ± 2 (158 ± 4)	Ambient
100 ± 2 (212 ± 4) 150 ± 2 (302 ± 4)	Ambient Ambient
23 ± 2 (73 ± 4)	50 ± 5
38 ± 2 (100 ± 4)	97 ± 3
70 ± 2 (158 ± 4)	97 ± 3
Other temperature and humidity selected for individual needs	

Foam Shrinkage on a Solid Substrate

Shortening and Curling of Foam

Key material concepts

- Shrinkage and curling



Key material concepts

- Exothermic.
  - Related to the pass thickness or multi passes
  - Insulation prevents effective cooling
  - 4-6" layers can reach 200-300 degrees F
  - Heat and cooling stresses can be imposed on the material
  - Differential cooling top to bottom
  - Ambient substrate and exterior temperatures also impact heat

Design Guidelines and Resources

- Industry Resources
  - IBC
  - IECC
  - ASTM C1029-10 "Standard Specification for Spray-Applied Rigid Cellular Polyurethane Thermal Insulation"
  - ASTM D7119/D7119M-13 "Standard Guide for Sampling Spray Polyurethane Foam and Coating in Roofing"
  - ASTM D5469/D5469M-12 "Standard Guide for Application of New Spray Applied Polyurethane Foam and Coated Roof Systems"
- Installation and detailing is primarily dictated by Manufacturer's product literature

Discussion of Failures

- Generally there are two factors contributing to recent failures in some installations:
  - SPF adhesion to materials is greater than material adhesion to substrates
  - SPF dimensional stability
- Currently there are industry standards for field testing of material adhesion and laboratory testing of dimensional stability for SPF, but they do not simulate in place conditions

Material Adhesion

- Self-Adhered Membrane Adhesion
  - Tested in accordance with D4541
  - Calibrated pull testing apparatus tests to failure

Material Adhesion

- **SPF Adhesion and Cohesion Testing**
  - Non-standard field check outlined by the Air Barrier Association of America
  - Specimens are not tested to failure

Testing Considerations

- Adhesion Testing
  - Test methods are typically intended to verify installed products at a given point in time and currently cannot be used to consistently predict the potential for failure over long term
  - Self-adhered membrane testing verifies adhesion prior to application of SPF and does not account for variations in properties due to application of SPF
    - The Spray Polyurethane Foam Alliance states proper application methods should limit SPF temperatures to 180° F or less
    - Many self-adhered membranes break down at 160° F
  - SPF Adhesion and Cohesion Test apparatus is not conducive to many of the orientations necessary to be able to test locations where self-adhered membrane failures have been observed

Recommendations to the Industry

- Detailing: SPF industry needs to outline and expand design criteria for SPF systems and details for functional integration with other envelope components
- Testing Procedures: Re-assessment of existing test methods to establish representative and functional testing procedures
- Testing Data: Reported test data should be clarified and expanded to provide information necessary for Designers to assess the feasibility of using SPF on a project

Material Properties

- Ultimately, the benefits of SPF as a component of the building envelope are dependent upon integrations with other wall and roofing components

Design Guidelines and Resources

- Often detailed similar to fluid applied air barriers
  - Self-adhered membranes at transitions between dissimilar substrates
  - Transition membranes at integrations with fenestration systems
  - Incorporation of self-adhered flashing membranes to direct water to the exterior

Difficult Solutions

Observed Concern

- Adhesion Failures of Flashing Membranes

Initial Installation of Flashing

- Self adhered flashing membranes were well adhered
- Substrate was primed in accordance with the flashing membrane installation instructions
- Laps were sealed with mastic

Initial Installation of SPF

- SPF was lapped onto vertical leg of flashing membrane
- Plastic sheeting was used to mask the horizontal leg of the flashing
- Flashing membrane was well adhered immediately after SPF application

Prior to Installation of Brick

- Localized adhesion failures on various flashing runs
- Primarily observed on horizontal leg of flashing membrane
- Manifested as air pockets and wrinkles in membrane

