

# Manual

Fifth Edition

Includes 2003 and 2006 Updates

The vertical line in the margin indicates an addition or change(s) in the text since *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, was originally printed in 2001.

Includes 2003 Update

Includes 2006 Update

First Printing 2001



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## Volume 2

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# Manual

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## Volume 3

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# Manual

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## Volume 4

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- Non-Nailable Roof Decks—On non-nailable roof decks, NRCA recommends applying perlite roof insulation boards in hot bitumen or manufacturers-approved adhesive over a properly prepared deck. Priming of the deck may be required to achieve adequate adhesion with this type of installation.
- Loose-laid Ballasted Systems—Perlite insulation is not recommended to be used directly under the membrane where the roof system is intended to be loose-laid ballasted.

#### **2.4.4.6 Equipment and Construction Traffic**

Improperly mounted equipment and construction traffic can compress perlite insulation boards, causing damage to the insulation and, in some cases, deflection in the roof deck, resulting in separation of the insulation boards from the deck. NRCA recommends that equipment be installed in penthouses or at ground level. Proper protection of the roof assembly must be provided before allowing construction traffic over any finished roof system.

## **2.5 Polyisocyanurate Foam Board Roof Insulation**

### **2.5.1 Description**

Polyisocyanurate foam board roof insulation is a rigid insulation material manufactured from closed cell, polyisocyanurate rigid foam sandwiched between two facers. Commonly used facers include aluminum foils; glass-fiber reinforced cellulosic mats; coated or uncoated polymer-bonded glass-fiber mats or other rigid board materials including perlite board insulation, wood fiberboard insulation and oriented strand board (OSB). Where rigid board materials are used as a facer, NRCA considers these products to be composite board insulation; see Section 2.8—Composite Board Roof Insulation for information about these products.

The ASTM standard for polyisocyanurate is ASTM C 1289, “Standard Specification for Faced Rigid Board Cellular Polyisocyanurate Thermal Insulation.” This standard includes the following applicable classifications:

–Type I—Aluminum-foil-faced on top and bottom sides:

- Class 1—Nonreinforced polyisocyanurate foam core
- Class 2—Glass-fiber reinforced polyisocyanurate foam core

–Type II—Mat-faced on top and bottom sides:

- Class 1—Faced with glass-fiber reinforced cellulosic mats or coated or uncoated polymer-bonded glass-fiber mats on top and bottom sides:
  - Grade 1—16 psi (110 kPa) minimum compressive strength polyisocyanurate foam core
  - Grade 2—20 psi (138 kPa) minimum compressive strength polyisocyanurate foam core
  - Grade 3—25 psi (172 kPa) minimum compressive strength polyisocyanurate foam core
- Class 2—Faced with coated polymer-bonded facers on top and bottom sides.

Type I, Class 1 and Type II, Class 1 polyisocyanurate foam board are generally used in roofing applications. It is generally understood that Type I, Class 2, and Type II, Class 2, products are used in wall sheathing applications and are not intended for use in roof assemblies

NRCA recommends polyisocyanurate foam board insulation used in low-slope membrane roof assemblies be manufactured to have a minimum of 20 psi (138 kPa) compressive strength and facer sheets that are compatible with the assembly method and other components of the roof assembly. Therefore, NRCA recommends the use of polyisocyanurate foam board roof insulation that complies with ASTM C 1289, Type II, Class 1, Grade 2. This classification designates polyisocyanurate foam board insulation with a minimum 20 psi (138 kPa) foam core and faced with glass-fiber reinforced cellulosic mats or coated or uncoated polymer-bonded glass-fiber mats on the top and bottom sides.

Furthermore, NRCA suggests designers who specify polyisocyanurate foam board insulation incorporate the following criteria into their designs:

- Board size: 4-foot by 8-foot (1.2-m by 2.4-m) maximum board size for loose-laid and mechanically attached insulation boards and 4-foot by 4-foot (1.2-m by 1.2-m) maximum board size for insulation boards adhered to a substrate.
- Board thickness: 2 inches (51 mm) maximum; when thicker total thicknesses are necessary, specify insulation boards in multiple layers to achieve total desired thickness. When multiple insulation layers are used, the insulation board's joints in the topmost layer (cover board) should be staggered vertically and offset from the joints in the underlying layers.

NRCA recommends an R-value of 5.6 per inch (25 mm) thickness be used to calculate the total thermal resistance of polyisocyanurate foam board roof insulation. This 5.6 R-value is based upon an in-service R-value.

Most manufacturers' currently published literature provides for R-value data for polyisocyanurate foam board roof insulation based upon the long-term thermal resistance (LTTR) method of determination. The LTTR method provides for reporting of R-value based upon a calculated 15-year time-weighted average. At this time, NRCA does not endorse or recommend the use of the LTTR method for determining the thermal resistance of polyisocyanurate foam board roof insulation.

The following recognized properties of polyisocyanurate foam board roof insulation make it an effective insulation material:

- Bitumen and adhesive compatibility

- Component compatibility
- Impact resistance
- Fire resistance
- Durability
- Moisture resistance
- Thermal resistance
- Attachment capability

## 2.5.2 Manufacturing Process

Polyisocyanurate foam board insulation is manufactured through a controlled chemical reaction. Primary chemicals are metered and mixed at a specific temperature, and the mixture is applied to a moving base platen. Once the mixture is combined, the chemical blowing agent reacts with a catalyst to cause the liquid to quickly rise and form into cellular foam. In a matter of seconds, the liquid mixture becomes a solid, lightweight, and thermally resistant material.

To create polyisocyanurate roof insulation, the closed-cell rigid foam stock is bonded to reinforcing facer material as the foam rises during the manufacturing process. Once the facers are bonded, the board stock is cut to size, and should be allowed to cure before distribution.

The following table shows the common sizes, thicknesses, k- and R-values for polyisocyanurate insulation:

Available Sizes	Available Thicknesses	Approx. k-value	Approx. R-value (per in. or 25 mm)
48 in. x 48 in. (1.2 m x 1.2 m) 48 in. x 96 in. (1.2 m x 2.4 m)	1 in. to 4 in.* (25 mm to 100 mm)	0.16	5.6
Taper 48 in. x 48 in. (1.2 m x 1.2 m)	Slopes: 1/8 in. 1/8 in., 1/8 in., 1/4 in., 3/8 in., 1/2 in. per foot (0.3, 0.6, 0.9, 1.2, 1.8, 2.4 degrees)	0.16	5.6

Although available in thicknesses up to 4 inches (100 mm), NRCA recommends that polyisocyanurate insulation be installed in layers 2 inches (50 mm) thick (maximum).

## 2.5.3 Guidelines for Use

### 2.5.3.1 Multiple-layer Insulation

The recommended specification is for multiple-layer insulation, especially when the total required insulation thickness is more than 2 inches (50 mm). NRCA recommends designers specify a suitable cover board over polyisocyanurate insulation in all low-slope membrane roof systems. Cover boards are considered to be components of a multiple-layer insulation assembly.

### 2.5.3.2 Joints

When double-layer insulation is used, the joints of the insulation boards in the top layer should be vertically staggered and offset from the joints in the underlying layer. The end joints of adjacent insulation boards should be staggered, and the edges of abutting insulation boards should be in moderate contact.

### 2.5.3.3 Storage and Handling Protection

During storage and handling, polyisocyanurate insulation should be protected from the weather. All roof system materials that are susceptible to retaining moisture or that may be damaged by moisture should be stored in a dry location before application.

When moisture-sensitive materials are stored outside, they should be placed on pallets or platforms that are raised off the ground or roof deck. Materials sensitive to moisture should be covered with water-resistant coverings that have been properly secured. Coverings that are “breathable,” such as water-resistant canvas tarpaulins, are preferred. Some insulation materials are extremely light and may need to be secured in storage.

#### 4.3.1.1.2.1 Copolymer Alloy (CPA)

CPA roof membrane materials are produced by alloying polymeric plasticizers, stabilizers, biocides and antioxidants with PVC compounds. CPA roof membrane materials typically are produced in thicknesses ranging from 30 mils to 50 mils (1.3 mm). Some CPA roof membrane materials are resistant to some chemicals and may be resistant to certain oils and greases.

Like PVC membranes, CPA membrane laps are seamed by heat-welding according to a specific manufacturer's recommendations. CPA membrane systems may be used in the following configurations, as recommended by the membrane manufacturer: ballasted, fully adhered, mechanically fastened to an approved substrate or as a protected membrane roof system. Designers and contractors should consult the CPA membrane manufacturer regarding membrane securement configuration options.

#### 4.3.1.1.2.2 Ethylene Interpolymer (EIP)

EIP membranes are compounded with PVC and ethylene interpolymer stabilizers, certain pigments and antioxidants, and other proprietary modifiers specific to a manufacturer. EIP membranes generally are reinforced with polyester scrim or fabric. These membranes typically are 32 mils to 60 mils (0.8 mm to 1.5 mm) thick. Laps typically are seamed by heat-welding according to a manufacturer's recommendations.

EIP membrane systems typically are applied in ballasted or mechanically attached configurations over approved substrates. Designers and contractors should consult the EIP membrane manufacturer regarding membrane securement configuration options.

#### 4.3.1.1.2.3 Nitrile Alloy (NBP)

NBP roof membranes are compounded with PVC; butadiene-acrylonitrile copolymers; plasticizers; and other additives, such as fungicides, algacides, fire retardants and pigments. Nitrile copolymer, when blended with thermoplastic resins, is intended to impart flexibility and weathering characteristics. NBP membranes may be 30 mils to 40 mils (0.8 mm to 1.0 mm) thick, but they typically are produced as 40-mil (1.0 mm) sheets. These membranes are spread-coated using polyester scrim as reinforcement. NBP membrane laps typically are seamed by heat-welding.

NBP membrane systems may be specified as ballasted, fully adhered, mechanically attached to an approved substrate or as a protected membrane roof system. Designers and contractors should consult the NBP membrane manufacturer regarding membrane securement configuration options.

#### 4.3.1.1.3 Other General Types of Thermoplastic Membranes

##### 4.3.1.1.3.1 Thermoplastic Olefin (Polyolefin) (TPO)

TPO roof membranes are compounded from a blend of polypropylene (PP) and ethylene-propylene rubber (EPR) polymers. Flame retardants, pigments, UV absorbers and other proprietary ingredients may be included in TPO membrane formulations. TPO membranes may be reinforced. The membranes usually are produced as white or black sheets, but other colors may be obtained. TPO membrane thicknesses generally range from 40 mils to 100 mils (1.0 mm to 2.5 mm).

TPO membranes vary in look, feel and physical properties. Some are soft and flexible, and others are "boardy" or rigid. TPO membranes exhibit positive physical properties, such as heat aging, cold-temperature flexibility, puncture resistance and tear strength. They also are resistant to degradation from exposure to animal fats, some hydrocarbon oils and vegetable oils. They also are resistant to microbial attack and will not support growth of microorganisms.

TPO membrane systems may be specified as ballasted, fully adhered, mechanically attached to an approved substrate or as a protected membrane roof system. Designers and contractors should consult the specific TPO membrane manufacturer regarding membrane securement configuration options.

NRCA recommends specifying TPO membrane sheets complying with or exceeding the criteria set forth in ASTM D 6878, "Standard Specification for Thermoplastic Polyolefin Based Sheet Roofing."

### 4.3.1.2 Thermoplastic Roof Membrane Securement

Thermoplastic roof membranes may be installed in four general configurations: ballasted, mechanically attached, fully adhered to an approved substrate or as a protected membrane. Designers and contractors should consult thermoplastic membrane manufacturers regarding their specific membrane securement configuration options.

### **4.3.1.3 Thermoplastic Roof Membrane Surfacing**

Some thermoplastic roof membranes may have factory-applied acrylic coatings to enhance weather resistance, improve aesthetics or provide other properties to the membranes. Most factory-surfaced thermoplastic roof membrane sheets are not field-surfaced with other materials after installation on a roof except when used in ballasted or protected roof membrane configurations. When thermoplastic roofing sheets are used in ballasted or protected roof membrane configurations, the surfacings commonly used are rounded stone or concrete roof pavers. When concrete pavers are used, the roof membrane should be protected from paver abrasion with a separator sheet.

### **4.3.1.4 Thermoplastic Membrane-related Roofing and Flashing Materials**

- Separator Sheets

One purpose of a separator sheet is to allow a membrane to move independently from a substrate without damaging the membrane by abrasion. Another purpose is to isolate the membrane from bituminous or other incompatible materials or substrates, such as polystyrene insulation. Materials that are used as separator sheets include relatively thick polyester or glass-fiber fabrics, reinforced kraft paper, polyethylene sheeting or factory-applied fleece backing.

- Adhesives

Solvent- or water-based adhesives are used to adhere thermoplastic membranes in fully adhered membrane configurations and some flashing situations. The membrane manufacturer should be consulted for specific guidelines and recommendations regarding the type of adhesive and application rates.

- Related Flashing Materials

Thermoplastic resin-coated or thermoplastic clad metal often are used as flashing materials in various flashing and counterflashing conditions. Thermoplastic membrane systems sometimes employ thermoplastic-coated metal for perimeter terminations and some flashing details. Other metals may be used with thermoplastic systems but may require adhesive in lieu of hot-air welding when bonding the membrane to metal. Relatively thick, such as 60 mil (1.5 mm), reinforced or unreinforced thermoplastic membrane material, also is used as membrane base flashing in many flashing applications. Unreinforced thermoplastic membrane material and prefabricated flashing boots often are used to flash common penetrations, inside and outside corners, and other specific detail conditions.

## **4.3.2 General Guidelines for Thermoplastic Roof Membrane Materials and Application**

### **4.3.2.1 Delivery and Storage**

The following are general suggestions for care and protection of membranes and materials.

- All materials delivered from manufacturers and suppliers should be carefully inspected at the time of delivery and examined during unloading. Manufacturers' product labels should be intact. Any damaged or unsuitable material should be rejected. Material that has been exposed to the weather in transit or storage should be examined carefully for deterioration and damage.
- Rolled single-ply membrane sheets may be stored as shipped, in original wrappings with rolls laying horizontally, or as required by the manufacturer.
- When storing rolled single-ply materials, the storage substrate should be swept to rid the surface of loose gravel, sharp objects and other debris that could damage the membrane material.
- When storing roofing materials on a roof deck, caution should be taken not to overload the roof deck or structural assembly.
- Lids should be secured on cans or buckets stored on a job site.
- Water-based adhesives and other water-based materials should be protected from freezing.
- Moisture-sensitive materials should be covered with water-resistant coverings, some of which may be manufacturers' shrink-wrapped coverings, that have been properly secured. Coverings that are "breathable," such as water-resistant canvas tarpaulins, are preferred for covering moisture-sensitive materials.

Overall Length x Width	Exposure Length x Width	Approx. pieces/sq. (Approx. pieces/m <sup>2</sup> )	Approx. lbs./sq. (kg/m <sup>2</sup> )
11 in. x 8¾ in. (280 mm x 220 mm)	8 in. x 8 in. (200 mm x 200 mm)	225 (209)	900 lbs./sq. (44 kg/m <sup>2</sup> )
14 in. x 9 in. (360 mm x 230 mm)	11 in. x 8¾ in. (280 mm x 210 mm)	158 (147)	800 lbs./sq. (40 kg/m <sup>2</sup> )
16½ in. x 13 in. (420 mm x 330 mm)	13½ in. x 11¼ in. (340 mm x 300 mm)	90 (84)	900 lbs./sq. (44 kg/m <sup>2</sup> )

Table 4: S-tile dimensions

### 2.1.4 Standards

The following ASTM standards apply to roof tile:

- ASTM C 1167, “Standard Specification for Clay Roof Tiles.” This standard addresses material characteristics and physical properties and establishes sampling procedures for clay tile. ASTM C 1167 contains type classifications for tile based upon the tiles’ profile: Type I—High-profile tile are tiles having a rise-to-width ratio greater than 1:5; Type II—Low-profile tile are tiles having a rise-to-width ratio equal to or less than 1:5; and Type III—All other tile, including flat. The standard also contains grade classifications for tile based on tiles’ resistances to “frost action”: Grade 1—resistance to severe frost action; Grade 2—resistance to moderate frost action; and Grade 3—negligible resistance to frost action. See Figure 3.

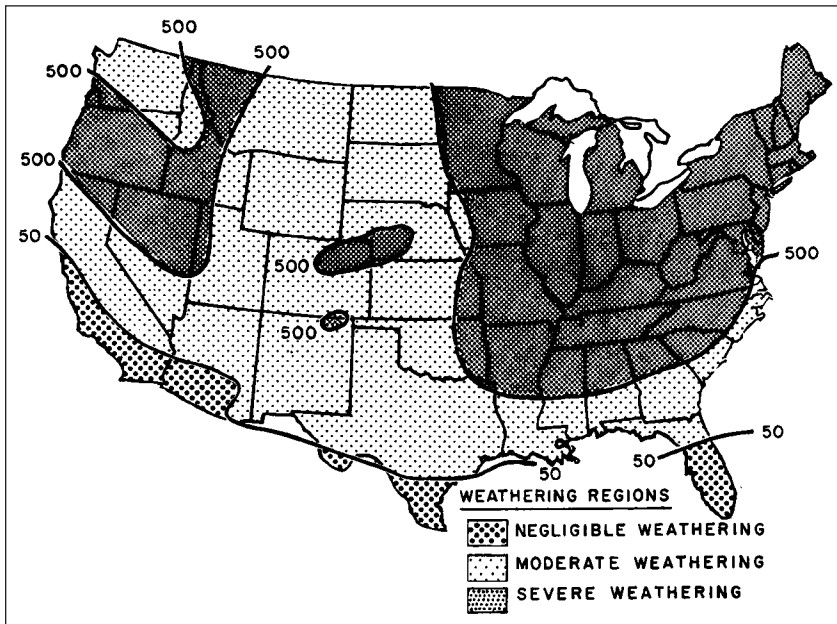


Figure 3: Frost action map

- ASTM C 1492, “Standard Specification for Concrete Roof Tile.” This standard addresses material characteristics and physical properties and establishes sampling procedures for concrete roof tile. ASTM C 1492 contains type classifications for tile based upon the tiles’ profile: Type I—High Profile Tile; Type II—Medium Profile Tile; Type III—Low Profile Tile; and Type IV—Accessory Tile, which includes those tiles such as ridge, rake, hip and valley tile used in conjunction with those tile defined as Type I, Type II or Type III.

NRCA recommends designers specify clay roof tile in accordance with ASTM C1167 and concrete roof tile in accordance with ASTM C1492.

## 2.2 Underlayment

NRCA recommends the use of underlayment with tile roof systems. An underlayment is applied over a roof deck prior to the application of roof tile. An underlayment performs two primary functions: it provides temporary weather protection until the tile is installed, and it provides a secondary weatherproofing barrier should moisture migrate below the tile. The water-shedding capability and relative resistance to water migration differs between tile roof system types. In many instances, the underlayment is considered an integral part of tile roof system and performs a more significant role in protecting a building structure from moisture intrusion.

In addition, underlayment generally is necessary for the following reasons:

- to comply with local building codes
- to help prevent dust, dirt and insects from entering the building

There are different underlayment configurations that can be used for tile roof systems. Generally, these configurations can be categorized as follows:

- single layer of underlayment
- single layer of self-adhered membrane
- double layer of underlayment
- two-ply membrane underlayment system, where the first ply is fastened and the second is adhered in bitumen

### **2.2.1 Asphalt-saturated Felt**

Asphalt-saturated felt underlayment is the most common underlayment used in steep-slope roof systems and typically used as an organic reinforcing mat.

The weatherproofing material used to manufacture roof underlayment felt is asphalt flux. Asphalt flux is obtained from the fractional distillation of petroleum that occurs toward the end of the petroleum refining process. Asphalt flux is sometimes further refined by air blowing to produce roofing-grade asphalt at the refinery or product manufacturer's facility.

Depending on the type of underlayment, asphalt may be used in two separate processes: first as a saturant, and second as a coating.

**Saturant grade asphalt**—The asphalt used in the saturation process is a “soft,” less viscous asphalt than coating asphalt and is used to impregnate an organic reinforcing mat. The saturant grade asphalt has a lower melting point than coating-grade asphalt. Common underlayments, such as No.15 and No. 30, are asphalt-saturated felts.

**Coating grade asphalt**—If a felt underlayment is a coated felt, a coating grade asphalt is applied to the felt after the saturation process. Coating asphalt is more viscous than saturant asphalt. Mineral additives, or “fillers”, are added to coating asphalt to stabilize the bitumen and reduce its natural flow characteristics and increase fire resistance and weatherability, to make the bitumen more suitable as a coating material.

Underlayment is reinforced with a mat that is designed to carry or support the asphalt. Reinforcing mats of different thicknesses are used to produce underlayments of different weights. These reinforcements, sometimes referred to as carriers, are most commonly made out of organic fibers. However, some underlayments are produced that use a reinforcing mat made of glass fibers.

- **Organic Mats**

During the past years, organic mat has been produced from various combinations of cotton rag, wood fiber and other cellulose fibers. Currently, wood and other cellulose fibers are the types of reinforcements most widely used in organic mats. Organic mats then are saturated with a soft, saturant-grade asphalt intended to fill voids between fibers.

- **Glass Fiber Mats**

Glass fiber mats are composed of inorganic, glass fibers. The fibers may be continuous or random and are bonded together with plastic binders or resin. Additionally, these glass fiber mats may be further reinforced with chopped glass fiber strands. The mats are then coated with asphalt. These fiberglass-reinforced felt underlayments differ from perforated glass fiber plysheets used in bituminous, low-slope roof systems.

- **Polyester or Synthetic Mats**

Although not as common, some underlayments now are available which use synthetic fibers, such as polyester, for the reinforcing mat.

# INTRODUCTION

The Architectural Sheet Metal and Metal Roofing section is written to provide in-depth technical information concerning the design and installation of sheet-metal components and architectural and structural metal panel roof systems.

Roofs can generally be divided into two categories: low-slope and steep-slope. The incline, or slope, of a roof determines which of these categories a particular roof falls. *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, defines these categories as follows:

Low-slope roofs: a category of roofs that generally include weatherproof membrane types of roof systems installed on slopes at or less than 3:12 (14 degrees).

Steep-slope roofs: a category of roofs that generally include watershedding types of roof systems installed on slopes exceeding 3:12 (14 degrees).

In some instances, roof systems designed for low-slope applications are used when roof slopes are greater than 3:12 (14 degrees). Some steep-slope roofing materials are used when roof slopes are less than 3:12 (14 degrees). For either application, it is important to realize certain design modifications may be necessary.