Observed Failures

Observed Failures

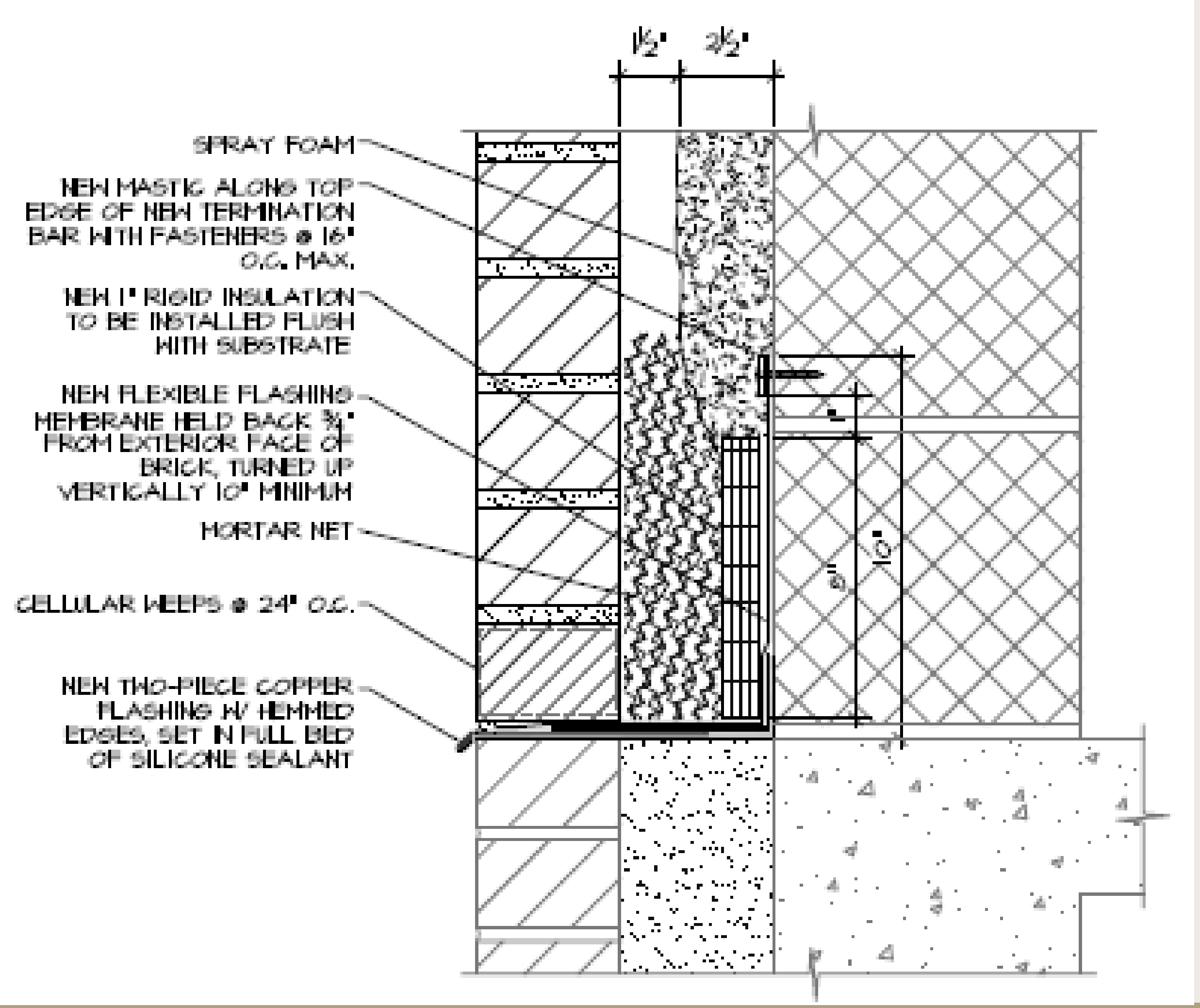
Continued Degradation

- Brick was removed where the flashing membrane had been well adhered at the time the brick was laid
- Adhesion failures were observed
- The drainage plane was disrupted by folds in the membrane