Low-slope roof systems usually employ a weatherproof covering or membrane to keep water from entering the structure. Some examples include but are not limited to built-up roof membranes, polymer-modified bitumen sheet membranes, thermoplastic and thermoset single-ply membranes, spray polyurethane foam-based (SPF) roof systems and some metal panel roof systems.

Steep-slope roof systems are generally watershedding rather than weatherproof. They are typically composed of many individual pieces or components installed in a shingled fashion. Watershedding roof systems function with gravity to shed water from one course to the next, thereby draining roof surfaces. Asphalt shingle, clay and concrete tile, slate, wood shake and shingle, metal shingles, synthetic products, some metal panel roof systems and fiber cement products fit this category.

A roof is composed of several primary parts, and collectively these parts are referred to as either a “roof assembly” or “roof system.” *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, defines these terms as follows:

Roof assembly: an assembly of interacting components including a roof deck, vapor retarder (if present), roof insulation and roof covering.

Roof system: a system of interacting roof components, generally consisting of a membrane or primary roof covering and roof insulation (not including the roof deck) designed to weatherproof and sometimes improve the building's thermal resistance.

In general, a roof assembly consists of a structural roof deck and roof system. A roof system includes every component above the roof deck.

Roof assemblies are designed in one of two basic configurations: compact “warm” roofs or ventilated “cold” roofs.

- Compact, or “warm,” roof designs are configured with each component of the roof assembly placed in contact with the preceding component. For example, the roof insulation is placed directly on top of the deck (or vapor retarder), and the roof covering is applied directly on top of rigid insulation. The term “compact” is given to these systems because each component is in immediate contact with the adjacent component—the assembly is thus compact—with no space provided for ventilating the roof assembly.
- Ventilated, or “cold,” roof designs are configured with insulation located below the deck, allowing for a ventilation space. In steep-slope roof assemblies, this space or cavity for ventilation generally occurs in the space above an insulated ceiling assembly and below the deck. In ventilated roof designs, the temperature of the roof covering and the deck is intended to remain close to the outside air temperature. In some climates, the outside air temperature may be colder than the temperature inside the building for most months of the year—thus the term “cold” roof.

Architectural metal panel roof systems are used in steep-slope roof systems; structural metal panel roof systems are used in steep-slope and low-slope roof systems.

The information contained in the Architectural Sheet Metal and Metal Roofing section is intended to primarily address new construction roofing situations. When considering reroofing projects, the Reroofing section of this manual should be consulted regarding the decision to re-cover or remove existing roof systems and for general information applicable to the reroofing of metal panel roof systems. Once a decision to re-cover or remove existing roof systems is made, most of the information contained with the Architectural Sheet Metal and Metal Roofing section also applies to reroofing.

Because of the wide variety of roofing products, this manual cannot address all the different methods and practices for designing and installing all the products available to designers, contractors and building owners.

In this manual, the National Roofing Contractors Association (NRCA) attempts to present a consensus of opinion from professional roofing contractors throughout North America as to the principles of good roofing practice. Where this manual provides specific suggestions or recommendations, it should be noted that these may take a more conservative approach than may be commonly provided by individual product manufacturers, roof system designers or roofing contractors. The roof design and application procedures included in this manual generally are recognized to be sound and time-proven and apply throughout North America.

The recommendations contained in the Architectural Sheet Metal and Metal Roofing section should not be construed as the only methods for designing and installing architectural sheet metal and metal roof systems. Some design criteria and application techniques vary according to climatic conditions and some geographical areas employ “area practices” that are sound and time-proven. NRCA does not mean to imply by any statement or exclusion that time-tested and proven area practices are unsatisfactory. Users of this manual are encouraged to contact NRCA members in their geographical areas for specific advice concerning area practices and current technical information.

This information represents a consensus opinion of professional roofing contractors throughout North America. Some design criteria and application techniques may vary according to climatic conditions, and each geographical area may employ “area practices” that are sound and time-proven. NRCA does not mean to imply by any statement or exclusion that proven area practices are unsatisfactory.

Roofing technology continues to change. New and ongoing research is expanding the industry’s knowledge of roof assemblies, including design and installation. Readers are encouraged to contact NRCA members in their geographical areas for specific advice concerning area practices and current technical information.

The Architectural Sheet Metal and Metal Roofing section is composed of the following primary sections:

- **Fundamentals of Metal Used for Roofing.** This section provide an overview of roofing metals and contains detailed information about metal types and characteristics, gauges/thicknesses of metals, protective coatings used with metals, standards applicable to metal and galvanic reaction of dissimilar metals.
- **Architectural Sheet Metal.** This section contains information about metal used as accessory materials with roof systems, such as flashing metals, counterflashings and edge metals. It also contains information addressing cleats, clips, fasteners, copings, gutters and downspouts, scuppers, perimeter edge metal, counterflashing, expansion and control joints, and joinery.
- **Fundamentals of Metal Panel Roof Systems.** This section has information about metal used in a roof systems, as well as system types, panel configurations, seam types, seaming methods, panel lengths and widths, common substrates, underlayments and slip sheets, vapor retarders, and panel application and flashing. It also contains considerations for expansion and contraction, slope and drainage, on-site panel storage, hoisting panels, oil-canning and wind.
- **Architectural Metal Panel Roof Assemblies.** This section contains design considerations and application information for metal roof panels used for architectural roof systems; that is, systems that require continuous or closely spaced decking and are typically considered watershedding, not water-barrier systems. Architectural metal panel roof systems are generally used for steep-slope applications.
- **Structural Metal Panel Roof Systems.** This section contains design considerations and application information for metal roof panels used for structural systems; that is, systems in which the roofing panels are capable of spanning supports and designed to be water-barrier, not watershedding systems. Structural metal panel roof systems are generally used for low-slope applications.

NRCA suggests the Architectural Sheet Metal and Metal Roofing section be used in the design of architectural and structural metal panel roof systems and sheet-metal components only after a number of criteria have been carefully considered, including:

- Climate
- Exterior and interior temperature and humidity conditions
- Building and roof life expectancy
- Type of roof deck and load-bearing capacity
- Building code requirements
- Slope and drainage

- Thermal requirements
- Fire, wind and impact resistance

These criteria play important roles in the ultimate success or failure of every roof assembly and must be considered by the designer to determine the appropriate components of the roof assembly, applicable specifications and construction details to be used.

In addition, the designer should be certain roofing product manufacturers' requirements are taken into account, as well as requirements of any applicable insurance, building code enforcement and other regulatory agencies.

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# Architectural Sheet Metal and Metal Roofing

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## **1. FUNDAMENTALS OF METALS USED FOR ROOFING**

### **1.1 Introduction**

A wide variety of metals and metal alloys are available for the fabrication of roofing panels and accessories. The variety of metals used in roofing can be divided into two main types: those that are naturally weathering, and have surfaces that possess or develop a layer of protection upon exposure to the elements and those that require a protective coating. Metals that are naturally weathering include aluminum, copper, lead, lead-coated copper, stainless steel, terne-coated stainless steel and zinc. Metals that use a base layer of carbon steel require a coating of paint or other metals, such as aluminum (aluminized steel) or zinc (galvanization), for corrosion protection. Selection of the metal type depends on such factors as expected performance, suitability, compatibility, economics, degree of desired corrosion-resistance and aesthetics.

Historically, copper, lead and lead-coated copper sheets used for roofing have been considered nonstructural, that is, used for architectural metal panel roof systems and therefore require continuous or closely spaced decking. All current metal types used in roofing applications can be incorporated as part of an architectural metal panel roof system; only steel, either carbon or stainless, and aluminum panels are currently used as part of a structural metal panel roof system. For more information about architectural and structural metal panel roof systems, See Section 3, “Fundamentals of Metal Panel Roof Systems.”

### **1.2. Naturally-weathering Metals**

All metals oxidize with weather exposure; however, some oxides offer excellent protection of the base metal for extended periods of time, others do not. For a metal to be considered a naturally weathering metal, the base metal itself must be able to form its own protective layer by oxidation sufficient to withstand environmental exposures common to roofs. Metals that successfully withstand long-term weather exposure will develop oxidation layers that are durable and well-bonded to the base metal with minimum porosity and minimum solubility in water. Some naturally weathering metals will out-perform others in specific environments or geographic locations, such as urban, industrial, marine or locations subject to specific chemical corrosion. It is important the type of metal chosen is appropriate for the specific environment in which it is installed.

The most common types of naturally-weathering metals are:

- aluminum
- copper
- lead
- stainless steel
- zinc

Also available are naturally weathering metals that are coated with another metal. These metals are:

- lead-coated copper
- terne-coated stainless steel

In some instances, the weathering of metal and subsequent oxidation result in a different appearance altogether that may be aesthetically desirable. A good example of this is copper, which, depending on atmospheric conditions and exposure to moisture, over time typically develops a characteristic brown or blue-green patina.

Also, a naturally weathering metal may be coated with another naturally weathering metal or paint, such as a pre-painted aluminum, lead-coated copper and terne-coated stainless steel, to provide a material that is more suitable to a specific environment or aesthetically more appealing.

#### **1.2.1 Aluminum**

The minimum nominal thickness used for aluminum roof panels is 0.032 inch (0.8 mm), although 0.040 inch (1 mm) is used when a greater span is required or to minimize the effects of oil-canning. For accessory sheet-metal and flashing components, common thicknesses range from 0.032 inches to 0.050 inches (0.8 mm to 1.3 mm). However, aluminum is also available in 0.063-inch (1.6-mm) thickness.

Aluminum develops a thin oxide film on the surface that is impermeable to most airborne contaminants except strong alkalis and acids. For this reason, it is not recommended to use aluminum as an in-wall flashing embedded in concrete or masonry, which have a high alkaline content, unless the aluminum is protected by a thick layer of bituminous paint or other material that can isolate it from the contaminant.

Aluminum has a substantially higher coefficient of expansion than any other roofing metal except zinc. Refer to Figure 2.27, “Expansion Coefficients of Common Building Materials,” in Section 2, for information about expansion coefficients. Detailing and attachment must be designed to handle the anticipated thermal movement.

Various aluminum alloys are available. Some alloys have greater rigidity and strength for panel and flashing use but may fracture when sharp bends are formed. This may be avoided by the use of radius bends. The most common aluminum alloy used for architectural sheet goods and flashing metal is 3003-H14, which has good formability.

- 3003 is an aluminum alloy with 1.2 percent manganese and exhibits a tensile strength range of 17,000 psi to 30,000 psi (117,000 kPa to 207,000 kPa). It has excellent workability, weldability and corrosion resistance and is used for sheet-metal work and other applications where slightly higher strength is required.
- 5005 is an aluminum alloy with 0.8 percent manganese and exhibits a tensile strength range of 18,000 psi to 30,000 psi (124,000 kPa to 207,000 kPa). It has excellent workability, weldability and corrosion resistance. It is specified for applications comparable to 3003, where anodizing is required.

Aluminum provides a lightweight, easily formed panel that does not require protective coatings for most exposures. It is readily available with pre-painted finishes or anodic coatings. Extruded aluminum can be used for perimeter edge metals and other sheet-metal roof accessories.

### 1.2.2 Copper

Copper does not require a protective finish. Copper’s appearance typically changes during its exposure to the elements; however, this change is dependent upon geographic and atmospheric conditions, such as exposure to moisture and air pollutants. Over a period of time, copper develops a brown or blue-green color, referred to as patina, resulting from the formation of a protective layer of copper sulfate. Generally, within the first two months to four months of exposure, copper’s bright finish gives way to a dull dark brown. In approximately three years, a green patina will become noticeable, and at seven to 20 years, this patina will be the copper’s predominant color. In some arid locations or locations with low levels of air contaminants, the time it takes for copper to begin to develop a patina may be much longer. The position of the metal, or slope of the roof, can also affect the development of the patina. In some regions of the country and on vertical surfaces or soffits, copper may never turn green.

Some manufacturers of copper have methods and suggestions for pre-patinaing copper panels. Consult the manufacturer for specifics. There are also field methods that may provide rapid patinaing; however, the resulting color can vary significantly.

The copper alloy used for roofing is alloy 110, which is 99.9 percent pure copper. Bronze is a copper alloy containing 10 percent zinc, and brass, another copper alloy, contains 15 percent or more zinc. Copper is commonly designated by weight, not gauge. For roofing applications, both 16 ounces and 20 ounces per square foot (4.9 kg/m<sup>2</sup> and 6.1 kg/m<sup>2</sup>) copper are common. For flashings, 16 ounces, 20 ounces, 24 ounces and 32 ounces per square foot (4.9 kg/m<sup>2</sup>, 6.1 kg/m<sup>2</sup>, 7.3 kg/m<sup>2</sup> and 9.7 kg/m<sup>2</sup>) copper are common.

Copper is one of the more malleable metals and is available in various tempers, or ranges, of hardness. For example, soft copper is used where a high degree of formability is required, but it is easily dented. Cold-rolled copper in the ½ to ¾ hard temper range is recommended for roll forming because of its resistance to stretching. Cold-rolled copper in the ⅙ to ¼ hard temper range is used for most sheet-metal flashings and brake-formed roof panels. Because of its softness, copper is not recommended for structural applications.

Water run-off from copper can visibly stain light-colored building materials, such as concrete, brick and stone. In these cases, lead-coated copper might be used; however, lead run-off can stain dark-colored building materials.

### 1.2.3 Lead

Lead is used as a roofing accessory metal because of its workability. It is an extremely soft metal, can be formed by hand, and is very useful for flashing irregular shapes and junctures. For example, lead is commonly used in low-slope bituminous roof systems as a flashing material for interior roof drains and vent pipes.

Sheet lead has little structural strength or puncture resistance and must therefore be installed over solid surfaces. Sheet lead is commonly designated by weight, not gauge, from 1 pound to 8 pounds per square foot (4.9 kg/m<sup>2</sup> to 39.0 kg/m<sup>2</sup>). A weight range of 2 pounds to 4 pounds per square foot (9.8 to 19.5 kg/m<sup>2</sup>) is typical for roofing applications, but heavier weights may be desirable for soldering purposes.

### 1.2.4 Lead-coated Copper

Lead-coated copper is copper in sheet or coil form, coated either on one or both sides with lead. The lead coating is applied to the copper by hot dipping or electro-deposition in a plating bath. Lead coating applied in a hot-dip process

will provide a less uniform and more rough appearance.

Lead-coated copper was developed in the early 1900s to provide a roofing and flashing material with the appearance and corrosion-resistant characteristics of lead but with less cost and weight than lead alone. Lead-coated copper has greater tear resistance than lead. Water run-off from lead-coated copper will produce a light to dark gray stain.

For roofing applications, both 16 ounces and 20 ounces per square foot (4.9 kg/m<sup>2</sup> and 6.1 kg/m<sup>2</sup>) lead-coated copper is available. For flashings, 16 ounces, 20 ounces, 24 ounces and 32 ounces per square foot (4.9 kg/m<sup>2</sup>, 6.1 kg/m<sup>2</sup>, 7.3 kg/m<sup>2</sup> and 9.8 kg/m<sup>2</sup>) lead-coated copper is typically used. Normally, cold-rolled copper is used for lead coating. Specifiers should recognize there will be a slight loss of temper induced during the lead-coating process of the copper. When naturally weathered, it gradually darkens into a soft gray color.

Two classifications for lead-coated copper are common. Class A provides a 12-pound to 15-pound (5.5-kg to 6.8-kg) lead coating, and Class B provides a 20-pound to 30-pound (9.1-kg to 13.6-kg) lead coating. In both classes, the weight of the coating designated is the total weight of lead applied to two sides per 100 square feet (9.3 m<sup>2</sup>) of copper sheet. Approximately one-half of the coating is applied to each side of the sheet. For Class A, which is recommended for general application, the average coating thickness is approximately 0.002 inches to 0.003 inches (0.05 mm to 0.08 mm) of lead. Class B is used for more industrial atmospheres or other severe environments such as polluted urban areas.

### 1.2.5 Stainless Steel

Stainless steel is a durable, corrosion-resistant material. It is often used in harsh environments that would harm other metals or paint finishes. It is also used when a nonweathering finish is desired. It generally will not stain adjoining materials.

Stainless steel is an alloy. Chromium, nickel, manganese and sometimes molybdenum are added to the base steel for corrosion resistance. Chromium is the essential ingredient and composes a minimum of 11.5 percent of the product in any of the 38 standard stainless steel alloys. Obtaining sheet stock or coil that is dead flat and true is more difficult with stainless steel than with many other metals. Tension leveling to flatten and true the stock is recommended.

For roof applications, sheet-metal flashing and roof panel fabrications, 300 series stainless steel material is preferred. Types 302 and 304 are the most common. Type 302 stainless steel is 18 percent chromium and 8 percent nickel, which gives it high corrosion resistance. Type 304 stainless steel is similar to Type 302 except it has a lower carbon content, making it more suitable for welding. Types 302 and 304 are considered interchangeable for many roofing purposes, and many specifications will indicate either type is acceptable. Type 316 stainless steel has molybdenum added, which increases resistance to pitting and corrosion in harsh environments, such as coastal or industrial areas.

For roof panel applications, 24 gauge, 26 gauge, and 28 gauge (0.024 inch, 0.018 inch and 0.015 inch thick [0.61, 0.46, and 0.38 mm], respectively) stainless steel is common. For flashings, 24 gauge (0.024 inch thick [0.64 mm]) is common. A fully annealed or standard annealed temper is commonly used for ease of forming.

Stainless steel is available in a number of different mill finishes, from dull matte to highly polished. For high-visibility applications, different types of stainless steel finishes can be used for aesthetic effect without causing compatibility problems. For roofing and sheet-metal applications, the most common finishes are designated 2B and 2D. The 2B finish is a bright, cold-rolled finish that is highly reflective; 2D is a dull finish that is less reflective and more conducive to soldering.

### 1.2.6 Terne-coated Stainless Steel

Terne-coated stainless steel is a Type 304 stainless steel base metal, coated on both sides with a thin coating of zinc and tin. Historically, terne-coated stainless steel was coated with lead and tin, but that product is no longer manufactured. Unlike terne metal, which requires a coating of paint, the terne coating is applied to enhance corrosion resistance and provide a natural weathering gray color. Terne-coated stainless steel does not require painting. Consult manufacturers' requirements for painting terne-coated stainless steel. Terne-coated stainless steel is marketed in 0.015 inch, 0.018 inch and 0.024 inch (0.38 mm, 0.46 mm and 0.61 mm) thicknesses, which are equivalent to 28 gauge, 26 gauge and 24 gauge thicknesses, respectively.

### 1.2.7 Zinc

Zinc is a natural, self-healing metal that weathers to a soft blue-grey patina. Zinc is a metal alloy used as an exterior building material. This soft architectural metal offers a combination of aesthetics, design flexibility, malleability and durability. Available in bright-rolled (initially similar to polished stainless steel) and preweathered surfaces, zinc reacts with the environment to produce a zinc carbonate patina that protects the underlying metal from corrosion. The

patina formation takes approximately 2 years to 5 years.

Zinc has been used for rainwater drainage components, roof coverings and wall cladding. Zinc can be folded, roll-formed, pressed, stretched and soldered to produce a wide variety of panels, shapes and accessory fittings. In addition, exterior building materials should not be stained when exposed to storm water runoff over zinc.

Zinc used for architectural applications contains 99.8 percent high-grade zinc (99.995 percent pure) alloyed with small amounts of copper and titanium (approximately 0.1 percent each by weight) for improved physical properties. Current zinc formulations for architectural applications are actually termed “titanium zinc” but are referred to generically as “zinc.” Compared to previous zinc alloys, current zinc alloys are monolithic metals that have a lower coefficient of expansion (less than aluminum), improved tensile strength and improved cold-weather formability. Architectural zinc is available in 0.7-mm (0.028-inch [24 gauge]) and 0.8-mm (0.031-inch [22 gauge]) thicknesses and is suitable for most roofing applications. Produced in 1-meter (39.4 inches) wide sheets, zinc is available in standard 10-foot (3.048-m) lengths, custom lengths or coils for roll-formed profiles.

For roof applications, ventilation of the zinc underside is standard practice and necessary for durability. Standing-seam roof applications require the zinc sheet to be elevated above the underlayment with a capillary break, such as a tangled mesh ventilation mat. This flat-panel installation practice ensures the bottomside of the zinc panel will not be in contact with trapped moisture. Flat-lock zinc shingles create an air space inherently and may not require additional separation. As an alternative to ventilation, bottomside-coated zinc is available for roof panels, shingles or edge-metal details that do not provide adequate ventilation or a capillary break. As with most roof covering materials, adequate slope is important for vertical seam panels and flat-seam shingles to minimize any potential for ponding water and hydroxide formation.

It is important to avoid contact with copper and copper runoff at all times. Red rosin paper, wet mortars and cement, and acidic sealants should not be in contact with zinc. Rainwater runoff from certain wood species, such as red cedar, larch and chestnut can also cause adverse reactions. Generally, zinc needs a solid substrate, a working metal temperature greater than 48 F (9 C) during field fabrication to prevent fracturing, and inside corner cuts to punched holes to avoid tearing. When working with zinc, it is necessary to have an understanding of the material to effectively fabricate and install zinc on a roof or wall.

### **1.3 Metallic-coated Steels**

Of the wide variety of metals used in the manufacture of metal roof panels and sheet-metal roof accessories, metallic-coated carbon steel is the most prevalent. This category of roofing metal is composed of metal types that contain a base layer of carbon steel to which a corrosion-resistant metallic coating is applied.

The most common types of metallic-coated carbon steels are:

- aluminized steel (steel coated with aluminum)
- Galvalume® (steel coated with an aluminum-zinc)
- galvanized steel (steel coated with zinc)
- terne metal (steel coated with a lead and tin or zinc and tin alloy)

The characteristics most commonly associated with steel are its strength and susceptibility to corrosion, the former being its greatest asset and the latter its most prominent liability. Corrosion results from the steel reacting with oxygen and reverting to its naturally oxidized state. Corrosion is generally undesirable for two reasons: performance and appearance. The primary purpose of metallic coatings is to protect the steel from environmental conditions and thereby reduce the chance of rapid oxidation. Metallic coatings of aluminum, lead, tin, zinc or a combination of these accomplish this in two ways: sacrificial protection and barrier protection. At the same time the coating forms a barrier between the base steel and the environment, it also provides sacrificial protection by oxidizing first.

Depending on climatic and environmental conditions, metallic-coated carbon steels commonly use an additional protective finish (e.g., a paint system) to provide extended corrosion resistance. Paint systems also provide aesthetic qualities with many paint types and colors available. Metallic coatings may also provide aesthetic qualities and enhance reflectivity, which also serves to reduce heat buildup.

#### **1.3.1 Aluminized Steel**

Unlike galvanized steel, aluminized steels rely almost solely on the aluminum’s ability to act as a barrier for protecting the base steel. Sacrificial protection is only provided in the presence of chloride ions, such as those found in marine environments. Unlike zinc, aluminum oxide is virtually inert under normal conditions, which means it reacts little with other elements and typically is not water-soluble, thus it does not self-heal. This means the protection provided by aluminum is not directly proportional to the thickness of the coating. A total of 0.65 ounce per square foot (198

g/m<sup>2</sup>) of aluminum, total both sides, is normally used, which is about 1.4 mils (0.04 mm) per side. The durability of aluminized sheet steel varies with the severity of the environment in a similar but less pronounced manner than galvanized steel.

The most common thickness used in roofing is 24 gauge (0.025 inches [0.64 mm] thick). Lighter gauges (e.g., 26 gauge [0.019 inches (0.48 mm) thick] may be applicable for architectural metal roof applications over continuous or closely spaced decking. Heavier gauges, such as 22, 20, 18, and 16 gauge (0.031 inches, 0.038 inches, 0.050 inches and 0.063 inches [0.79 mm, 0.97 mm, 1.27 mm and 1.60 mm] thick), are sometimes used for structural metal panel applications where extended spanning abilities or performance is desired or for structural members such as purlins. Seaming of heavier gauge roof panels may not be possible.

Aluminized steel has an appearance known as a matte finish without a visible spangle, which is a random geometric pattern associated with galvanizing that resembles frost on a window. This finish has a relatively high level of initial reflectivity.

### 1.3.2 Galvalume®

Galvalume® is another type of metallic coating commonly used for steel roof panels. This proprietary alloy coating is reported to be 55 percent aluminum and 45 percent zinc by weight. Because of its composition, Galvalume® protects steel sacrificially and as a barrier. The zinc phase of the coating will sacrifice itself to protect the base steel, and the aluminum phase provides a barrier. For roofing applications, a minimum of 0.55 ounces per square foot (168 g/m<sup>2</sup>) of aluminum-zinc alloy of coating, having a 0.9 mil (0.02 mm) thickness per side, is common.

The most common thickness used in roofing is 24 gauge (0.025 inches [0.64 mm] thick). Lighter gauges (e.g., 26 gauge [0.019 inches (0.48 mm) thick]) may be applicable for architectural metal roof applications over continuous or closely spaced decking. Heavier gauges, such as 22 gauge, 20 gauge, 18 gauge, and 16 gauge (0.031 inches, 0.038 inches, 0.050 inches and 0.063 inches [0.79 mm, 0.97 mm, 1.27 mm and 1.60 mm] thick), are sometimes used for structural metal panel applications where extended spanning abilities or performance is desired or for structural members such as purlins. Seaming of heavier gauge roof panels may not be possible.

Galvalume® has a matte hue, sometimes with a lightly visible spangle, which is a random geometric pattern associated with galvanizing that resembles frost on a window. This finish has a relatively high level of initial reflectivity.

### 1.3.3 Galvanized Steel

Galvanized steel is one of the oldest and most common metallic-coated metals. Although the zinc coating extends the weatherability of the base steel, it is generally not considered adequate by itself for providing long-term service life for a carbon steel-based roof system.

Coating weights for galvanized sheet vary but for roofing applications they are typically 0.90 ounce (G-90) of zinc per square foot (275 g/m<sup>2</sup>), total both sides. The coating is a little less than 1 mil (0.03 mm) per side. Galvanized steel of equal coating weights will oxidize at different rates depending on the environment. Environmental factors include the duration and frequency of moisture contact, the rate at which the surface dries, the saline content of the moisture and the extent of industrial pollution. The more severe the conditions, the more rapid the loss of zinc, which means a more rapid loss of protection.

The most common steel thickness used for roofing is 24 gauge (0.025 inches [0.64 mm] thick). Typically, 24 gauge (0.025 inch [0.64 mm] thick) steel is strong enough for structural applications and thick enough to produce a panel that does not exhibit an objectionable amount of oil-canning. Panels and accessories are commonly made from 24 gauge (0.025 inches [0.64 mm] thick) steel. Heavier gauges, such as 22 gauge, 20 gauge, 18 gauge and 16 gauge (0.031 inches, 0.038 inches, 0.050 inches and 0.063 inches [0.79 mm, 0.97 mm, 1.27 mm and 1.60 mm]), are sometimes used for accessories, structural members such as purlins, or structural metal panel applications where extended spanning abilities or performance is desired. Seaming of heavier gauge roof panels may not be possible. Lighter gauges (e.g., 26 gauge [0.019 inches (0.48 mm)] thick) may be applicable for architectural metal roof applications over continuous or closely spaced decking. Refer to Section 1.8 for more information about oil-canning.

Galvanized steel typically has the familiar bold spangle which is a random geometric pattern associated with galvanizing that resembles frost on a window which can be minimized. This finish has a relatively high level of initial reflectivity.

### 1.3.4 Terne Metal

Terne metal is a carbon steel-based metal, coated on both sides with a thin coat of zinc and tin. Historically, terne metal was coated with lead and tin, but that product is no longer manufactured. The coating is not applied solely with the intention of protecting the steel, but also to serve as a paintable surface and allow for ease of soldering. If not

painted soon after application, terne metal may rust rapidly in most environments. Terne metal is commonly used in 26 gauge, 28 gauge and 30 gauge (0.018 inches, 0.015 inches, and 0.012 inches [0.46 mm, 0.38 mm and 0.30 mm]) thicknesses and is not suitable for structural metal roof applications. Terne metal is not recommended for applications where high internal humidity is present because moisture migration may cause rust on the typically unpainted undersides of the panels.

Terne metal with a lead and tin coating must be painted on all exposed surfaces with a linseed oil-based paint. Terne metal with a zinc and tin coating can be painted on all exposed surfaces with either a linseed oil-based paint or acrylic emulsion based paint. Manufacturers painting requirements and paint specifications should be consulted for each terne metal product, as well as the manufacturers' requirements regarding the painting of the underside of the terne metal.

## **1.4 Standards Applicable to Metal**

### **1.4.1 Aluminum, Extruded**

ASTM B 221/B 221M, "Standard Specification for Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes." Among other properties, this standard addresses the following: tensile properties, chemical composition, heat treatment and response, stress-corrosion resistance, exfoliation-corrosion resistance, dimensional tolerances and internal quality.

### **1.4.2 Aluminum, Non-extruded**

ASTM B 209/B 209M, "Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate." Among other properties, this standard addresses the following: chemical composition limits, tensile properties, heat treatment response, bend properties, stress-corrosion resistance, exfoliation-corrosion resistance, cladding, dimensional tolerances and internal quality.

### **1.4.3 Aluminum/Zinc (Galvalume®)**

ASTM A 792/A 792M, "Standard Specification for Steel Sheet, 55 percent Aluminum-Zinc Alloy-Coated by the Hot-Dip Process." Among other properties, this standard addresses the following: chemical composition limits, coating weights, minimum bend tolerances, yield strength, tensile strength, elongation and tensile properties.

### **1.4.4 Copper**

ASTM B 370, "Standard Specification for Copper Sheet and Strip for Building Construction." Among other properties, this standard addresses the following: tempers, grain size, and dimensions, weights and permissible variations.

### **1.4.5 Galvanized Steel**

ASTM A 361/A 361M, "Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process for Roofing and Siding." Among other properties, this standard addresses the following: chemical composition, coating requirements, and dimensions and tolerances.

ASTM A 653/A 653M, "Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process." Among other properties, this standard addresses the following: chemical composition, coating requirements, and dimensions and tolerances.

ASTM A 924, "Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process." This standard addresses the following: strength levels, heat resistance, paintability and formability.

ASTM A 1008, "Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable." Among other properties, this standard addresses the following: chemical composition, mechanical properties, and finish and appearance.

### **1.4.6 Lead-coated Copper**

ASTM B 101, "Standard Specification for Lead-Coated Copper Sheets." Among other properties, this standard addresses the following: cold-rolled and soft lead-coated copper, weight classifications (A and B), thicknesses of lead coating and general exposure suggestions.

### **1.4.7 Stainless Steel**

ASTM A 167, "Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip." Among other properties, this standard addresses the following: heat treatment, chemical composition,

mechanical properties, and dimensions and tolerances.

ASTM A 240, “Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Application.” Among other properties, this standard addresses chemical composition and mechanical properties.

#### **1.4.8 Terne**

ASTM A 308, “Standard Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process.” Among other properties, this standard addresses the following: chemical composition, mechanical properties, coating tests, and dimensions and tolerances.

## 1.5 Metal Gauge, Thickness and Weight Information

Figure 1.1 shows the commonly available gauges and thickness of metals, as well as the approximate weight per square foot for each. These metals have allowable tolerances for gauge, thickness and weight. Designers should be aware of these tolerances when specifying these products.

Metal	Gauge	Nominal Thickness (inches)	Approximate Pound per Square Foot (lb/ft <sup>2</sup> )	Nominal Thickness (mm)	Approximate Kilogram per Square Meter (kg/m <sup>2</sup> )
Aluminum		0.024	0.35	0.64	1.72
		0.032	0.45	0.81	2.20
		0.040	0.57	1.02	2.75
		0.050	0.70	1.27	3.50
		0.063	0.89	1.63	4.40
Copper 16 oz. 20 oz. 24 oz. 32 oz.		0.022	1.00	0.56	4.87
		0.027	1.25	0.69	6.10
		0.032	1.50	0.81	7.31
		0.043	2.00	1.09	9.77
Lead Sheets 4 lb. 3 lb. 2½ lb. 2 lb.		0.062	4.00	1.57	19.53
		0.047	3.00	1.20	14.65
		0.039	2.50	0.99	12.21
		0.031	2.00	0.79	9.77
Lead-coated Copper Sheets 16 oz. 20 oz. 24 oz. 32 oz.		0.026	1.17	0.66	5.21
		0.031	1.31	0.79	6.39
		0.036	1.54	0.91	7.51
		0.047	2.03	1.19	9.95
Stainless Steel	28	0.015	0.66	0.38	3.19
	26	0.018	0.79	0.46	3.84
	24	0.024	1.05	0.61	5.12
Steel*: Galvanized Steel Galvalume® Aluminized Steel	28	0.015	0.63	0.38	3.06
	26	0.019	0.91	0.48	4.42
	24	0.025	1.16	0.64	5.64
	22	0.031	1.41	0.79	6.85
	20	0.038	1.66	0.97	8.08
	18	0.050	2.16	1.27	10.51
Terne	26	0.018	0.80**	0.46	3.91***
	28	0.015	0.67**	0.38	3.27***
	30	0.012	0.54**	0.30	2.63***
Terne-coated Stainless Steel (TCS)	28	0.015	0.66	0.38	3.19
	26	0.018	0.79	0.46	3.84
	24	0.024	1.05	0.61	5.12
Zinc	24	0.020	0.75	0.51	3.66
	21	0.027	1.00	0.69	4.87

\* U.S. Standard Gauge  
 \*\* 40-lb. Coating weight  
 \*\*\* 88.2-kg Coating weight

Figure 1.1: Metal gauge, thickness and weight information

## 1.6 Protective Coatings

### 1.6.1 Paint Systems

Paint is frequently used to protect various types of base metal, as well as to enhance metals' appearance. Paints can be either factory- or field-applied. Although less common, field painting offers flexibility because a wide range of colors are available. When field painting, proper substrate preparation is critical to achieve proper adhesion. Use of a

galvannealed material, such as Paint-Loc® or Paint Grip®, greatly improves the ability for paint to adhere. The life expectancy of field-applied paints is shorter than factory-applied paints, and periodic repainting may be required. Factory-applied painting results in a much higher quality finish and, therefore, greater life expectancy. However, factory-applied customized colors may be difficult to obtain because of blending and pigment limitations. Custom colors may also be difficult to obtain with smaller quantity orders. Manufacturers should be consulted for specific requirements.

Paint systems used for metals may have limitations in corrosive locations or environments subject to coastal or chemical exposure. The manufacturer of a paint system type should be consulted about the paint's ability to withstand specific exposures.

The specified finish coat is typically only applied to the top (i.e., exposed) surface of the metal. A coating of paint, primer or wash coat is typically applied to the backside of a metal panel to enhance its resistance to potential corrosion from the underside.

Paint systems are characterized by the following performance measurements:

- exterior durability (fading and chalking resistance)
- adhesion (how well it bonds to the substrate)
- appearance
- hardness (scratch resistance)
- flexibility (which relates to formability of a coated metal)
- chemical and general corrosion resistance

Other considerations include the range of available colors, including customized colors and stain resistance, and fire resistance.

Paint may be factory-applied to individual panels before or after forming them to the required profile. If a finish is applied after forming, a spray application is typically used. If paint is applied before forming, continuous coil coating is most effective.

The advantages of coil coating are numerous, from both a productivity and quality standpoint. Like hot-dip metallic coating, coil coating is a continuous process. The head end of each coil is welded to the tail end of the previous one. The continuous strip is first cleaned to remove dirt and oil, and then the surface is chemically prepared for painting. A prime coat, approximately 0.2 mils (0.01 mm) thick, is applied and cured under heat. This is followed by a top coat approximately 0.8 mils (0.02 mm) thick, which is also cured. The coil-coating process will provide a superior product relative to the spray-applied coating process. Weather, crack, peel and fade resistance are typically better with coil-coated coatings than with spray-applied coatings.

A wax finish can be applied to facilitate roll forming. Factory-applied protective films can also be applied to protect the paint coating. These protective films should be removed before panel installation or immediately after the panel seaming process to prevent the films from bonding to the panels' surface after exposure to heat.

It is important to remember that spray-applied and coil-coat paint applications are different. This means the color and finish of one application type may not necessarily match the other.

There is a wide variety of available factory-applied paint systems, and some manufacturers have their own formulations for each. Two common types of these factory baked-on, paint-based systems are fluoropolymer and siliconized acrylic, or siliconized polyester.

### **1.6.1.1 Fluoropolymers**

Fluoropolymers are high-quality coatings that are chemically known as polyvinylidene fluoride (PVDF or PVF2) coatings. They are also known by the registered trade names Kynar 500® and Hylar 5000™. Care must be taken to distinguish between formulations of 70 percent and 50 percent resin content when specifying or ordering PVDF coatings. For metal roofing, a 70 percent PVDF resin content is commonly used. Reportedly, the 500 (Kynar) and 5000 (Hylar) designations prescribe a 70 percent resin content. In addition, fluoropolymer coatings are available in different thicknesses and gloss levels. The fluoropolymer coating is nominally 1.0 mil (0.03 mm) thick. For special applications, there are optional thicknesses available. There are also hybrid finishes, such as urethane Kynar composites. Coil-coating manufacturers should be consulted for specific information about finish warranties and coating formulations and the availability of specialized or custom finishes.

Fluoropolymer coatings can be applied to galvanized steel, Galvalume® or aluminum and have long-term weathering

characteristics. A well-formulated fluoropolymer coating is proving to be one of the better paint finishes used in architectural sheet metal and metal roofing applications. These coatings are reported to resist chalking, cracking and fading for up to 20 years depending on formulation and environment.

### **1.6.1.2 Siliconized Acrylic and Polyester**

Siliconized acrylics and polyesters, such as baked-on enamels, are widely used factory-applied paint systems for metal roof panels. Polyesters are organic polymers that are relatively hard and abrasion resistant. Durability varies depending on the specific formulation. Siliconized polyesters are polyesters modified by the addition of silicone, an inorganic substance. Silicone polyesters exhibit good durability for exterior use because of chalking resistance and gloss retention. These finishes offer good formability, heat resistance, color retention, and solvent and chalking resistance. Polyester and modified polyesters are applied as two-coat systems—prime and finish coat—having a total thickness of approximately 1.0 mil (0.03 mm) on the exposed side and approximately 0.5 mil (0.01 mm) on the back side. Depending on formulation and exposure, they resist chalking and fading for a moderate period of time.

### **1.6.1.3 Laminates**

Laminates are applied as a plastic film rather than a liquid. They are generally up to three times greater in thickness and generally more durable than liquid paint systems. They can be used with or without a liquid primer, depending on the metallic coating, and help eliminate problems of chalking, fading, chipping, peeling and other similar forms of degradation. Acrylic and fluorocarbon film laminates are the most common in exterior building applications. Laminates are also applied on coil coating lines; they are bonded to the metal under pressure and sometimes in the presence of heat. The remainder of the process is similar to coil coating with a liquid-applied finish system.

### **1.6.2 Pearlescent and Metallic Additives**

Paint systems using pearlescent and metallic additives are also available. These additives, which are small particles or chips of mica sometimes coated with titanium-dioxide or iron oxide or aluminum, are suspended in the paint coating. These types of additives can enhance the aesthetic characteristics of the prefinished metal by providing visual brilliance and color depth and dimension. Color variations can occur when viewed from different angles because of reflection differences and orientation of metal stock. A clear-coat finish commonly is used in conjunction with pearlescent or metallic additives. Consult with the coil stock supplier for more information about these types of additives.

### **1.6.3 Clear-coat Finishes**

Clear-coat finishes can be used with paint systems to extend the paint's color retention, fade resistance, appearance, depth of color and brilliance. Clear-coat finishes can increase the surface durability of a prefinished metal by offering further resistance to scratching or scuffing and can minimize fading or chalking of the paint during exposure; they may also offer increased corrosion resistance for the prefinished metal in certain exposures. However, clear-coat finishes may exacerbate the visual effects of oil-canning.

### **1.6.4 Anodizing**

One method of finishing aluminum metal is anodizing. Anodizing is an electrolytic process in which the base metal serves as an anode. Unlike paint or other liquid-applied coatings that bond to the surface, anodizing produces a relatively thick aluminum oxide film that becomes part of the aluminum sheet through an electrolytic reaction. Anodized aluminum resists abrasion, makes the surface of aluminum harder and increases corrosion resistance.

Anodizing can result in a clear or colored surface, although the color range is limited when compared to traditional paints. Also, anodized coatings can have noticeable shading variations within the same color. For this reason, it may be necessary to sort panels or flashing before installation so the shading variations can be uniformly distributed. Exterior finish anodizings are referred to as Class 1 coatings with a minimum thickness of 0.7 mils (0.02 mm). When anodized metal is brake-formed, hairline cracks in the anodized coating may occur. Designers should be aware that forming before anodizing can reduce the potential for hairline cracking. However, anodizing formed pieces is less efficient than anodizing sheet stock.

## **1.7 Galvanic Series**

Figure 1.2 shows part of the galvanic series for metals. The principle of the galvanic series is a more “active” metal will corrode when moisture and a more “noble” metal are present. The term “active” refers to electrode potential, which is greater in active metals than noble ones. For example, two metals that could be selected from the chart in Figure 1.2 are plain steel and zinc, which are used for galvanized steel. When zinc, with its high electrode potential, is used to coat plain carbon steel, the zinc coating corrodes sacrificially, thereby protecting the base steel.

Galvanic Series		
<b>ANODIC</b>	Magnesium	<b>ACTIVE</b>
	Zinc	
	Cadmium	
	Aluminum 2017	
	Steel (plain)	
	Cast iron	
	Lead	
	Tin	
	Brasses	
	Copper	
<b>CATHODIC</b>	Bronzes	<b>NOBLE</b>
	Titanium	
	Monel	
	Nickel (passive)	
	304 stainless (passive)	
	316 stainless (passive)	
	Silver	
	Graphite	

Figure 1.2: Galvanic series

The more anodic zinc coating, if penetrated, corrodes preferentially to prevent the more cathodic steel substrate from rusting. Once the zinc is nicked or scratched, the steel continues to be protected by galvanic action. Because zinc has self-healing properties, a nick in the coating may “heal.” The galvanic deposits, or zinc oxides, that form are water soluble. As they weather and wash away, more zinc oxide is formed. This sacrificial process continues until all the zinc in a localized area is consumed. Only then does the base steel begin to rust in that location.

While the zinc remains, it also acts as a barrier between the atmosphere and the base steel. The duration of the protection offered by zinc is directly related to coating thickness and the severity of the environment. Thus, all factors being equal, the thicker the zinc coating, the longer it will protect the base steel.

The galvanic chart is also useful for analyzing the interactions of different metals that may come in contact with one another in the presence of moisture, in particular the interaction that takes place when water run-off from a more noble metal passes over an active metal. This explains, for example, why the run-off from a copper gutter into an aluminum downspout results in premature failure of the aluminum downspout. On the other hand, an aluminum gutter draining into a copper downspout would not have the same effect, except at the connection point of the two metals. NRCA recommends the use of compatible metals or properly prepared or isolated metals in roof systems and related flashings.

**1.8 Oil-canning**

Oil-canning is an inherent phenomena prevalent in light-gauge, cold-formed metal products. Oil-canning refers to physical distortions in the flatness of the metal; however, this condition is only aesthetic in nature and it does not have any adverse effect on the structural integrity or the weatherproofing capability of the panel. Because some paint finishes, clear coats and metals are highly reflective and bright, distortions can be quite apparent. The visual effects of oil-canning can be exacerbated by changing or varying light conditions. Many metal roof panel manufacturers issue disclaimers regarding oil-canning, yet it can nevertheless become a customer-acceptance issue. If a specifier intends to reduce the severity of oil-canning, careful design consideration should be given to the width, gauge and profile of the specific product. NRCA does not consider oil-canning alone to be a cause for rejection.

There are a number of potential causes of oil-canning; however, all are attributable to residual stresses, either induced or redistributed, for different reasons.

- Residual stress during coil production can contribute to camber, the deviation of a side edge from a straight line. This longitudinal curving will place additional stress on the metal as it is pulled through the roll-forming machine, which attempts to form a straight edge on the panel.
- Slitting a master coil can release and redistribute stresses, especially if the slitter blades are out of adjustment or dull.
- The roll-forming equipment itself can cause oil-canning. As metal is run through the rolling stations, it is placed under stress and can stretch, particularly if the equipment is out of adjustment or operated beyond it’s limitations.

Despite having a properly adjusted, well-maintained roll-forming machine and good quality metal, oil-canning can still occur when panels are installed. It can result from temperature fluctuations and cycles, an uneven substrate or irregular bearing on the structural framing, structural movement or over-torqueing of the mechanical fasteners.

The following precautions and considerations should assist in the reduction of oil-canning and its visual effects.

- Specify that coil stock be tension-leveled to ensure flatness of material.
- Use a heavier-gauge metal that is more rigid and less likely to oil-can than lighter-gauge material.
- Limit individual panel pan widths.
- Limit face dimensions on the fascia metal.
- Use stiffening ribs or striations in the field of the metal panel.
- Use stiffening ribs in the fascia metal, or use two-piece fascia metal when the face dimension is greater than 8 inches (200 mm).