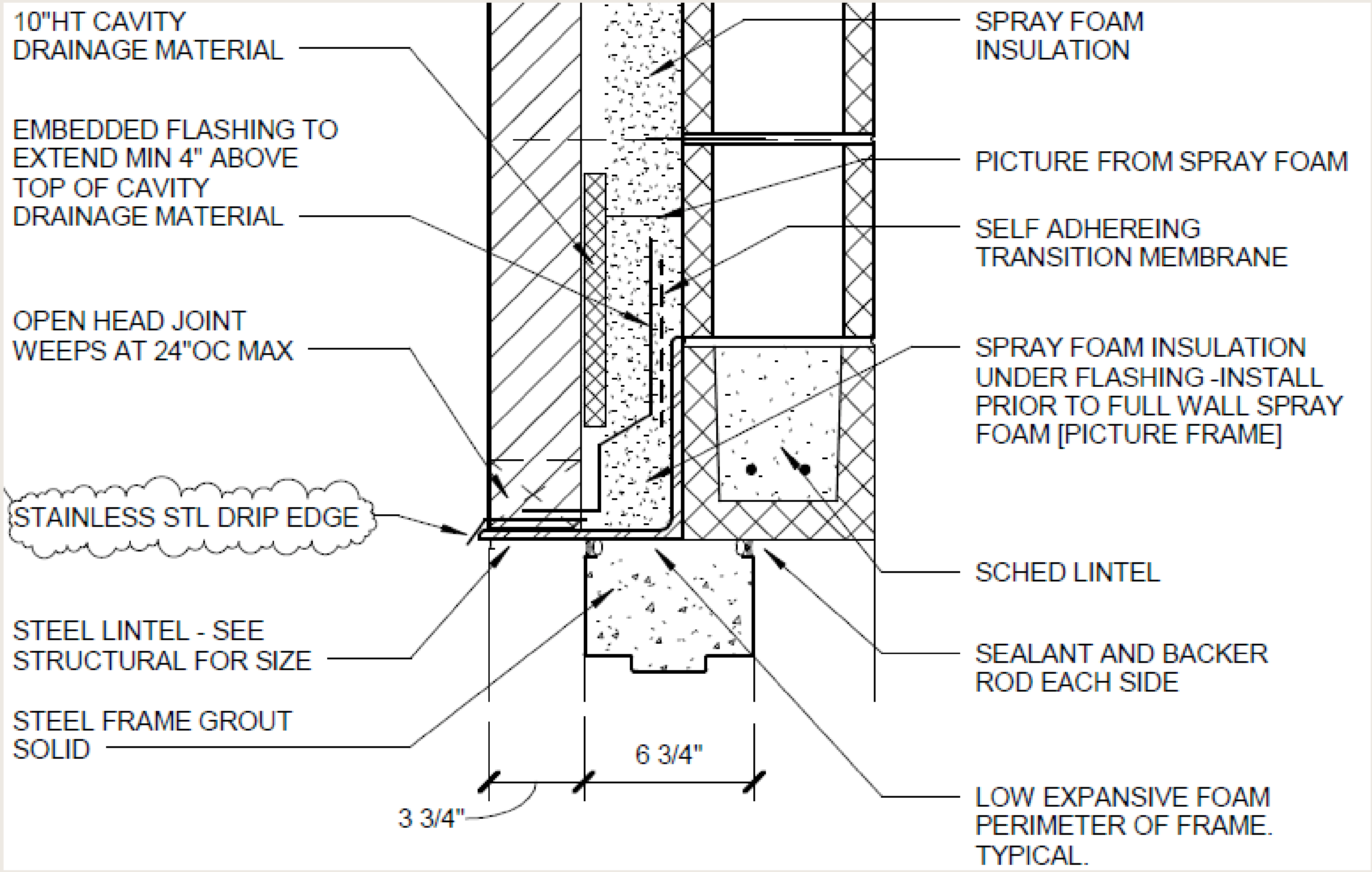
Detailing Tips

- Assume exaggerated movement
- Provide solid substrates
- Recognize dissimilar substrate materials
- Limit foam thickness
- Avoid large fields of foam
- Minimize tensile bond conditions
- Provide foam closures or picture frames
- Require sequenced foam installation
- Evaluate flame susceptibility