Following are considerations to reduce the visual effects of oil-canning:

- Use low-gloss finishes or special surface textures such as embossing or striations
- Consider using metals that weather naturally, as these metals typically dull or fade over time with the development of a layer of oxidation.

## **2. ARCHITECTURAL SHEET METAL**

### **2.1 Cleats/Clips/Fasteners**

Cleats, clips and fasteners are the components that secure a roof system's metal panels or associated sheet-metal roof accessories and flashings to the adjacent substrate.

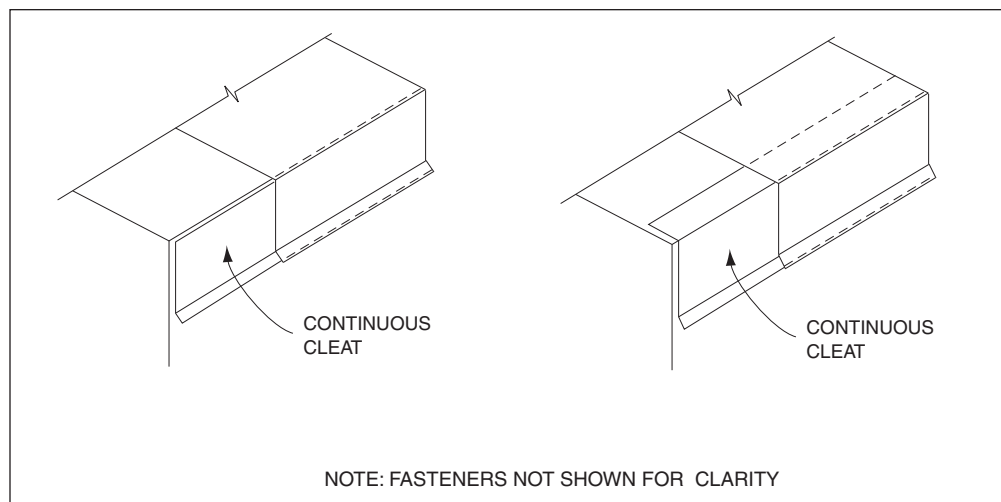
#### **2.1.1 Cleats**

NRCA defines a cleat as a continuous metal component installed behind the leading edge of a metal accessory, such as a coping cap or edge metal, used to engage and secure the metal accessory to the adjacent substrate or another metal component by means of a slip joint or by crimping the leading edge of the metal accessory to the cleat.

Cleats can be used with many metal accessories, such as copings, gravel stops and fascias, counterflashings, expansion joints and joinery. See Figure 2.1. Cleats provide continuous anchorage of the sheet metal component. Cleats are anchored with mechanical fasteners to the substrate. Cleats are often made of the same metal as the metal accessory that is being secured and are generally formed from one metal thickness, or gauge, heavier than the accessory metal.

Cleats provide a hidden method of anchorage. For some designs and applications, this may be preferred to exposed mechanical fasteners.

Figure 2.1: Example of common cleat styles



#### **2.1.2 Clips**

NRCA defines a clip as an individual metal component installed at predetermined locations along the edge of a metal roof panel or behind the leading edge of a flashing metal, used to engage and secure the metal roof panel or

flashing metal intermittently to the adjacent substrate or another metal component.

Generally, clips are made of sheet metal, that is either the same gauge or one gauge heavier than the metal component it is securing. Clips for securing metal roof panels, wall panels and flashings may be engineered or designed to allow for expansion and contraction within the completed system. Clips may also be used to secure the metal roof panels, wall panels and flashing system in a fixed position with no allowance for movement. It should be noted that all metals expand and contract even when they are installed in a fixed manner. Some examples of clips used to secure metal roof and sheet-metal accessories are shown in Figure 2.2.

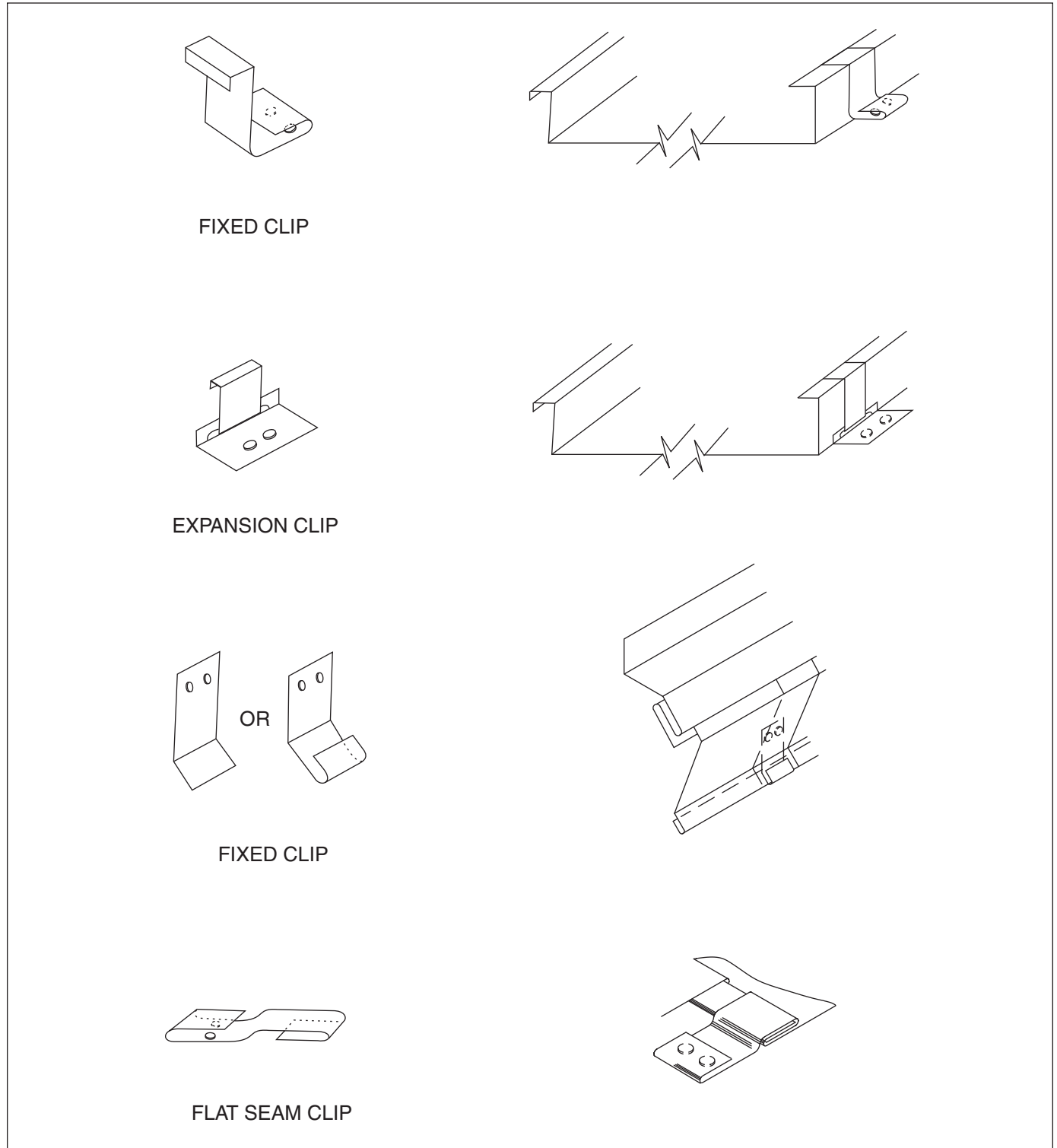


Figure 2.2: Examples of common clips

### 2.1.3 Fasteners

Sheet-metal fasteners are mechanical anchors that provide point anchorage for sheet metal. Fasteners are differentiated by the type of substrate or material being fastened. Figure 2.3 shows generic fastener types matched with common substrates.

Common Sheet-metal Fasteners


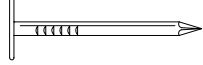
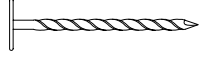

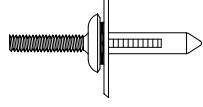
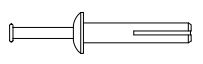

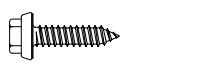
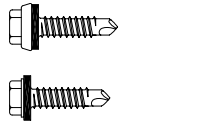
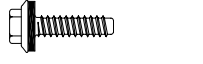

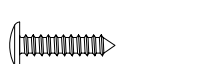
Fastener Illustration	Fastener type	Fastener usage	Fastener material recommendations <sup>4</sup>	Substrate				
				Sheet Metal 18 gauge or lighter	Sheet Metal heavier than 18 gauge	Wood <sup>6</sup>	Concrete	Masonry
	Ring or Annular Shank Nail	sheet metal to wood	hot-dipped galvanized, stainless steel, copper			X		
	Barbed Shank Nail (smooth)	sheet metal to wood	hot-dipped galvanized, stainless steel, copper			X		
	Screw Shank Nail	sheet metal to wood	hot-dipped galvanized, stainless steel, copper			X		
	Pop Rivet	sheet metal to sheet metal	carbon steel <sup>5</sup> , stainless steel, aluminum, copper	X <sup>1</sup>				
	Shear Rivet	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel, aluminum	X <sup>1</sup>	X <sup>1</sup>			
	Nail-in Expansion Fastener	sheet metal to concrete or masonry	lead, nylon, carbon steel <sup>5</sup> , or zinc alloy body with carbon steel <sup>5</sup> or stainless steel pin				X <sup>1</sup>	X <sup>1</sup>
	Concrete Screw	sheet metal to concrete	carbon steel <sup>5</sup>				X <sup>1</sup>	X <sup>1</sup>
	Self-piercing Screw	sheet metal to sheet metal, wood or purlin	carbon steel <sup>5</sup> , stainless steel	X <sup>2</sup>	X <sup>2</sup>	X		
	Self-drilling Screw	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel with neoprene washer	X	X <sup>2</sup>			
	Self-tapping Screw	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel with neoprene washer	X <sup>1</sup>	X <sup>1</sup>			
	Self-drilling Screw	sheet metal or clip to sheet metal, purlin or wood	carbon steel <sup>5</sup> , stainless steel	X	X	X		
	Self-drilling Screw	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel	X <sup>2</sup>	X <sup>2</sup>			

Figure 2.3: Common sheet metal fasteners chart

Common Sheet-metal Fasteners (cont.)


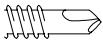


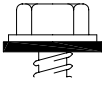















<b>Points<sup>3</sup></b>							
							
Self-piercing	Self-drilling	Self-cutting	Self-tapping				
<b>Heads<sup>3</sup></b>							
							
Hex washer head	Flat head	Wafer head	Oval head	Pancake head	Pan head	Bugle head	Trumpet head
<b>Drives<sup>3</sup></b>							
							
Slotted	Phillips	Phillips/slotted	Square	Hex socket	Phillips hex	Hex	Hex washer
<b>Notes:</b>							
<ol style="list-style-type: none"> <li>Requires a pre-drilled hole.</li> <li>May require a pre-drilled hole.</li> <li>Screw points, heads and drives may be combined with the fastener types shown. Check with the manufacturer for specific combinations.</li> <li>Check with fastener and substrate manufacturers for corrosion resistance requirements and information.</li> <li>Carbon steel fasteners have some type of coating (e.g., zinc, proprietary) applied to the fastener.</li> <li>When treated wood is the substrate, the following recommendations are suggested: <ul style="list-style-type: none"> <li>Carbon steel, aluminum and electroplated galvanized steel fasteners and connectors should not be used in contact with treated wood. Hot-dipped galvanized fasteners complying with ASTM A153 and connectors complying with ASTM A653, Class G185, generally are acceptable. Type 304 or Type 316 stainless-steel fasteners and connectors are recommended for maximum corrosion resistance.</li> <li>Fasteners with proprietary anti-corrosion coatings may be acceptable for use with treated wood. When considering the use of such proprietary coated fasteners and connectors, consult fastener manufacturers for specific information regarding the performances of their products in treated wood and any precautions or special instructions that may be applicable.</li> <li>Aluminum fasteners, flashings and accessory products should not be used in direct contact with any treated wood. ACQ-treated wood is not compatible with aluminum.</li> <li>Uncoated metal and painted metal flashings and accessories, except for 300-series stainless steel, should not be used in direct contact with treated wood. Metal products, except stainless steel, may be used if separated from treated wood by a spacer or barrier, such as single-ply membrane or self-adhered polymer-modified bitumen membrane material.</li> </ul> </li> </ol>							

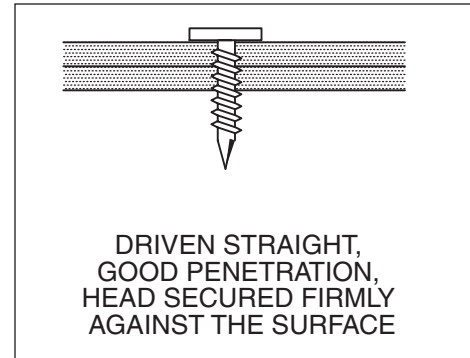
Figure 2.3: Common sheet metal fasteners chart (continued)

Exposed fasteners used in roofing applications often have gaskets. A gasket provides a compressible material at the contact point between the fastener “head” and the sheet metal and helps provide a more watertight seal. Gaskets are usually made from a synthetic rubber material and are in the form of a washer.

Pull-out resistance and the ability of a fastener to hold material in place is a function of the fastener’s size, shank, point or tip type, thread design—whether the fastener is a screw, compatibility, corrosion resistance, and type and strength of

the substrate material. Also critical is the tear resistance of the material held in place at the location where the fastener penetrates the sheet metal. Tear resistance depends on the diameter of the fastener's head and the thickness, or gauge, type and grade of the material being secured, as well as whether the fastener has been installed properly. See Figure 2.4. Pull-out resistance and material tear resistance are critical elements in selecting proper fasteners.

Figure 2.4: Proper fastening chart



Also, the corrosion resistance of a fastener should be considered, along with its desired service life, which should be equivalent to that of the secured material. A fastener should be compatible with the material being secured. The shear strength and tensile strength of a fastener are also important considerations.

For specifics about nails, screws and the other types of mechanical fasteners used in the roofing industry, refer to the Appendix Section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*. Figure 2.3 in this section also includes a chart depicting common sheet-metal fasteners and the appropriate substrate for each type.

## 2.2 Copings

Parapet walls must be adequately protected from moisture intrusion to prevent deterioration of the wall and damage to the roof system, building components and interior. Copings are used to cover the top of a parapet wall and provide a weatherproof cap, which seals and protects the wall from moisture intrusion. Metal is one of the more common materials used for copings. See Figure 2.5. Metal copings can be brake-formed or extruded. Premanufactured metal copings are also available. The more common metal types are galvanized or Galvalume® steel, standard or extruded aluminum, and copper. Metal copings are also commonly used to cover existing coping materials, which are more porous than, for example, stone, precast concrete or masonry units. Only metal copings are discussed in detail in this manual.

A coping needs the following:

- durable nonporous material
- compatibility with the adjacent materials—if not, an isolation sheet or coating may be required to separate incompatible materials
- proper attachment and fastening
- drip edges
- proper support—either continuous support, such as wood blocking, or intermittent supports
- adequate joiner—to prevent moisture infiltration
- proper slope—to drain water from the top surface
- adequate overlap on each vertical face—to prohibit moisture infiltration
- secondary, continuous sheet membrane liner to provide secondary weatherproofing unless weathertight joints, such as double-lock standing seams, are used
- expansion/contraction capabilities

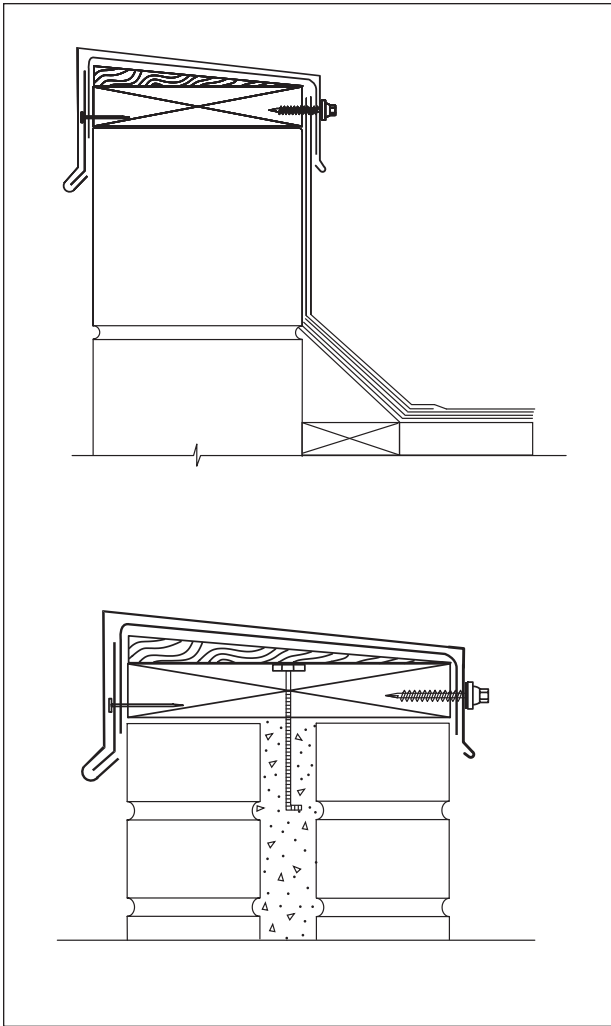


Figure 2.5: Metal coping (parapet caps)

For parapet walls, positive slope to the roof side should be provided at the top of the wall. A continuous tapered shim installed over the wood blocking is a common method of sloping the top of the wall to the roof side. When weather-tight seams are not installed, copings should have a continuous sheet membrane liner under the coping that should be capable of providing a secondary water barrier. If installed, a sheet membrane liner may also act as an isolation sheet for incompatible materials or act as a slip sheet for materials with differential movement.

Copings can be fastened by several methods. There are three common methods for securing metal copings, which can be seen in Figure 2.6. These methods are described as follows:

Option A: A continuous cleat is fastened on the exterior and interior faces of the wall. The hem at the drip edge of the coping metal on the interior side should be fabricated slightly open for ease of application. After the exterior face of the coping is hooked to the cleat, the interior face (roof side) is secured side by hand-tonging (crimping) the open hem of the coping to the cleat.

Option B: A continuous cleat is fastened to the exterior face of the wall, and clips are installed intermittently on the interior face (roof side) of the wall. After the exterior face of the coping is hooked to the cleat, the interior face (roof side) is secured by engaging the clips to the bottom edge of the interior face of the metal coping.

Option C: A continuous cleat is fastened on the exterior face of the wall. After the exterior face of the coping is hooked to the cleat, the interior face (roof side) of the coping is secured to the parapet with gasketed fasteners.

Refer to Figure 2.7 for information on metal thicknesses or gauges for copings.

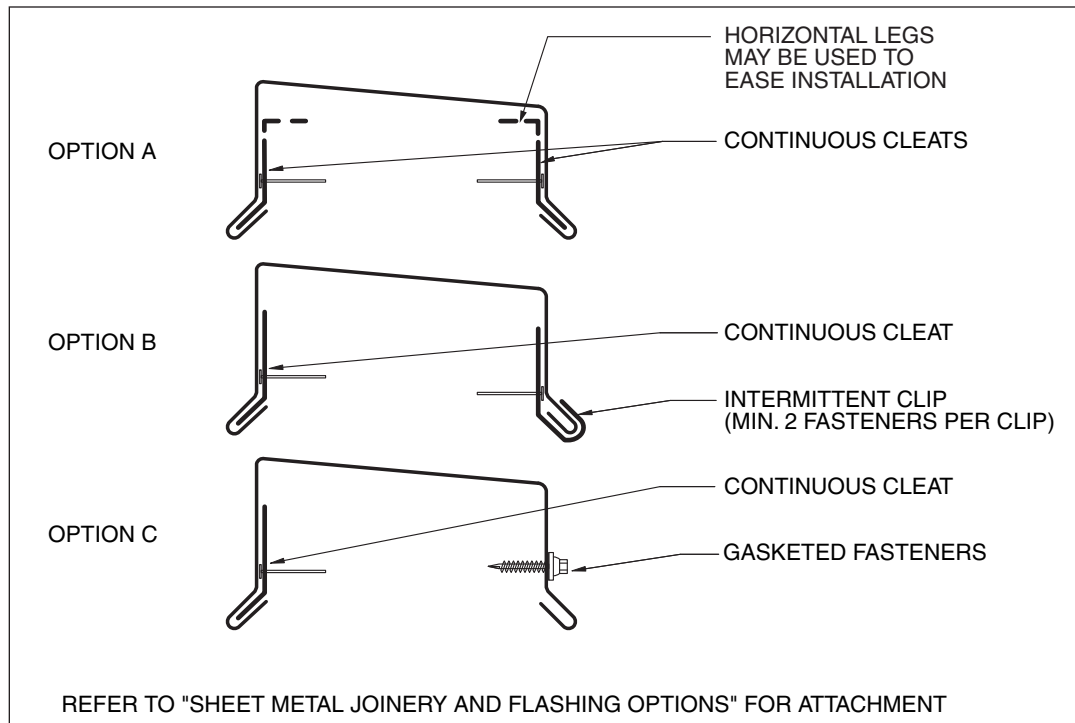


Figure 2.6: Alternate coping securements

LONGER "A" DIMENSION					
	0-3"	3"-6"	6"-8"	8"-10"	OVER 10"
ALUMINUM	.032" (.81 mm)	.032" (.81 mm)	.040" (1.02 mm)	.050" (1.27 mm)	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE
COPPER	16 oz. (4.87 kg/m <sup>2</sup> )	16 oz. (4.87 kg/m <sup>2</sup> )	20 oz. (6.10 kg/m <sup>2</sup> )	24 oz. (7.51 kg/m <sup>2</sup> )	
GALVANIZED	24 ga. (.64 mm)	24 ga. (.64 mm)	24 ga. (.64 mm)	22 ga. (.79 mm)	
STAINLESS STEEL	26 ga. (.46 mm)	24 ga. (.61 mm)	24 ga. (.61 mm)	22 ga. (.74 mm)	

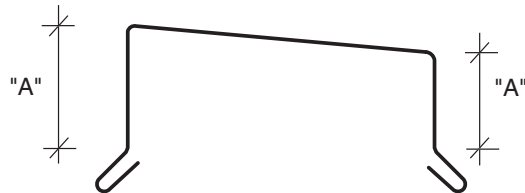


Figure 2.7: Thicknesses or gauges for copings

Copings are generally formed in 8-foot, 10-foot or 12-foot (2.4-m, 3.0-m or 3.6-m) long sections and joined to provide appropriate expansion/contraction capabilities. Coping seams should be constructed to limit moisture infiltration. See Section 2.9, Joinery, for information about coping joint configurations.

Corners should be sealed, soldered or welded, as appropriate, depending on the specific coping metal type. Joints that provide expansion/contraction capabilities should be located near the corners within 18 inches (460 mm) from each direction of the corner measured on the interior side, so movement because of to temperature changes does not pull apart the corner piece. The corner of the wall acts as a fixing point for the metal coping; thermal movement can only occur in one direction, that is, away from the corner. See Figure 2.8.

Brake-formed metal copings can be of a variety of shapes. See Figure 2.9. With the advancement of sheet-metal brakes, tighter bends and radii, or curves, can be fabricated.

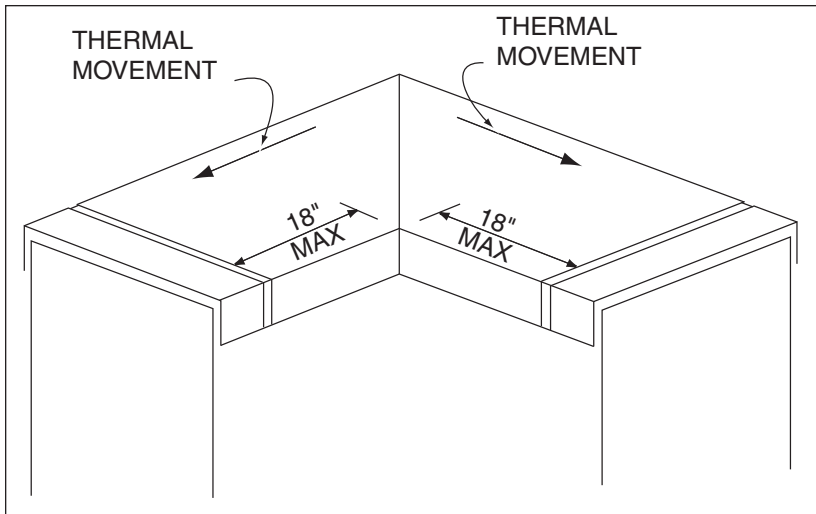


Figure 2.8: Coping corner

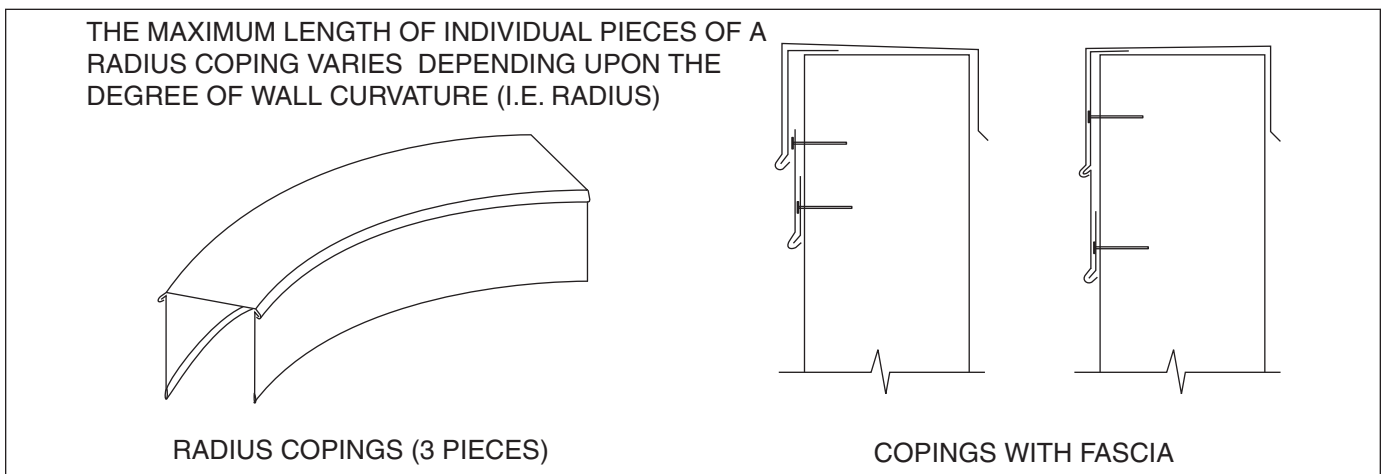


Figure 2.9: Radius copings and copings with fascia

Premanufactured copings are also available and come in many profiles, finishes and colors to accommodate differing aesthetic preferences. The more common metal types are galvanized or Galvalume® steel and standard or extruded aluminum. Common finishes include mill finished, etched, anodized or prefinished. Some premanufactured copings are supported on metal frames, called “chairs,” rather than supported and secured to wood blocking. The metal chairs should support and secure a coping adequately, as well as provide positive slope to the interior face, or roof side, of the parapet wall. When weathertight seams are not installed, NRCA recommends premanufactured copings have a continuous sheet membrane liner under the coping that should be capable of providing a secondary water barrier. If installed, a sheet membrane liner may also act as an isolation sheet for incompatible materials or act as a slip sheet for materials with differential movement. When specifying premanufactured metal coping, designers should consult manufacturers for design information. Manufacturer, metal type, color, finish and attachment method of the metal coping should be specified by the designer.

### **2.3 Gutters and Downspouts**

One way of controlling drainage of some steep-slope and low-slope roof systems is by using gutters and downspouts. Special consideration must be taken when determining size, style, attachment, location and construction to ensure adequate drainage and strength. Many types of metals can be used to fabricate gutters and downspouts; some of the more common metal types are aluminum, copper and galvanized, stainless or prefinished steel. It is important that metals used for gutters and downspouts be matched appropriately to prevent corrosion of metals by galvanic action.

There are two types of gutters: built-in and externally attached (hanging). Gutters must be able to support themselves, as well as the weight of ice and water. They must also remain leak free while enduring the continual stress of expansion and contraction.

The design of gutter and downspout assemblies is an area of building design that requires special attention. Leaking gutters, downspouts and joints can cause serious damage to a building's interior, as well as to its exterior.

The following are considerations when selecting the material, thickness and size of a gutter:

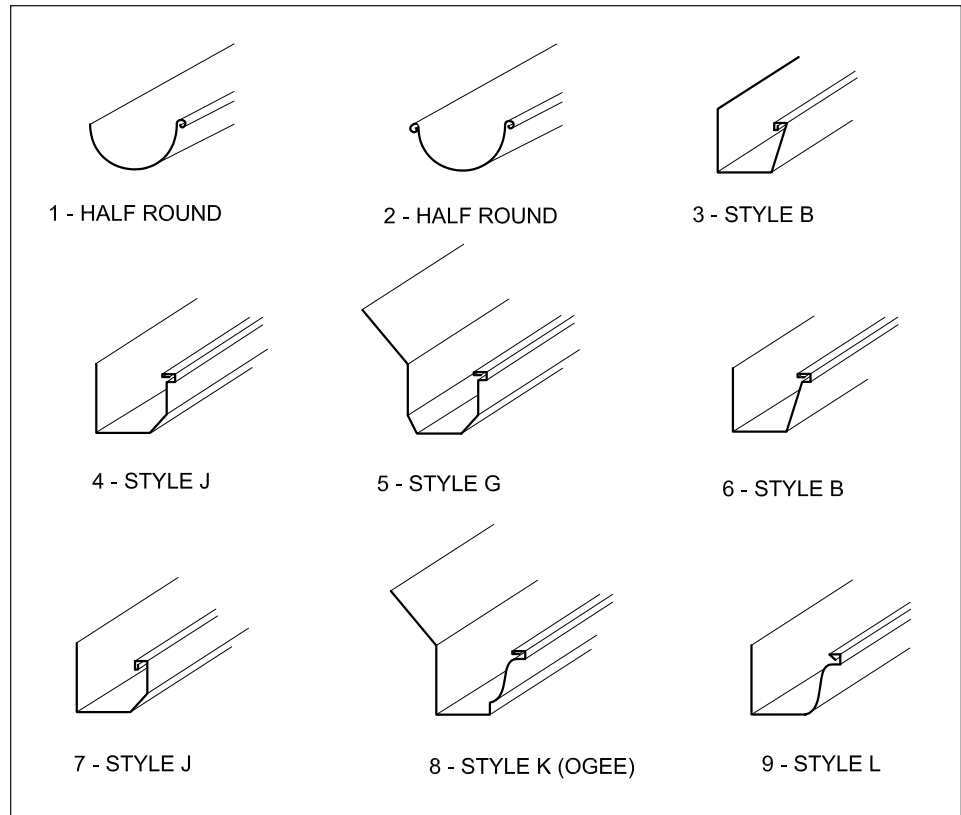
- the gutter support system, including expansion provisions
- the inherent strength and rigidity of the gutter material in the selected size and profile
- environmental effects, such as the weight of ice, water and debris in the gutter, and the anticipated amount of precipitation at the geographic location
- maintenance and assumed service life of the system, including corrosion and incidental damage if any is foreseen
- downspout placement, size and number

### 2.3.1 Externally Attached (Hanging) Gutters

Maintenance, durability and longevity of the metal and securement type are important factors to consider when designing gutters and downspouts.

Numerous types and styles of gutters exist. Shop-fabricated, that is brake-formed, or machine-fabricated, that is roll-formed, gutters provide a designer with an extensive selection of designs. See Figure 2.10 for examples.

Figure 2.10 Examples of common gutter profiles



Gauges and material type must be considered when determining adequate strengths. Adding longitudinal breaks, stiffening ribs or reinforcing bars will add rigidity and strength to the gutter. The gutter style and size will be factors in the selection of the support system. The recommended minimum thicknesses for hanging gutters are given in Figure 2.11. Girth refers to the width of the unformed flat stock metal.

<b>GIRTH</b> (not flanged onto roof)	<b>GALVANIZED STEEL</b>	<b>COPPER</b>	<b>ALUMINUM</b>	<b>STAINLESS STEEL</b>
up to 15 in.	26 ga.	16 oz./ft.	.032 in.	26 ga.
16 - 20 in.	24 ga.	16 oz./ft.	.032 in.	26 ga.
21 - 25 in.	24 ga.	20 oz./ft.	.040 in.	24 ga.
26 - 30 in.	22 ga.	24 oz./ft.	.050 in.	24 ga.
31 - 35 in.	22 ga.	24 oz./ft.	.063 in.	22 ga.
Over 35 in.	20 ga.	30 oz./ft.	.063 in.	20 ga.

Figure 2.11: Minimum thickness based on girth

There are three common types of support systems typically used with externally attached gutters:

- support brackets
- support brackets and spacers
- spacer hangers

Spacers are used to keep the front rim a designed distance from the back of the gutter. They normally attach only to the front and back of the gutter. If they attach also to the building, they may inhibit expansion. Cradle support brackets that extend up to the rim contribute to retention of rim position and alignment.

Brackets and gutter support systems are critical to the long-term performance and ability to withstand the weight and load applied to the gutter. Brackets should be installed between 12 inches to 30 inches (300 mm to 750 mm) on center, depending on conditions. Refer to Figure 2.12 to determine bracket size and gauge.

Three common methods for joining gutter sections are as follows:

- sections butted together and welded
- sections lapped (riveted, if necessary) and soldered
- sections lapped with sealant in the joint and riveted

<b>BRACKET GIRTH</b>	<b>GALVANIZED STEEL COATED (G90)</b>	<b>COPPER</b>	<b>ALUMINUM</b>	<b>STAINLESS STEEL</b>
up to 20" (510 mm)	1/8" x 1" (3 mm x 25 mm)	1/8" x 1" (3 mm x 25 mm)	3/16" x 1" (5 mm x 25 mm)	1/8" x 1" (3 mm x 25 mm)
20 to 24" (510 to 610 mm)	1/4" x 1 1/2" (6 mm x 38 mm)	1/4" x 1 1/2" (6 mm x 38 mm)	1/4" x 2" (6 mm x 50 mm)	1/8" x 2" (3 mm x 50 mm)

Figure 2.12: Sizes for brackets and straps

For solderable metals, joints in gutters should be lapped 2 inches (50 mm), riveted and soldered. For soldered joints, rivets are often used to strengthen the joint and can assist in holding or fixing the joint during the soldering process. In soldering applications, it is recommended that solder be applied over the tops of the rivets on the interior of the gutter.

For metals that cannot be soldered or welded, such as prepainted metal or coated aluminum, an appropriate sealant should be applied continuously within the joint, and the joint should be riveted 2 inches (50 mm) on center. After the joint is sealed and riveted, sealant should be applied to cover the top of the rivets on the interior of the gutter. When prepainted gutters are used, the designer must designate the types of joints. Lapping joints in the direction of water flow is recommended.

In areas where severe ice or snow conditions exist or where there is the potential for excessive accumulation of debris, special considerations to account for the effects of debris or water back-up and the weight of the ice or snow are necessary. Additional support is typically required for these conditions. Establishing a routine inspection and maintenance schedule to remove debris periodically from gutters is especially important in these locations, as well as locations on the roof where excess accumulation of debris, such as vegetation, is expected. It is suggested that externally attached gutters be positively sloped. In addition, the front face of the gutter should be lower than the back face to allow excess water to spill over in a heavy downpour or because of a clogged gutter or downspout.

### 2.3.2 Built-in Gutters

Built-in gutters can be exposed or concealed from view and are at or near the eave, in a valley or at a parapet wall. This type of gutter design tends to serve special architectural or aesthetic preferences; however, designers and building owners are strongly urged to consider the ramifications of using the built-in gutter design. It is important to remember that a built-in gutter is an internal, rather than external drainage device and should be designed as such.

Leakage at built-in gutters, even when minor, can damage the roof deck and structural framing, cornice components or interior of the building. The intrusion of water can lead to rotting or rusting of structural components, as well as deterioration of the building finishes. Internal drainage devices typically use piping with welded or pressure-tight fittings; these types of connections typically are not possible where built-in gutters connect to the internal leaders, thereby increasing the potential for leakage. Expansion and contraction of the metal gutter components and differential movement of the gutter components and roof system should also be considered.

There are four common types of built-in gutters, as can be seen in figure 2.13. Those types are:

- built-in gutter at eave
- built-in gutter near eave
- built-in gutter at parapet wall
- built-in gutter at valley

When possible, built-in gutters at valleys and parapet walls should be avoided by designers and building owners; considering alternative roof drainage designs is strongly recommended by NRCA. When these built-in gutter types are used, overflow protection, or secondary devices, is critical, and consideration should also be given to using a secondary waterproofing membrane.

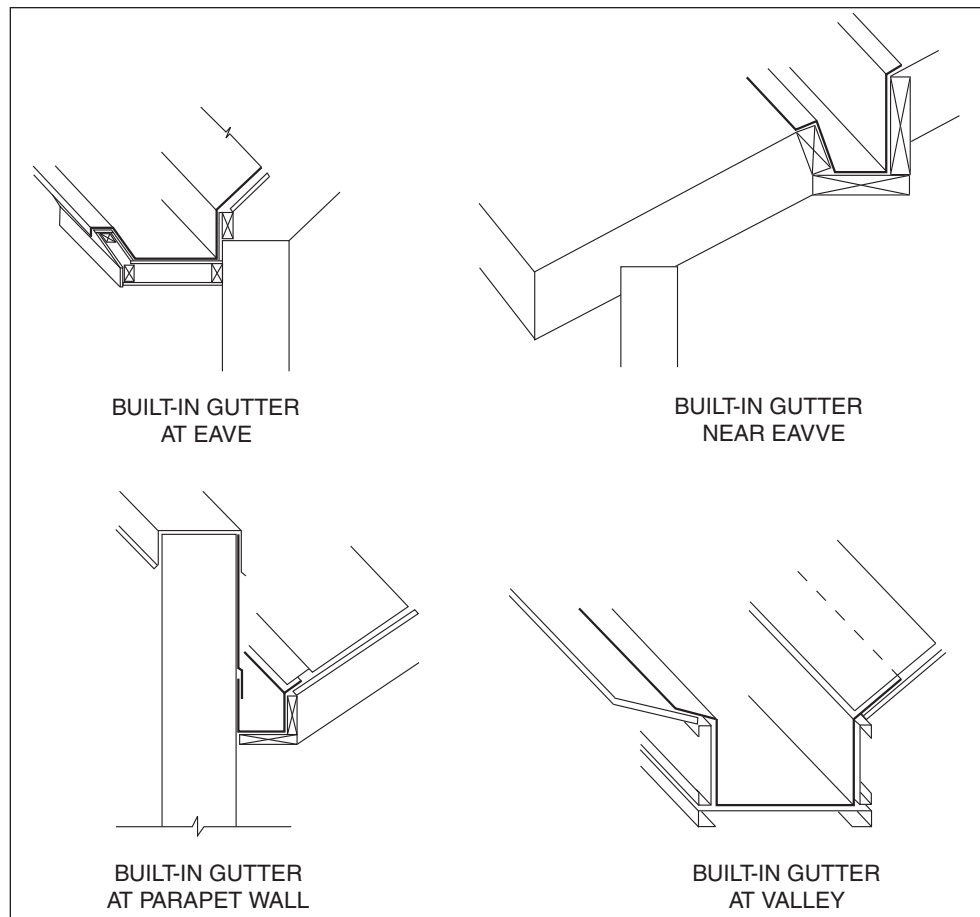


Figure 2.13: Examples of built-in gutters

When built-in gutters are used, the following items should be considered:

- Watertight seaming and joinery is critical to the performance of built-in gutters. Only metals that can be soldered or welded, such as copper, lead-coated copper and stainless steel, are recommended. Prefinished or other metals

that do not allow for soldering or welding are not recommended.

- The metal type should be compatible with adjacent materials to prevent galvanic corrosion and decreased service life.
- Controlling expansion is important. Provisions for expansion and contraction must be incorporated into the design, and clearances at gutter ends, corners and supports are necessary. Downspout locations must accommodate gutter movements. Using metals with high coefficients of thermal expansion, such as aluminum and zinc, should be avoided.
- Whenever possible, the front face of the gutter should be lower than the back face to allow excess water to spill over in a heavy downpour or because of a clogged gutter or downspout.
- Continuous support, rather than intermittent support of the built-in gutter, is recommended.
- Underlayment should be used and consist of a minimum of one layer of No. 30 asphalt saturated roofing felt. Self-adhering modified bitumen membranes can also be used with isolation/protection sheets beneath soldered joints. A slip sheet of rosin-sized paper over the underlayment is suggested.
- A secondary waterproofing membrane should also be considered.
- Designers should consider the potential loss of fire rating where the built-in gutter interrupts the roof system.
- Designers should consider insulation and ventilation needs because of the potential for condensation where the built-in gutter interrupts the roof system.

The previous items may not pertain to structural metal panel roof systems that incorporate built-in gutters. Regardless of the type of roof system, NRCA recommends that built-in gutters be positively sloped.

### 2.3.3 Gutter Expansion

As with all rigid materials, expansion is a significant design consideration. The system of gutters, downspouts and their supports must have the flexibility and strength to accommodate expansion.

Expansion joints are suggested for gutters to allow movement caused by thermal changes. Long, straight runs should not have expansion joints spaced more than 50 feet (15 m) apart and no more than 25 feet (7.5 m) from any fixed corner. Some types of expansion joints act as a water dam in the gutter; therefore, the number and placement of downspouts will be influenced by the type of expansion joint used.

Two types of expansion joints are shown in Figures 2.14 and 2.15: butt type and lap type. For butt-type gutter expansion joints, the gutter ends are flanged, then riveted and soldered or sealed to the ends of gutter sections to be joined. A cover plate can be placed over the expansion joint; however, installation of the cover plate should not restrict the movement of gutter sections.

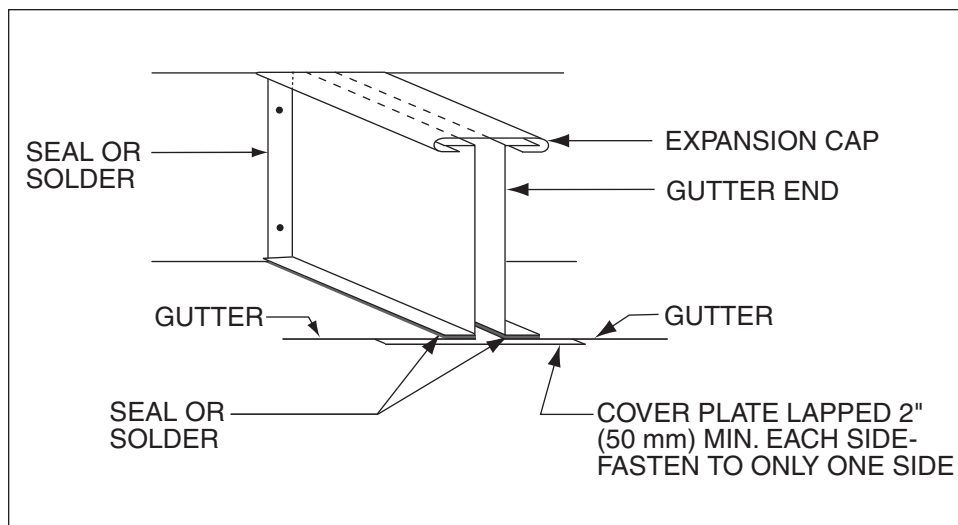
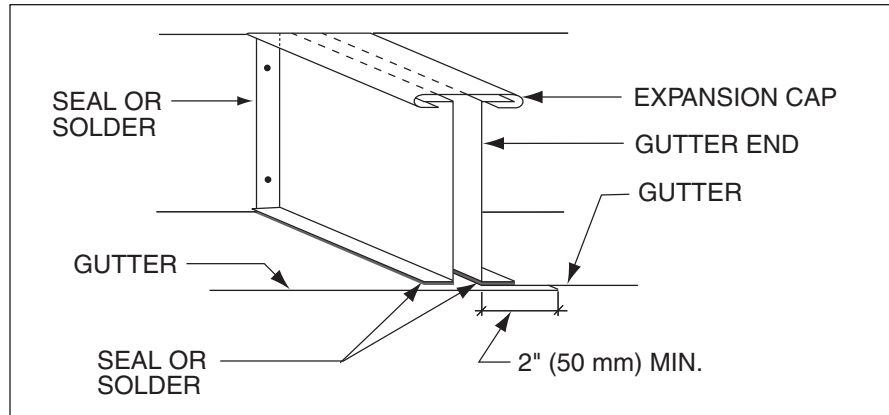


Figure 2.14: Example of a common butt-type expansion joint

For a lap-type gutter expansion joint, a gutter end piece is installed recessed 2 inches (50 mm) minimum into the gutter on one end of the gutter section. The opposite side is fitted with an end flush with the edge. Gutter ends are flanged, then riveted and soldered or sealed into the gutter sections. The flush end of the gutter section is then slipped into the recessed end of the next section. The expansion joint cap is then placed on top, in a manner similar

to the fabrication of butt-type gutter expansion joints.