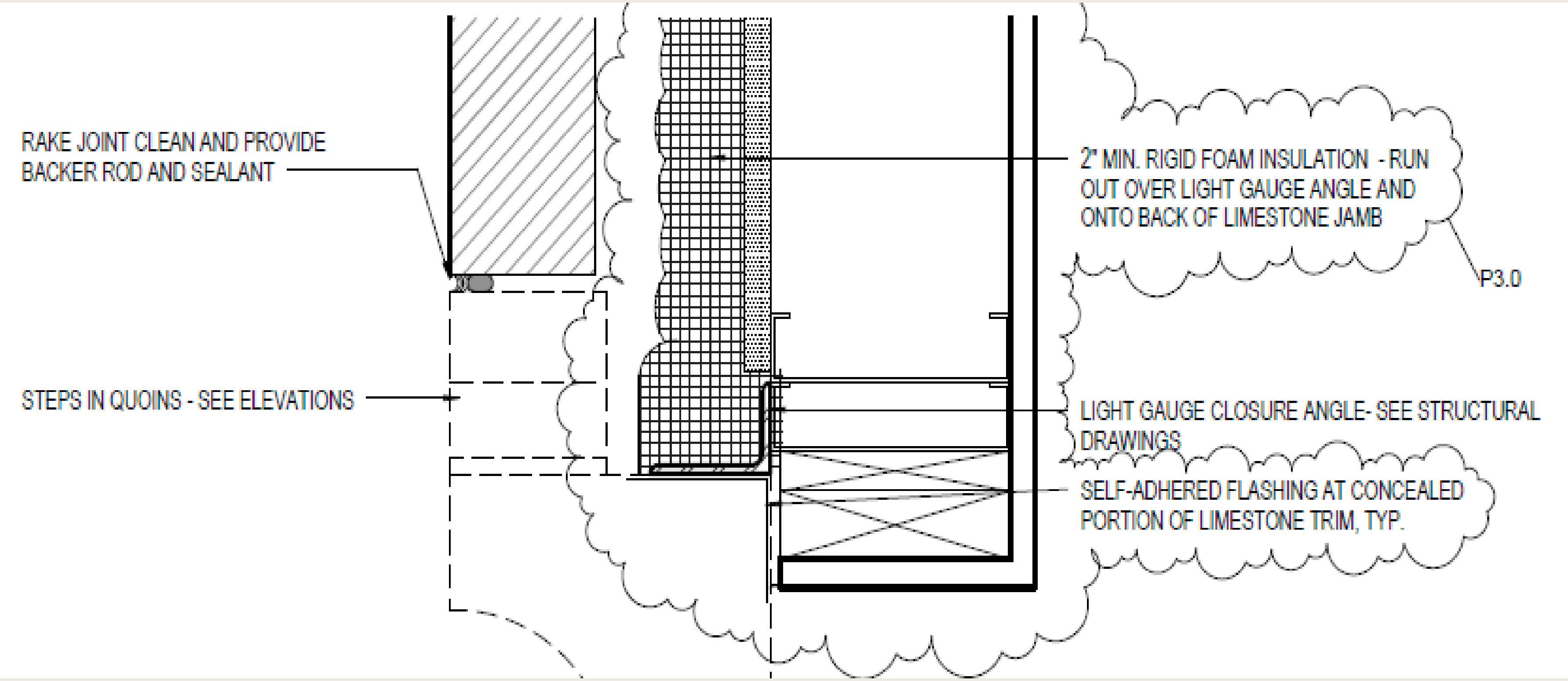
Base Flashing – Good or Bad