Figure 2.15: Lap-type expansion joint

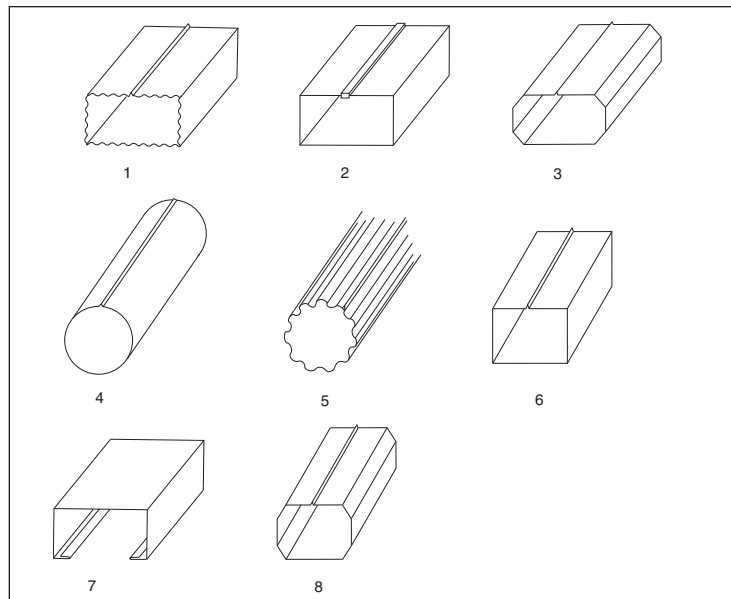


### 2.3.4 Downspouts

Sheet-metal downspouts are shop-fabricated or premanufactured in a wide variety of shapes and sizes. See Figure 2.16. Plain, corrugated, round, rectangular or square downspouts are typical. Manufactured downspouts use pre-manufactured parts and assemblies for ease of installation. Heavier gauge products and custom configurations normally require shop fabrication. It should be noted that not all downspout shapes can be shop fabricated. Sizing of downspouts should accommodate the gutter capacity.

Sheet-metal downspouts and their connections are generally not constructed to be pressure-tight, welded or waterproof. The length of a downspout between horizontal transitions must be considered to prevent potential blowout at elbows caused by pressure and velocity of storm water. In place of metal, PVC and cast-iron piping can be used in situations where greater drop distances are required or pressure-tight fittings are deemed necessary (e.g., with built-in gutters where the downspouts are inside the building). Any horizontal offsets should maintain slope for positive drainage.

Figure 2.16: Downspout examples



The downspout is joined to the gutter with an outlet tube, and an outlet tube is inserted through a hole in the gutter bottom. The hole size equals the outside dimension of the outlet tube. The flange of the outlet tube is fastened, then soldered, welded or sealed to the gutter. See Figure 2.17. The length of the outlet tube is a minimum of 4 inches (100 mm) from the flange edge to the bottom edge. The flange is typically 3/8 inch (10 mm) wide. The outside dimension of the outlet tube is typically 1/8 inch (3 mm) less than the inside dimension of the downspout. Three-sided downspouts are suggested in regions where ice formations may block and/or damage fully enclosed downspouts.

Downspout locations will be affected by gutter capacity and length, roof area, expansion joint locations and the building's aesthetics. Downspout locations should not exceed 50 feet (15 m) with a minimum of one downspout per expansion region.

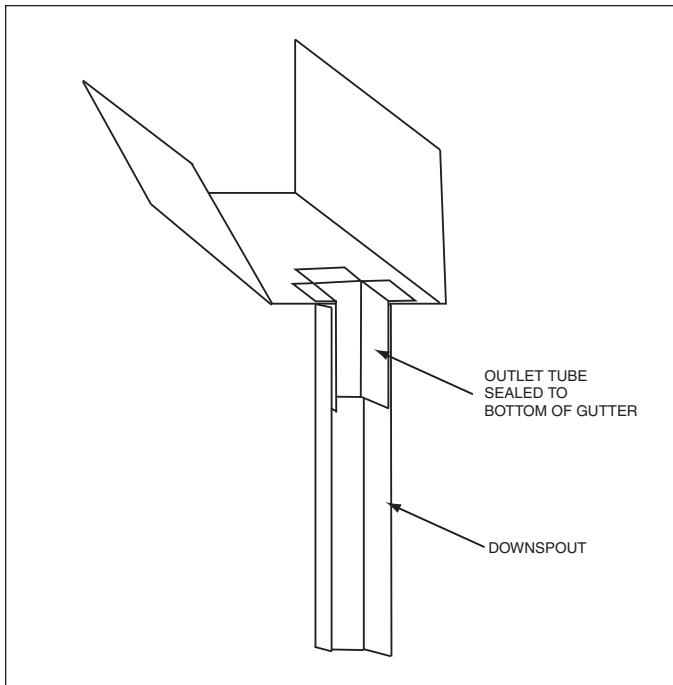


Figure 2.17: Outlet tube in an external gutter

### 2.3.4.1 Elbows

Premanufactured or shop-fabricated elbows complete the transition of downspouts. See Figure 2.18. Premanufactured elbows are usually machine-crimped and are available in shapes to match the downspout configuration. Elbows are designed to be inserted into the lower downspout and over the connecting unit in order not to impede the flow of water. Elbows are manufactured with varying angle degrees.

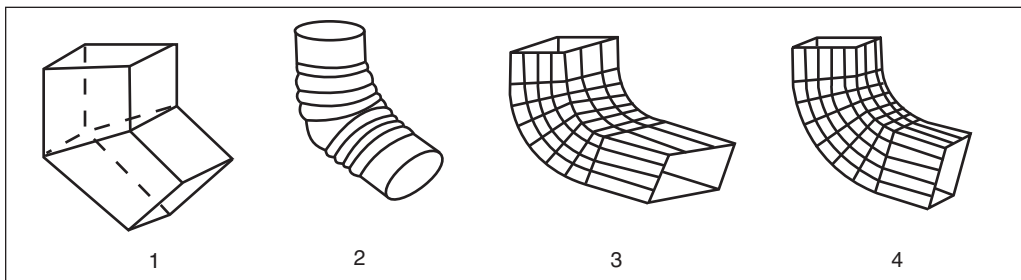


Figure 2.18: Common examples of downspout elbows

Elbows can restrict and slow the flow of storm water, as well as increase the potential for clogging of the downspout. Designers should carefully consider the placement and number of elbows to minimize water flow restriction or clogging. The length of downspout between connections should also be considered to avoid blowouts or damage at elbows or transition pieces caused by water velocity and pressure or ice accumulation.

Typically, the joints in shop fabricated elbows are mitered and should be fastened and soldered, welded or sealed. They should be fabricated so the flow of water is not restricted.

### 2.3.4.2 Downspout Hangers

Hangers or straps are used to hold downspouts in position. Downspouts should be secured to walls with hangers or straps at a minimum of one every 10 feet (3 m) and at every directional change.

Hangers and straps should be fabricated from similar material of substantial size and gauge to secure downspouts. They are recommended to be one or two gauges heavier than the downspout. Figure 2.19 illustrates some typical straps and hangers. The straps are attached to the building with noncorrosive fasteners appropriate to the wall material.

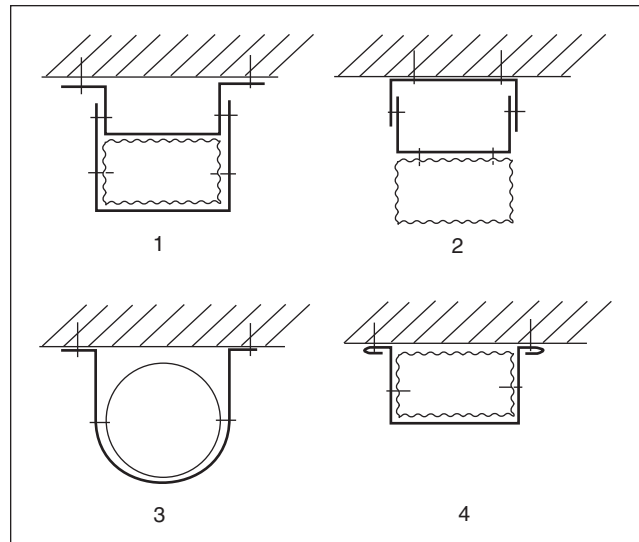


Figure 2.19: Common downspout strap examples

### 2.3.4.3 Cleanouts/Overflows

Smooth, uninterrupted flow of water through gutters, conductor heads and downspouts is essential to the overall weatherproofing of any building. It is common for these devices to accumulate dirt, leaves, twigs and other debris over time. Eventually water-restricting obstructions can develop, usually at turns and transitions (e.g., elbows, miters). Blockage can cause storm water to back up or overflow, potentially resulting in structural or interior damages.

Downspout cleanouts are short, angled appendages with removable tops to access the interior of the downspout for manual extraction of debris. Overflows are openings in the front face of a gutter or conductor head designed to function as relief openings for storm water.

## 2.4 Scuppers

There are two general types of scuppers: through-wall scuppers, which are four-sided, and open scuppers, which are three-sided. Scuppers are typically installed at roof edges, either through the perimeter parapet wall, see Figures 2.20 and 2.21, or within a raised edge design, see Figure 2.22. Scuppers can be the primary or secondary source of drainage. Scuppers used as secondary drainage devices are defined as overflow scuppers. Scuppers may also be used to direct drainage from one roof to another.

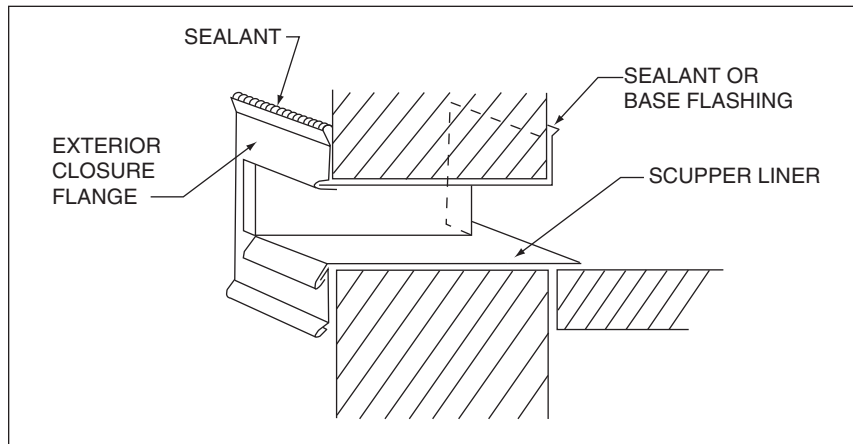


Figure 2.20: Through-wall scupper

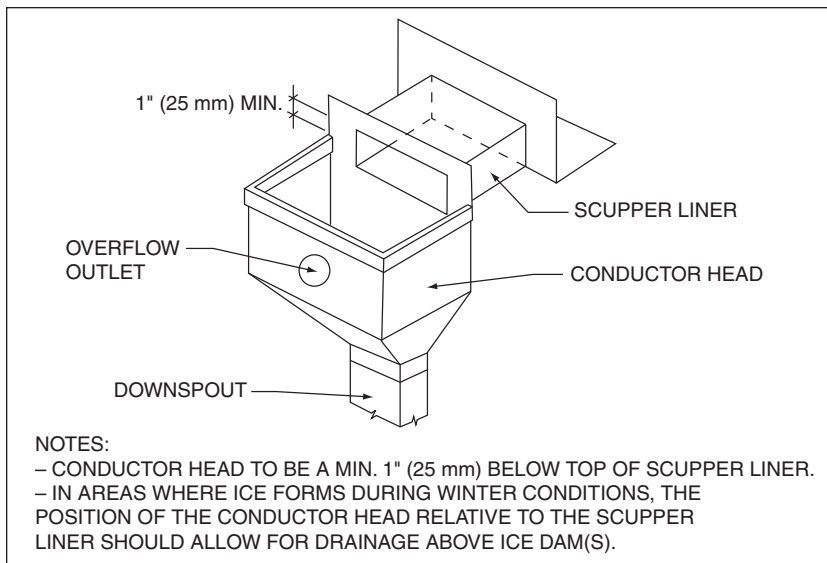


Figure 2.21: Through-wall scupper with conductor head

Either type of scupper can discharge water into a conductor head and downspout, be extended to allow unrestricted discharge of water or can discharge water directly into a gutter. Typically, a through-wall scupper discharges into a conductor head and not a gutter.

It is important to use compatible metals and fasteners when designing the scupper/conductor head/downspout combination, and minimum thicknesses should be 24 gauge (0.025 inch [0.64mm] thick) for galvanized or Galvalume® steel, 0.032 inch (0.8 mm) thick aluminum, 16 ounce (4.9 kg/m<sup>2</sup>) copper, or 26 gauge (0.018 inch [0.46 mm] thick) stainless steel. Greater thicknesses of metal may be required where greater accumulations of ice, snow or debris are expected. If it is not possible to use compatible metals, the metals must be separated with tape or sealant to prevent galvanic corrosion. NRCA suggests avoiding the use of sealants at critical joints in the scupper construction. See Section 1.7, "Galvanic Series," for more information about galvanic corrosion of metals.

If scuppers are the primary drainage devices, the elevation of the base of a through-wall scupper should not inhibit the flow of water and create ponding, and the bottom of the scupper should provide positive drainage away from the roof surface. Keeping the bottom of the scupper at the level of the membrane or insulation may not allow for positive drainage because the addition of the stripping ply—regardless of membrane type—and/or a gravel stop and will tend to prohibit positive drainage at this location. Because there are many seams and component attachments, this area needs to remain free of standing or ponding water. When a scupper is the primary drainage device, NRCA recommends the use of a drainage sump, a tapered insulation, at the scupper opening at the roof side of the scupper. Proper slope of the roof system and installation of crickets between scuppers is necessary.

It is a designer's responsibility to provide drainage amounts, or the sizing of primary and secondary drainage, that meet applicable building code requirements. Overflow scuppers should be positioned at the proper height above the primary drainage location to prevent storm water accumulation on the roof caused by plugged primary drains or high intensity of a storm. A large quantity of water may overload the structure.

### 2.4.1 Through-wall Scuppers

Scuppers are often installed through a parapet wall, directing water to a conductor head and downspout. The conductor head should be wider than the scupper opening, and conductor heads should be attached to the wall securely with the appropriate fasteners. See Figure 2.21.

Overflow openings are recommended in conductor heads when the conductor head surrounds and encloses the scupper opening. If overflow openings are not used, the rim of the conductor head should be installed a minimum of 1 inch (25 mm) below the bottom opening of the scupper.

An exterior closure flange on the scupper is recommended. This should be sealed at the top and side edges to minimize water infiltration at the wall/closure metal juncture. As an alternative, a loose lock connection to the conductor head can be used. On the roof side, the scupper should have a flange that is formed or soldered to the scupper to provide a surface to which the roof membrane is adhered. When a gravel stop is included as part of the scupper, the gravel stop should be V-notched or perforated to allow proper drainage.

## 2.4.2 Open Scuppers

An open scupper is an opening that allows discharge of water through raised perimeter edge metal. See Figure 2.22. The scupper should be fabricated with the same material as the edge metal to prevent galvanic corrosion. Open scuppers may discharge into conductor heads that are attached to downspouts.

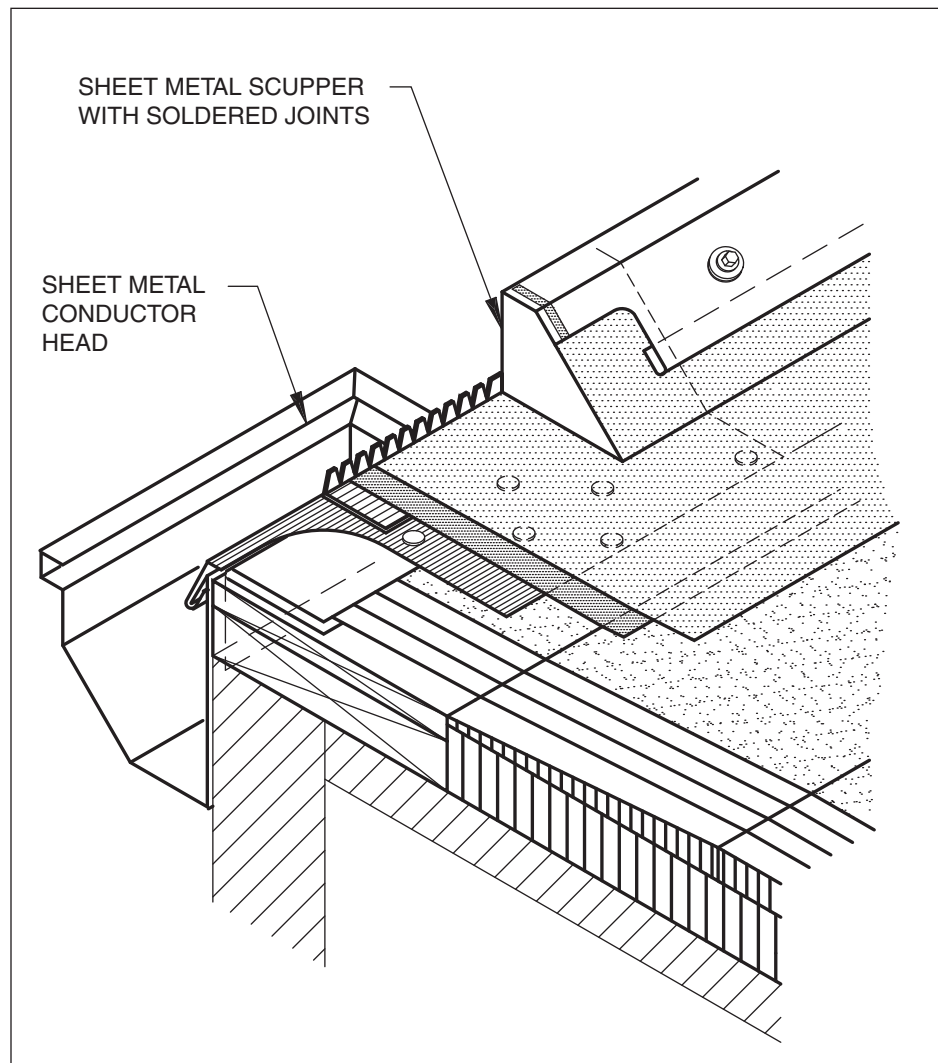


Figure 2.22: Example of open scupper

It is recommended that when open scuppers are used as the primary drainage system, proper slope, tapered sumps at scupper locations and crickets between scupper locations also be used.

## 2.4.3 Scuppers Without Conductor Heads and Downspouts

Where no conductor head and downspout are used, it is recommended that the scupper liner be extended beyond the face of the wall. Extending the scupper liner and adding a drip edge will help prevent water from wicking back under the scupper and into the wall or down the face of the wall. When a conductor head and downspout are not used, it is important to consider the path of discharge and the effects this may have on the face of the wall and adjacent structures.

## 2.5 Perimeter Edge Metal

Perimeter edge metal is a sheet metal roof component designed to provide a continuous finished edge along the outer edges of a roof system. It typically provides a termination point and often secures the perimeter edge of the roofing membrane. It can also help retain loose gravel or ballast at the edge of the roof.

The more common profiles of perimeter edge metal include “A,” “T” and “L” shaped metals, and fascia caps used on raised roof edges. See Figure 2.23. Depending on the design of the roof edge, fascia metal components may also be used with the perimeter edge metal.

Perimeter edge or fascia metal with a large, flat face may have a tendency to oil-can. Intermediate, horizontal stiffening ribs or heavier gauges can reduce the possibility of oil-canning. See Section 3.16.7, “Oil-canning,” for more information about limiting the effects of oil-canning.

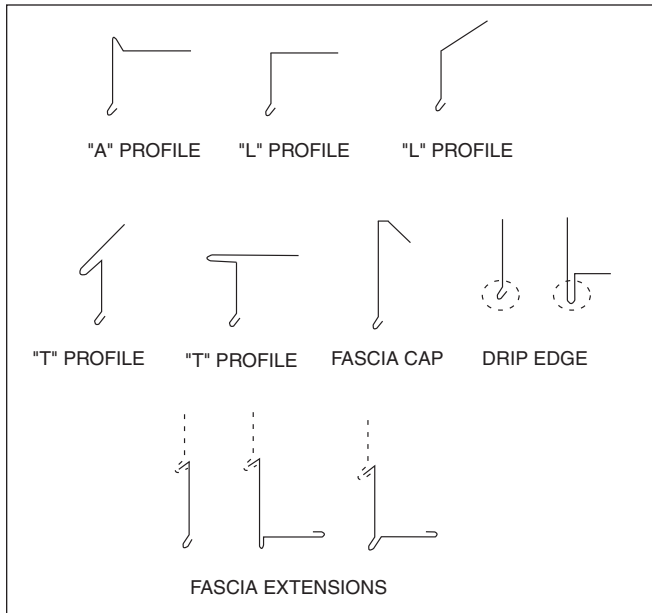


Figure 2.23: Common examples of perimeter-edge metal

Perimeter edge and fascia metal are commonly shop fabricated but can be prefabricated by a manufacturer. Specific information about premanufactured perimeter edge metal can be obtained from product manufacturers.

Perimeter edge and fascia metal can be fabricated from a variety of sheet metals, including aluminum, copper, Galvalume® or galvanized steel, stainless steel and other exterior metals. Aluminum, Galvalume® and galvanized steel are commonly prefinished (painted). Gauges, or thicknesses, of these products vary depending on the type of material used and the length of the vertical face of the gravel stop. See Figure 2.24 for information about metal types, thicknesses/gauge and profile dimensions of perimeter edge and fascia metals.

	"A" Dimension			OVER 8"
	0-3"	3-6"	6-8"	
Aluminum	.032" (.81 mm)	.040" (1.02 mm)	.050" (1.27 mm)	Add Brakes To Stiffen or Use Two Piece Face
Copper	16 oz. (4.87 kg/m <sup>2</sup> )	16 oz. (4.87 kg/m <sup>2</sup> )	20 oz. (6.10 kg/m <sup>2</sup> )	
Galvanized	24 ga. (.64 mm)	24 ga. (.64 mm)	24 ga. (.64 mm)	
Stainless Steel	26 ga. (.46 mm)	24 ga. (.61 mm)	24 ga. (.61 mm)	

Note: For information regarding cleats, refer to the Construction Details section.

Figure 2.24: Perimeter edge and fascia metal profiles, minimum thicknesses, maximum dimensions

End lap joining of perimeter edge metal can be accomplished by following methods:

- concealed joint plates
- cover plates
- overlap joint

For detailed information on these joining methods, see Section 2.9, “Joinery.”

Edge metal/fascia corners should be formed and mitered. Securement of the mitered joint should be accomplished by overlapping and fastening, soldering, sealing or welding, depending on the thickness and type of metal used. Mitered outside leg dimensions should be a minimum of 12 inches (300 mm) in each direction to facilitate joining adjacent components. This will allow for a better fit.

Perimeter edge metals are secured on the face, or exterior, side with a continuous cleat or, less commonly, with exposed fasteners to wood blocking at the edge of the roof. The flange of the perimeter edge metal—with the exception of fascia caps—should be fastened to the blocking at 3 inches (75 mm) on center and staggered using 1¼ inch (32 mm) annular or barbed shank roofing nails, with rows being approximately ¾ inch (19 mm) from the edges of the flange or as required by the roof membrane manufacturer.

Fastening and joining requirements of edge metal used in steep-slope roof application differs greatly from that of low-slope application. Commonly, the ends of edge metals are lapped, not sealed, and are secured in place with fasteners located in the roof-side flange only. Refer to the Steep-Slope section and Low-Slope section of this manual for additional information.

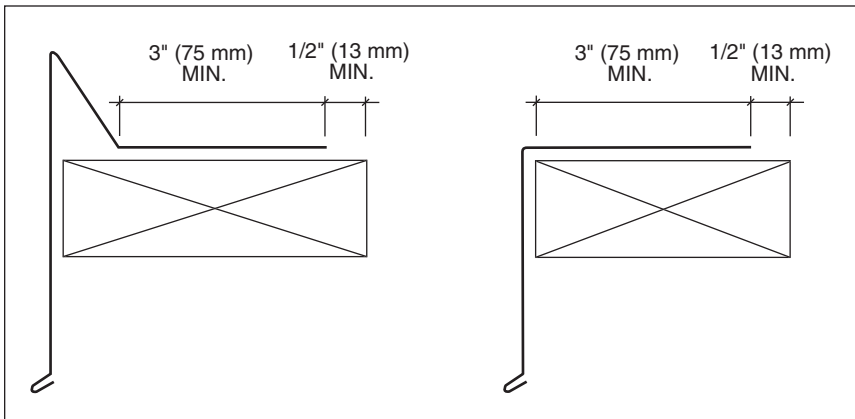
### 2.5.1 “A” Profile Edge Metal

“A” profile edge metal, commonly called “gravel stop,” is often used in low-slope applications. See Figure 2.23. Fabrication of a gravel stop should include a minimum cant-dam height of ¾ inch (19 mm) for gravel surfacings and a minimum 1½ inches (38 mm) for ballast. The height of the cant dam will vary depending on the type and thickness of the ballast used. Gravel stops are either installed at the level of the roof membrane or elevated above the roof membrane by adding another nailer.

For nondraining roof edges, NRCA suggests the perimeter edge metal be elevated slightly above the surface of the roof. Additional blocking and tapered edge strips are typically used to construct an elevated roof edge.

The angle of the cant dam should be 30 degrees to 45 degrees when brake forming to allow for a better fit at end lap locations. The gravel stop fabrication should include a drip edge at the bottom of the vertical face. This design feature will allow for latent rainwater to flow or drip away from the exposed face of the building. It will also allow for vertical face attachment by means of a concealed cleat. The angle of the drip edge should also be between 30 degrees to 45 degrees when break forming and should return upon itself with an open hem design to accept the concealed cleat. This will give the gravel stop a finished, rigid, straight-edge appearance. The roof flange should be a minimum of 3 inches (75 mm), recessed a minimum ½ inch (13 mm) from the back of the wood nailer. See Figure 2.25.

Figure 2.25 Gravel stop and wood blocking



NRCA suggests avoiding, where possible, flashing details that require metal flanges to be embedded or sandwiched into the roof membrane. Because of differing coefficients of expansion and contraction of the metal and roof membrane materials, membrane splits may occur at the end joints of embedded edge metals. A raised perimeter edge with fascia cap is preferred. See BUR-2, MB-2, TP-2 and TS-2 in the Construction Details section.

### 2.5.2 “L” and “T” Profile Edge Metal

“L” profile and “T” profile edge metals, commonly called “drip edge metal,” are used in both low-slope and steep-slope roof systems. See Figure 2.23. For low-slope applications, “L” profile is commonly used with roof systems without an aggregate surfacing or in draining edge locations with smooth-surfaced roof systems.

With watershedding steep-slope roof coverings, such as slate and tile, edge metal, typically “L” profile or “T” profile, may be installed at the roof’s eave and/or rake. In this application, the edge metal is fastened to the deck, with suc-

ceeding pieces overlapped onto the next. It is common that the end joints and corner pieces are not sealed, soldered or welded. Also, edge metal used in steep-slope roof systems – other than metal panel roof systems – with nailable decks typically does not incorporate wood nailers or cleats at the perimeter edge; generally, only the flange of the edge metal is fastened to the deck.

A “T” profile is commonly used as the edge metal at the downslope perimeters and rake edges of metal panel roof systems. The extended flange on the face of the “T” profile edge metal also functions as a cleat that secures the ends of the metal panels along the eave. For metal systems, the “T” profile edge metal is typically secured at its lower edge with a cleat, and the roof flange is fastened to the deck.

### **2.5.3 Fascia Cap Edge Metal**

Fascia cap edge metal is used in low-slope roof systems and is preferred because its design does not require the edge metal to be embedded or sandwiched into the roofing membrane. See Figure 2.23. Because of differing coefficients of expansion and contraction of the metal and roof membrane materials, membrane splits may occur at the end joints of embedded edge metals. Fascia cap edge metal is typically installed over wood cants—often 4 x 4s ripped diagonally. The wood cants can be directly fastened to nailable substrates. Where non-nailable substrates exist, a wood nailer bolted to the substrate to serve as a base layer for attachment may be necessary. The roof membrane is installed to the top of the wood cant and a secondary stripping ply, that is a base flashing, is installed over the cant down the face of the wall behind the cleat. Some prefabricated edge metal systems incorporate a raised profile design and do not require a wood cant.

NRCA suggests avoiding, when possible, flashing details that require metal flanges to be embedded or sandwiched into the roof membrane. Because of differing coefficients of expansion and contraction of the metal and roof membrane materials, membrane splits may occur at the end joints of embedded edge metals. A raised perimeter edge, or fascia cap, is preferred.

### **2.5.4 Fascia Metal**

Depending on the design of the roof edge, fascia metal components may also be used with perimeter edge metal. Extension pieces, called fascia extenders, are commonly used with perimeter edge metal for aesthetic reasons or to provide further weather protection along the top of the exterior building wall. See Figure 2.23. Fascia metal designs may even include elaborate metal cornice components or other ornamental metal work.

A fascia metal extender should be used when the face of the perimeter edge metal exceeds 8 inches (200 mm). This extending metal typically is formed with a raw, unhemmed edge at the top and a drip edge at the bottom. At joints, alignment should be maintained, and openings in butt or lap joints should be avoided. The fascia should be secured with the appropriate fasteners depending on substrate type.

When the face dimension of fascia metal exceeds 8 inches (200 mm), special considerations are required, such as stiffener ribs, multiple fascia pieces or alternative fascia cladding systems. Stiffening ribs should not hold water.

## **2.6 Counterflashing**

A counterflashing is defined as a formed metal component secured on or into a wall or curbing or to another component, such as a vent, conduit or mechanical unit, to cover and protect the upper edge of the membrane base flashing or underlying metal base flashing and its associated fasteners from mechanical damage and exposure to the weather. Counterflashings also provide additional weather protection at roof system interruptions, directional changes, penetrations and terminations. See Figure 2.26 for examples of counterflashing options

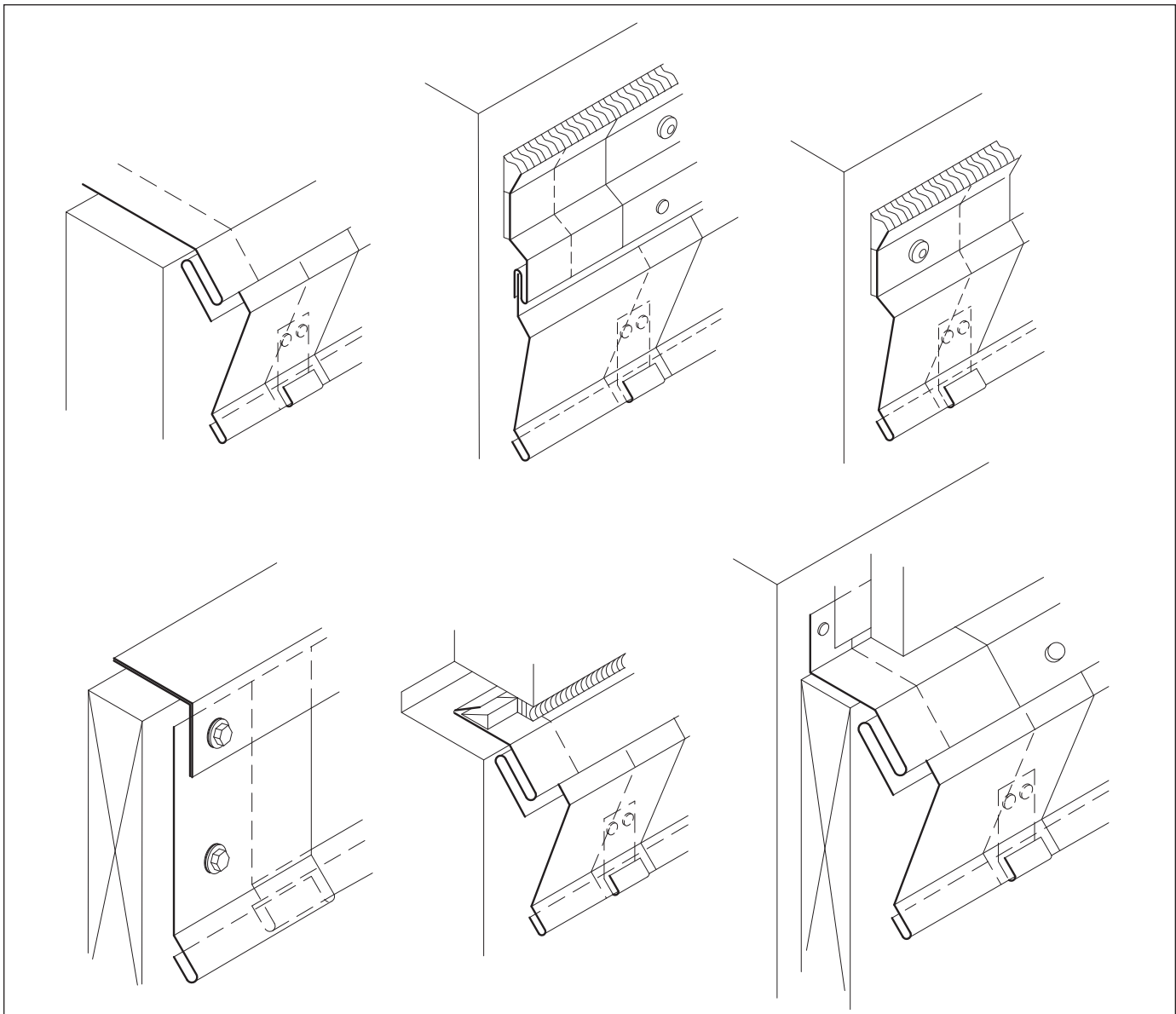


Figure 2.26: Common counterflashing options

There are numerous styles of counterflashing, which can be formed from many types of metals. The styles range from pre-manufactured metal sections for applications with membrane roof systems to pre-manufactured sections as a component of a metal roof system to various styles of shop-fabricated metal. Depending on the type or intricacy of construction, counterflashing may be extensive and cover multiple surfaces, sometimes in combination with other metal components.

Counterflashing typically is fastened to the substrate above the termination of a roof system or roof component it is protecting. This allows for independent movement of the roof system in relation to the counterflashing. Counterflashing in conjunction with masonry walls, where the roof assembly is sloped, may require “stepped” counterflashing.

The Construction Details section has details and figures depicting typical construction scenarios using metal counterflashing.

There are two general categories of counterflashing:

- counterflashing at walls
- counterflashing at roof penetrations

Counterflashings should extend over the top of the base flashings approximately 4 inches (100 mm) and have a ½ inch (13-mm) minimum drip edge at the bottom. Counterflashing joints may be lapped, lapped and sealed,

fastened, welded or soldered. If a joint is welded or soldered, the counterflashing system should be designed to allow for expansion and contraction within the system. Counterflashing joints should be 3 inches (75 mm) minimum and sealed.

In some applications, counterflashing may need additional securement, such as face fasteners or clips, along the lower edge for added wind-uplift resistance and weatherproofing integrity and should typically be flush with the base flashing.

Care must be taken to isolate dissimilar metals that will have a galvanic reaction. See Section 1.7, “Galvanic Series,” for more information about galvanic corrosion. Counterflashings and receiver flashings may come into contact with nonmetallic materials that can cause corrosion or staining. For example, unfinished aluminum counterflashings that contact mortar are apt to corrode quickly.

### **2.6.1 Counterflashing at Walls**

Counterflashing is used at walls to protect the top edge of the base flashing membrane and typically is of one- or two-piece design. NRCA suggests that counterflashing at walls follow a two-piece design that incorporates a “receiver” (i.e., reglet) for ease of installation and future maintenance and repair/replacement. A reglet may be inset into a raggle, embedded behind cladding, formed as part of a through-wall flashing, or surface-mounted. If the receivers are surface-mounted, the metal counterflashing should be set in an elastomeric sealant tape. Additionally, the top edge should have a formed edge to receive an appropriate sealant. See Figure 2.26, items 2 and 3. Counterflashing is anchored to the hemmed edge of the receiver with mechanical fasteners or locking-type metal clips or may be a self-locking joint configuration.

### **2.6.2 Counterflashing at Penetrations**

Counterflashing is also used to complete the roof system at roof penetrations, such as roof curbs, skylights, pipe or conduit penetrations, and chimneys. A “slip” type counterflashing is commonly used at curbed mechanical equipment or skylights; it is slipped under the curb’s counterflashing to cover and protect the roof’s base flashing membrane at this location. Sheet-metal rain collars are typically fastened to pipes, flues or conduit, which do not occur through a roof curb, to shield the penetrations’ base flashings.

### **2.6.3 Through-wall Flashings**

Walls or cladding materials of a porous nature, such as masonry, are recommended to incorporate a through-wall flashing to prevent moisture transfer or migration from entering and damaging the roof system. Proper design of through-wall flashing location and slope is essential. Through-wall flashings are often installed by other tradespeople, such as masons, during the initial construction of a building. It is important that designers understand the nature and porosity of the cladding or wall materials used and specify through-wall flashings, when appropriate. Adding through-wall counterflashing after-the-fact is a costly procedure but may be necessary to properly weatherproof and seal building surfaces that can affect the roof system.

Common metals used for through-wall flashings are copper and stainless steel. Longevity of the through-wall flashing material is important; the service life of a material should match that of the building’s. For masonry walls, aluminum should be avoided because of the high alkaline content of the wall and risk of corrosion.

## **2.7 Expansion Joints**

Roof expansion joints are used to minimize the effects of stresses and movements of a building’s components. The effects of these stresses have the potential to cause damage to the roof system by splitting, buckling or ridging. Expansion joints in a roof assembly must be located in the same location as the building – structural expansion joints—although they may be required in other locations. Each of a building’s components has varying coefficients of expansion and contraction, and each of them is subjected to varying temperature changes and resulting thermal movement. See Figure 2.27. For new construction, it is the designer’s responsibility to account for building movement and the placement of expansion joints.

In the case of metal components, the expansion and contraction that take place with changes in temperature can cause severe problems if it is not accommodated for in the design and construction. Expansion and contraction factors are often overlooked or regarded as insignificant. The lack of or improper placement of expansion joints can result in ruptured or loosened flashings or even a failed roof system. Metal panel roof systems can be the least forgiving of all roof systems if provisions for expansion and contraction are omitted during the design of the system.

Metal Type	Coefficient of Thermal Expansion	Increase in 10 Foot Lengths per 100° F Temperature Change
Galvanized Steel	0.000067 in./in./°F	.080 in.
Steel	0.000067 in./in./°F	.080 in.
Terne	0.000067 in./in./°F	.080 in.
Wrought Iron	0.000067 in./in./°F	.080 in.
Monel	0.000078 in./in./°F	.094 in.
Copper	0.000094 in./in./°F	.113 in.
Stainless Steel	0.000096 in./in./°F	.115 in.
Bronze	0.000101 in./in./°F	.121 in.
Brass	0.000104 in./in./°F	.125 in.
Aluminum	0.000129 in./in./°F	.155 in.
Lead	0.000151 in./in./°F	.193 in.
Zinc	0.000174 in./in./°F	.209 in.

Figure 2.27: Expansion coefficients of common building materials

In the design and placement of roof expansion joints, NRCA recommends the designer consider the following:

- The thermal movement characteristics of the building. Factors such as a building’s size, components, interior use, orientation to the sun and the resulting heat load contribute to the overall thermal movement of the building. In general, larger buildings will be subjected proportionally more to overall thermal movement than smaller ones. Also, the sun will induce more thermal stress on the exposed side of a building than the shaded portion.
- The structural supports and roof deck. Because of the many possible combinations of weatherproofing elements and substrates, the relative dimensional stability of a roof and underlying deck or substrate are key factors in the design and placement of roof expansion joints.
- The roof system selected. A roof membrane is the first line of defense against sun, rain, wind, etc. The seasonal cycles of wind, precipitation and temperatures, as well as daily cycles of heating and cooling, must be accommodated by the roof system, substrate and other building components. Although all conventional roof systems can accommodate expansion and contraction to some extent, the specific systems and materials selected will have their own sets of parameters to handle thermal stress. Expansion joints and/or area dividers should be designed and installed accordingly.
- The climatic conditions to be encountered. Because thermal expansion and contraction are functions of changes in temperature, providing for them will be most important where the greatest temperature swings are prevalent. Roof systems can experience “thermal shock” caused by extreme temperature variations occurring in short periods of time, sometimes in only a few seconds. Rapid roof surface temperature swings of 100° F (38° C) or more, for example from sudden rainstorms rapidly cooling a surface area, are common for roof systems, and the need to address the resulting expansion and contraction will be a critical design consideration.

NRCA recommends raised curb-type expansion joints be designed and installed in most geographic locations. Drainage of the roof must be coordinated with the overall roof expansion joint layout to prevent damming of water and provide for the free flow of water to interior roof drains or to the perimeter scuppers or eave.

Roof expansion joints should be provided at the following locations:

- Where expansion joints are provided in the structural assembly. It is simply good practice to allow a structural assembly to move.
- Where steel framing, structural steel or decking change direction. Independent movement because of thermal stress occurs typically with structurally independent components. Thermal movement is also directional. For example, steel decks will expand and contract along the length of the flutes. Therefore, where flute direction changes, thermal stresses will occur in different directions. Good practice dictates that this movement be anticipated and accommodated for within the roof system.
- Where separate wings of “L,” “U,” or “T” shaped buildings or similar configurations exist. Again, structurally isolated or independent building segments should be viewed as moving independently of adjacent segments.
- Where the type of decking changes. Where the composition of roof decks differs, so do the coefficients of expansion and contraction. Failure to recognize this difference could result in greater than normal stress at that junction.
- Whenever additions are connected to existing buildings. As stated previously, independent building segments will exhibit independent or different thermal stresses. The junction between a new and an existing building creates a natural place for differential movement to manifest itself.

- At junctions where interior heating conditions change, such as a heated office abutting an unheated warehouse, canopies, etc. The ambient deck and structure temperatures can be vastly different at an unheated warehouse and above a heated office. Differential deck movement because of thermal stress is likely where the temperature of the deck and roof vary.
- Wherever differential movement between vertical walls and the roof deck may occur. The fixed nature of a vertical wall creates an independent structural segment (or part), and the roof area must be allowed to expand and contract within itself. This is true where interior structural or fire walls separate roof areas. The roof areas can be at the same level (elevation), or one roof area can be higher. Shear movement and the subsequent stresses occurring along this joint caused by temperature changes are a result of the difference in the coefficient of expansion of the materials of which the wall is constructed compared to the material of which the roof is constructed. Building sway can be caused by wind loading or seismic activity and settlement resulting in the roof moving laterally at the roof or wall joint.

Where expansion joints are necessary, both the structural and roof expansion joint should occur in the same location, extend across the entire width of the roof, and continue through to the roof edge or perimeter. Expansion joints should be designed to accommodate contraction, as well as expansion. For most low-slope membrane systems, expansion joints should be detailed and constructed to a height of 8 inches (200 mm) above the finished roof membrane. Typically, wood curbing secured to the substrate on both sides of the joint is flashed with the appropriate roof membrane. An expansion joint cover is then installed.

There are three common types of expansion joint covers.

1. Brake-formed sheet-metal cover. This type of expansion joint cover is of a two- or three-piece design to accommodate movement. The metal cap is generally formed in 8-foot, 10-foot or 12-foot (2.4-m, 3.0-m, or 3.7-m) lengths, and the end joints receive a cover piece or are joined with a drive-cleat or standing seam. See Figures 2.28 and 2.29.
2. Premanufactured joint cover. These covers are typically a one-piece design that contain a bellows in the center of the cover to accommodate movement. Premanufactured expansion joint covers are available in different lengths, and the end joints require seaming or membrane splices, depending on the material type.
3. Hidden joint cover. This type of expansion joint cover is used in some thermoset roof membrane systems. It should only be used with loose-laid, unreinforced, ballasted roof systems that are able to accommodate movement at the expansion joint. The joint in the deck is covered with a sheet metal plate fastened only on one side of the joint. The loose-laid, unreinforced, ballasted roof system is installed over the metal plate.

With certain loose-laid single ply roof membranes capable of extensive elongation, such as unreinforced, ballasted EPDM, a below-membrane or concealed type of expansion joint may be applicable in certain climates. However, NRCA recommends raised curb-type expansion joints be designed and installed in most geographic locations. Water drainage should never be designed to go through or over a raised expansion joint.