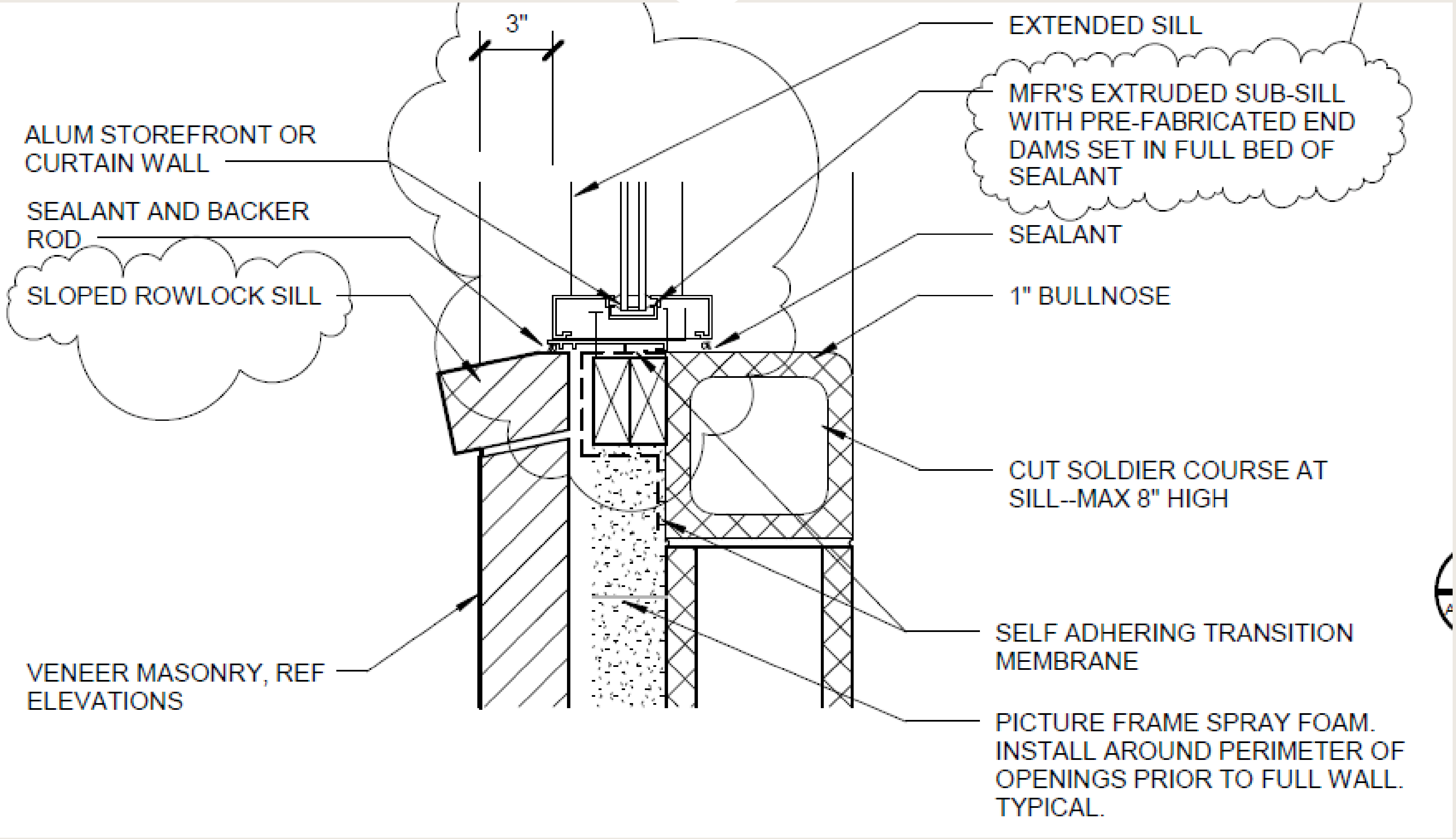
Window Head Detail – Good or Bad?



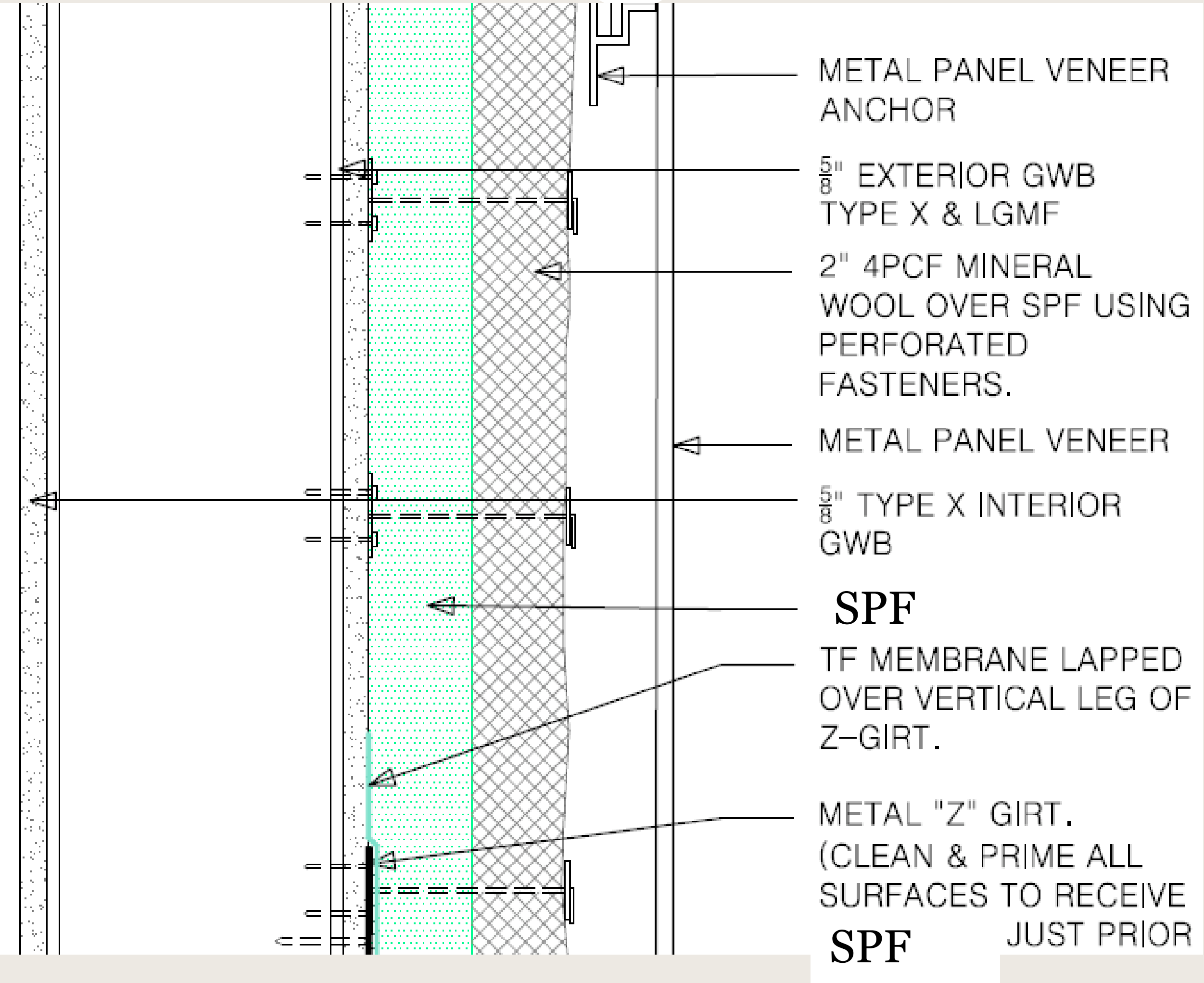
Jamb Detail – Good or Bad



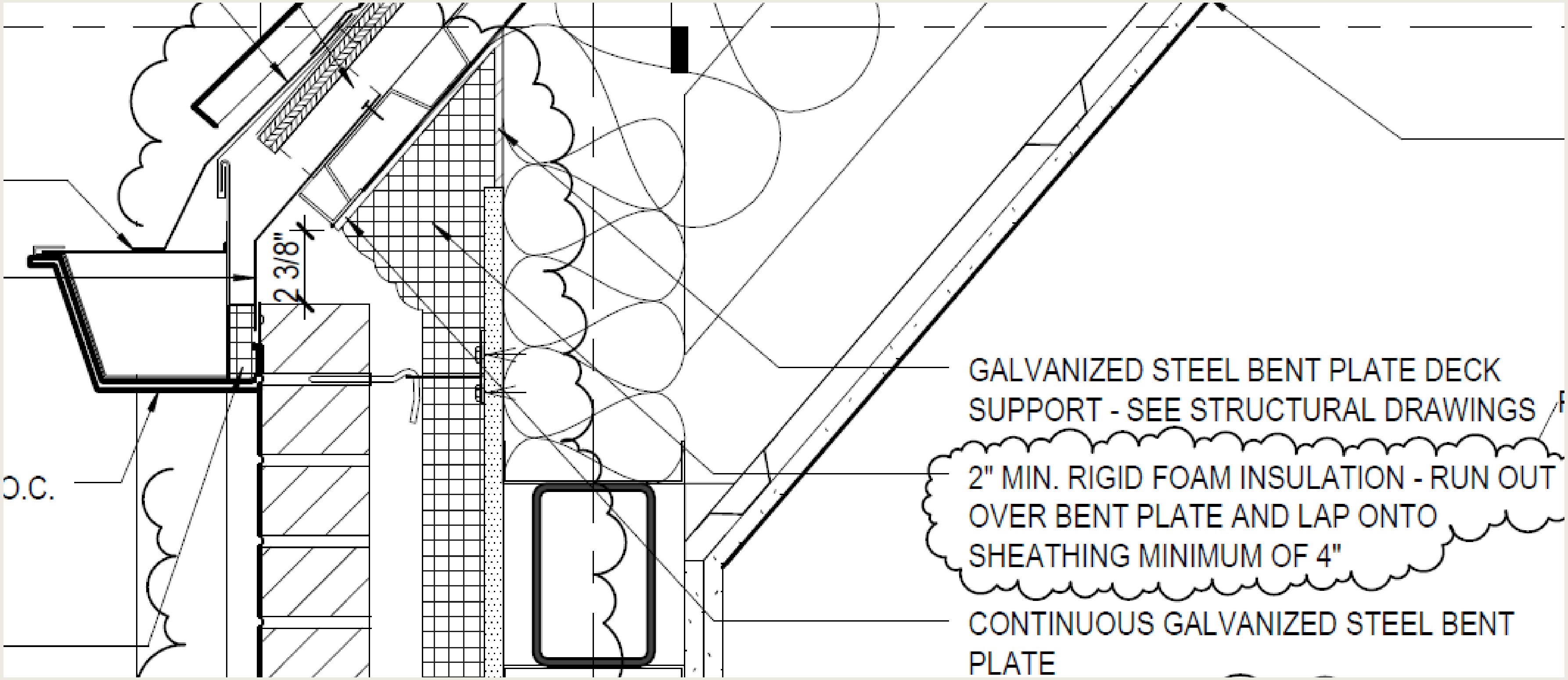
Sill Detail – Good or Bad



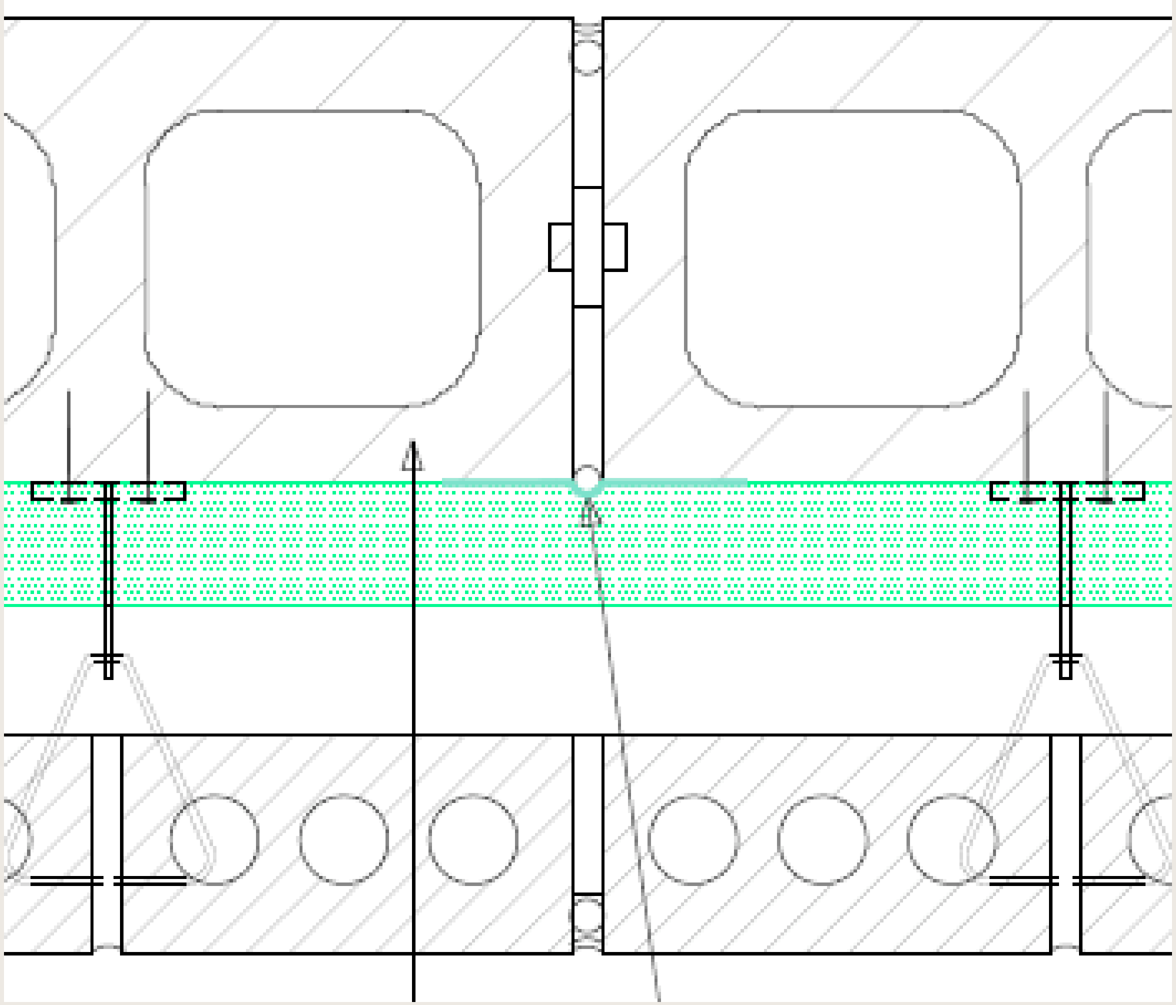
Metal Panel Detail – Good or Bad



Sloped Roof Closure – Good or Bad



Control Joint/Gap Closure – Good or Bad



Summary

- Mind the behavior of the foam when detailing wall sections.
- Evaluate manufacturer’s details to verify that they are consistent with your design intent.
- Be aware of conditions that can affect the behavior of the foam during installation and watch for them on site.

Questions

Thank you!

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