The use of low-profile area dividers that are designed to be installed in the horizontal plane of the roof is not recommended. If roof area dividers are to be used, raised curbs are recommended.

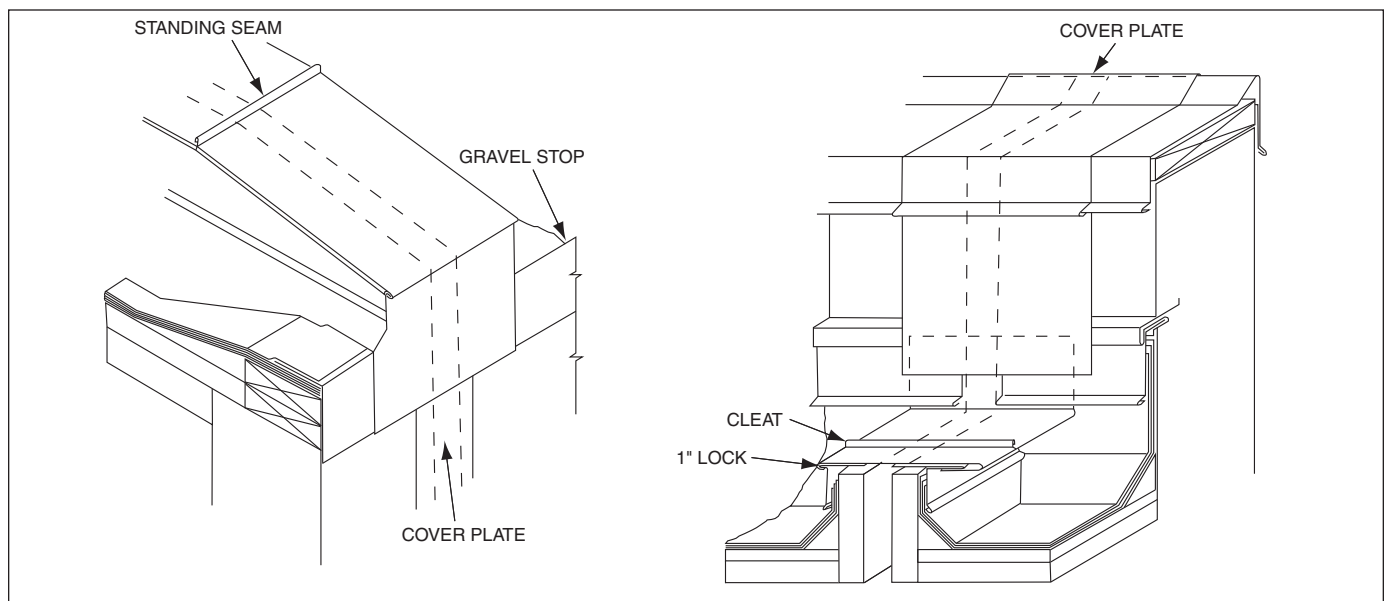


Figure 2.28: Expansion joints at parapet wall and roof edge

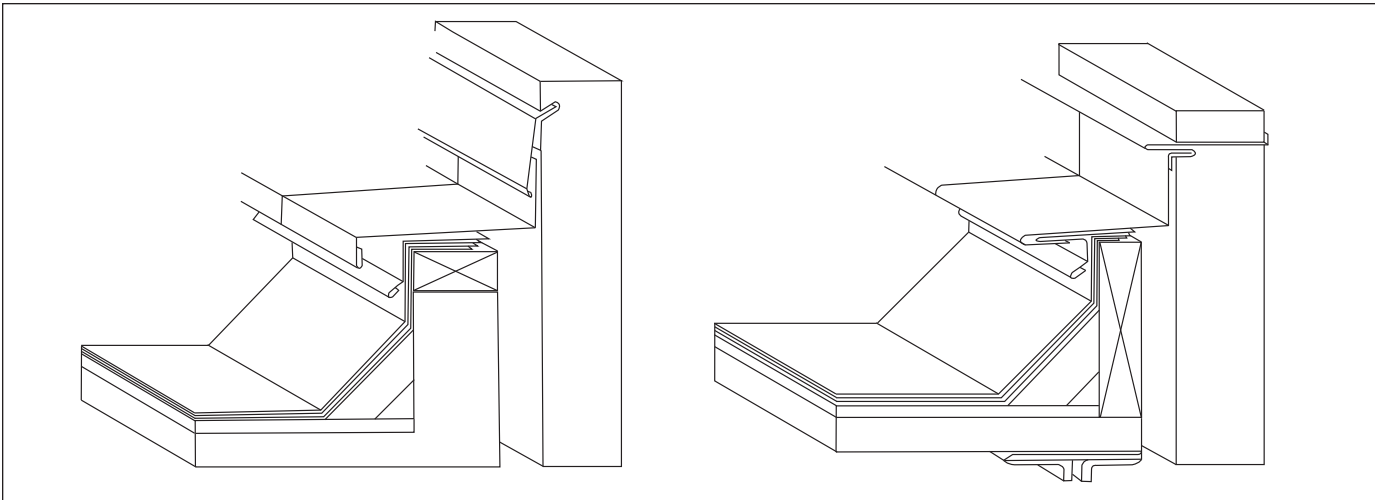
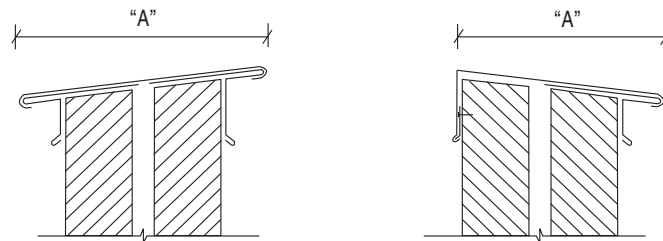


Figure 2.29: Expansion joint along parapet wall

See Figure 2.30 for information on minimum material thicknesses/gauges and maximum dimensions for sheet metal expansion joint covers.

	"A" DIMENSION		
	UP TO 12 INCHES (300 mm)	12 INCHES TO 18 INCHES (300 mm to 460 mm)	MORE THAN 18 INCHES (460 mm)
ALUMINUM	.032" (.81 mm)	.040" (1.02 mm)	ALTERNATIVE DETAILS AND MATERIALS MAY BE REQUIRED
COPPER	16 oz. (4.87 kg/m <sup>2</sup> )	20 oz. (6.10 kg/m <sup>2</sup> )	
GALVANIZED	24 ga. (.64 mm)	24 ga. (.64 mm)	
STAINLESS STEEL	26 ga. (.46 mm)	24 ga. (.64 mm)	

Figure 2.30: Expansion joint cover profiles, thicknesses, dimensions



## 2.8 Area Dividers

NRCA formerly recommended that roof area dividers be considered for all types of roof membrane systems. In earlier editions of The NRCA Roofing and Waterproofing Manual, NRCA recommended that roof area dividers be required for attached and adhered membrane systems at intervals of 150 feet to 200 feet (45 m to 61 m). These recommendations were based on the experience of professional roofing contractors working primarily with organic felt built-up roof (BUR) membranes. More recently, experience with other types of membranes, such as BUR membranes with fiberglass felts, modified bitumen membranes, and thermoplastic and thermoset single-ply membranes, has proved that roof area dividers may not be required at 150-foot to 200-foot (45-m to 61-m) intervals or may not be required at all. Designers should consider climatic conditions and regional practices and check with membrane manufacturers to determine their recommendations for the necessity of roof area dividers.

It should be noted that roof area dividers may perform some important functions, regardless of whether they are required or recommended by membrane manufacturers. In climates where there are protracted periods of freeze-thaw cycles and expansion joints are not provided, roof area dividers may help control thermal stresses in the roof system—the term roof system does not include the roof deck. Roof area dividers may also be used to divide the roof into smaller sections, facilitating periodic maintenance and future reroofing.

A roof area divider is a raised curb, attached to the structural deck and then properly flashed. If roof area dividers are used, they should be flashed to a minimum height of 8 inches (200 mm) above the roof surface and located at high

points in the roof with drainage away from or parallel to the divider. Roof area dividers should not restrict or impede drainage.

The use of low-profile control joints that are designed to be installed in the horizontal plane of the roof is not recommended. Movement of the membrane on either side of these control joints may cause separation of the membrane and control-joint interface. These separations, because they are not raised above the plane of the membrane, can allow water to leak into the roof assembly. If roof area dividers are to be used, raised curbs are recommended.

## **2.9 Joinery**

Joinery is the method of joining two or more pieces of sheet metal. Joints can be made with mechanical fasteners, interlocking seaming methods, sheet-metal cover plates, sealants, metals (e.g., solder, welding) or combinations of these methods. See Figure 2.31. The type of joinery used is dependent on the function and location of the sheet-metal joint, its exposure or susceptibility to water infiltration and type of metal used. Some joints are constructed to simply be watershedding in nature, while others require a more weatherproof seal. Metal roof panels, copings, edge metals, gutters, downspouts, scuppers and counterflashings require some method of joinery to complete their fabrication or connect these components to other metal components.

The joinery of sheet metal uses one or more of the following:

- mechanical fasteners
- interlocking seaming methods
- sheet-metal cover plates
- sealants
- metals—soldering or welding

Many times, a combination of these methods is used to join the sheet metal components.

### **2.9.1 Joints With Mechanical Fasteners**

Screws, bolts and rivets are perhaps the simplest and most common method of joining two pieces of sheet metal. For roofing applications, it is often necessary to have a weatherproof joint. The use of mechanical fasteners for joints may prove difficult to keep weatherproof.

Mechanical fasteners used in conjunction with other materials, such as sealant, gaskets or solder, can provide a weatherproof joint. Sheet metal joined by back sealing, installing pop rivets and face sealing is one method. Sheet metal joined by soldering and pop riveting is another method.

### **2.9.2 Joints Without Soldering or Welding**

For joinery of sheet-metal components without the use of soldering or welding, NRCA recognizes a number of joining methods. Prepainted metals and nonsolderable metals are commonly joined with these methods because the coating does not allow for soldering or welding. Refer to Figure 2.31.

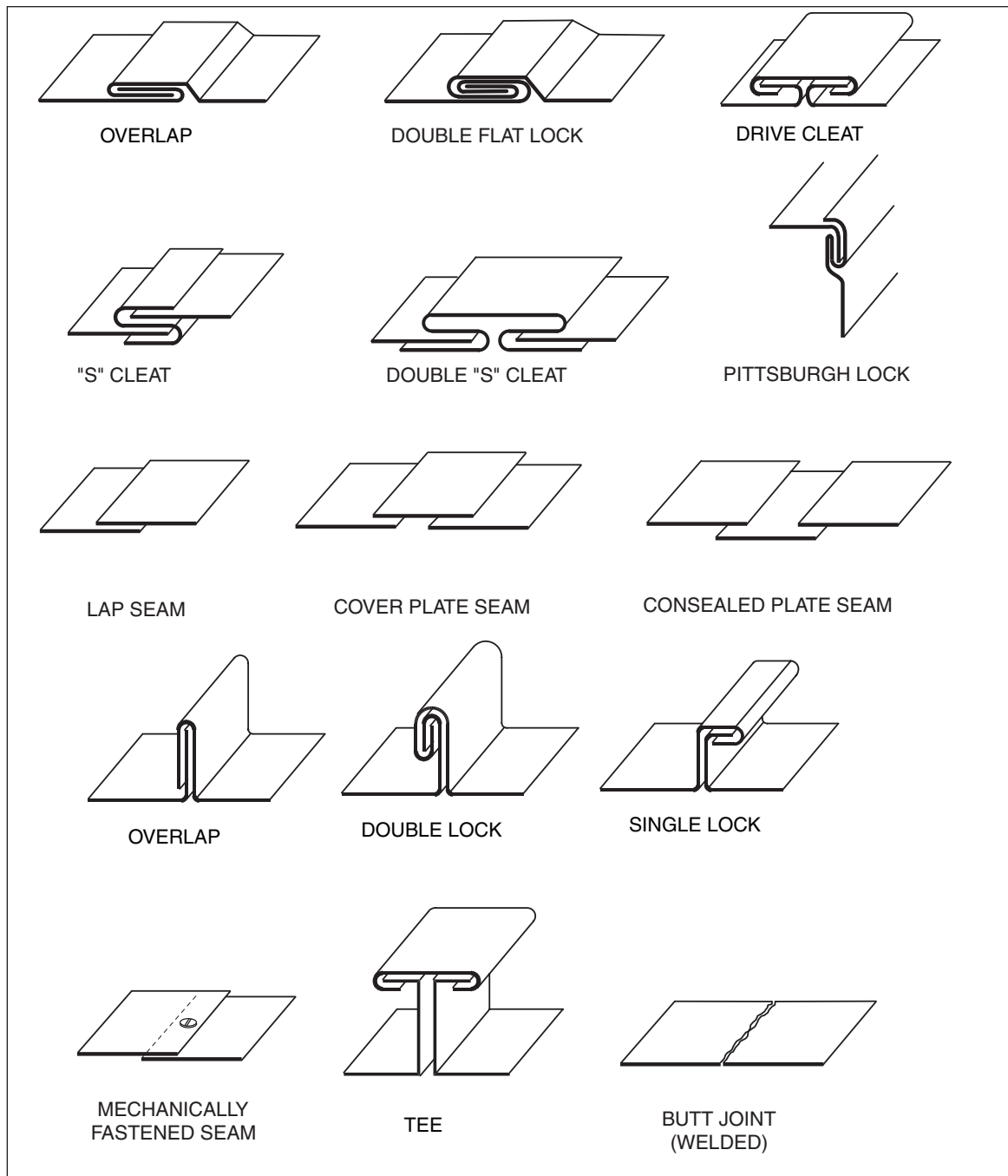


Figure 2.31:  
Examples of  
common joinery  
methods

The following are methods for joining metal components:

- Overlap standing seam. A minimum  $\frac{7}{8}$  inch (22 mm) high female leg should be installed over the adjoining metal shape's male leg and crimped to complete the seam. Sometimes sealant is installed in the female leg before installation of the metal shape to provide additional weatherproofing capabilities. For example, the seam is secured by the button-punch method or with rivets.
- Double lock standing seam. A minimum  $\frac{7}{8}$  inch (22 mm) high female leg should be installed over the adjoining metal shape's male leg. The legs are folded over themselves twice to complete the double lock seam. Double lock standing seams are generally weatherproof without the addition of sealants or sealant tapes.
- Drive cleat seam. A minimum 2-inch (50-mm) wide folded drive cleat should be installed over the folded ends of two metal shapes. The space between the ends of the metal shapes will vary depending on type of material used, gauge thickness and building locale.
- Exposed cover plate seam. A minimum 6-inch (150-mm) wide exposed joint cover plate should be installed, evenly

divided and placed, over the two edges of adjacent metal pieces. It should be attached separately allowing the metal pieces to act independently during thermal movement. The space between the ends of the adjacent metal pieces will vary depending on type of material used, gauge thickness and building locale. Each side of the space requires sealant; a minimum of two beads of sealant should be installed under the cover plate.

- Concealed backer plate seam. A minimum 6-inch (150-mm) wide concealed joint plate should be installed, evenly divided and placed, under the two edges of adjacent metal pieces. It should be attached separately allowing the metal to act independently during thermal movement. The space between the ends of the adjacent metal pieces will vary depending on type of material used, gauge thickness and building locale. Each side of the space requires sealant; a minimum of two beads of sealant should be installed under the cover plate.
- Cover plate with backer plate seam. A minimum 6-inch (150-mm) wide concealed joint plate and exposed joint plate should be installed, evenly divided and placed, between the two edges of adjacent metal pieces. It should be attached separately allowing the metal pieces to act independently during thermal movement. The space between the ends of the adjacent metal pieces will vary depending on type of material used, gauge thickness and building locale. Each side of the space requires sealant; a minimum of two beads of sealant should be installed under the cover plate.
- “S” cleat seam. A minimum 2-inch (50-mm) wide “S” cleat should be installed between the unhemmed ends of two metal shapes. Sealant is recommended to be installed in the female legs before installation of the metal shape to provide additional weatherproofing capabilities. The space between the ends of the metal shapes will vary depending on type of material used, gauge thickness and building locale.
- Lap seam. Simple joinery consists of overlapping the adjacent ends of two pieces of sheet metal. Sometimes mechanical fasteners or rivets are used to secure the metal in place. Succeeding pieces of metal, lapped a minimum of 3 inches (75 mm) over the preceding pieces, should be installed. A notch can be cut into the return hem along the bottom edge of the metal that receives and locks in place the preceding piece. For weatherproof installations, sealant is required in the seam.

Crimping and locking is a typical method used to join laps in sheet-metal components. For example, a standing seam is a locking type of seam. Also, for example, at the outer face of a through-wall scupper where the scupper overlaps the flange, the two pieces of metal are crimped and locked together. Copings and cleats are joined in the same fashion. The gauge of metal must be considered when designing the joinery detail.

### 2.9.3 Metallurgical Joints

Metallurgical joints are those that form a chemical bond, such as soldered or welded joints, between two metal shapes. Aluminum, copper, steel and stainless steel can be metallurgically joined with proper preparation. The final appearance and color of certain metals and metal finishes will be changed because of the installation of metallurgical joints.

Welding or soldering creates a fixed joint that is not capable of accommodating expansion or contraction. To provide for movement, unfixed joints may be necessary near fixed joints.

METAL TYPE	SOLDERABLE	WELDABLE
Aluminum, 0.063" (1.6 mm)	No	Yes
Aluminized Steel	No	No
Copper, 16 oz. (4.9 kg/m <sup>2</sup> )	Yes	No
Galvalume®	No	No
Galvanized Steel, 22 ga. (0.031 inch [0.79 mm])	Yes	Yes
Galvanized Steel, 26 ga. (0.019 inch [0.48 mm])	Yes	No
Lead, 2 lb. (9.8 kg/m <sup>2</sup> )	Yes	No
Lead-coated Copper, 16 oz. (5.2 kg/m <sup>2</sup> )	Yes	No
Stainless Steel, 22 ga. (0.029 inch [0.74 mm])	Yes	Yes
Stainless Steel, 28 ga. (0.015 inch [0.38 mm])	Yes	No
Terne-coated Stainless Steel, 0.015 inch (0.38 mm)	Yes	No
Zinc, 0.027 inch (0.7 mm)	Yes	No

Figure 2.32: Weldable metals based on thicknesses

Note: Lighter gauges than those listed may be metallurgically joined depending on equipment and operator skill.

## **3. FUNDAMENTALS OF METAL ROOF SYSTEMS**

### **3.1 Introduction**

There is a wide variety of metal panel roof systems on the market today. Some metal panel roof panel systems are shop-fabricated with stationary equipment, some are field-fabricated with portable equipment and some are factory-formed by manufacturers that market their metal panel roofing products to contractors throughout the U.S. As with traditional steep-slope and low-slope membrane roof systems, there is no one system that is best for all applications.

When choosing a metal roof system, the designer must carefully consider the following:

- the project's requirements
- whether the roof will be steep- or low-slope
- whether continuous or closely spaced decking will be used to support the panels or whether panels will be required to span between structural members
- the system's exposure to climatic and environmental conditions
- moisture control and ventilation for interior conditions
- aesthetic characteristics of the roof system
- the desired life expectancy and potential maintenance
- applicable code requirements

A complete list of criteria to consider before designing a roof system is located in the Foreword of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*.

The service life of a metal panel roof system varies depending on metal type, configuration, slope of substrate and environment. As systems age, they also require varying degrees of maintenance during their service lives. Only after considering these kinds of design criteria can the correct metal panel roof system be selected.

### **3.2 System Types**

Metal panel roof systems are traditionally divided into two categories: architectural and structural. Metal panel roof systems can have substantially different aesthetic and performance characteristics, as well as different design requirements. It is important the correct system be selected for each specific application. An architectural metal panel roof system is similar to and a viable substitute for a traditional steep-slope shingled roof, in that it is considered to be a watershedding flat roof system (i.e., hydrokinetic) rather than a water barrier (i.e., hydrostatic) roof system. An exception is a flat-seamed, soldered metal (e.g., copper) panel over a continuous or closely spaced substrate. Some structural metal panel roof systems may be compared to traditional low-slope roof membrane systems because they are designed to resist moisture infiltration on low-slope applications.

Historically, copper, terne, light-gauge aluminum, light-gauge stainless, zinc, tin, light-gauge galvanized steel, lead and lead-coated copper sheets used for roofing have been considered nonstructural, or architectural metal panel roof systems, and therefore require a continuous or closely spaced substrate. All the metal types listed in Section 1 can be used to construct architectural metal panels. Structural metal panels typically are constructed from steel, Galvalume®, galvanized or stainless steel, or aluminum.

The following is a more detailed explanation of architectural and structural metal panel roof systems.

#### **3.2.1 Architectural Metal Panel Roof Systems**

Architectural metal panel roof systems are typically hydrokinetic, or watershedding, roof systems. They are designed to shed water rapidly over the surface of the panels, so the seams are not necessarily watertight. For the panel to shed water rapidly, the roof must have adequate slope. Architectural metal panel roof systems perform well on slopes of 3:12 (14 degrees) or greater. For lower slopes, climatic conditions must be carefully considered, particularly the amount of expected ice, snow and debris accumulation, and sealant or sealant tape, such as butyl, may need to be used in the interlocking ribs. Architectural metal panel roof systems require continuous or closely spaced decking. A minimum underlayment of a No. 30 asphalt-saturated felt underlayment and separate slip sheet, such as rosin-sized sheathing paper or underlayment with slip-sheet capabilities, is recommended. Metal panel manufacturers should be consulted for specific underlayment requirements. With architectural metal panel roof systems, an ice dam protection membrane is recommended where the January mean temperature is 30° F (-1° C) or less or where building codes mandate it. Also, for some types of metal, ventilation at the underside of the architectural metal panel may be necessary.

Architectural roof panels are usually characterized by a flat pan with a  $\frac{7}{8}$ -inch to  $1\frac{1}{2}$ -inch (22-mm to 38-mm) high rib on each side. The absence of intermediate ribs and large side ribs provides the panels with a clean appearance, but these panels typically do not have adequate strength for use without a continuous or closely spaced substrate.

Metal panels classified as “structural panels” can also be used as architectural metal panels; however, the reverse is not necessarily true. See Section 5, “Structural Metal Panel Roof Systems,” for more information about structural systems. For more detailed information about architectural systems, see Section 4, “Architectural Metal Panel Roof Systems.”

### 3.2.2 Structural Metal Panel Roof Systems

Structural metal panel roof systems are typically hydrostatic, or water-barrier, roof systems. They are designed to resist the passage of water at joints, laps and junctures under hydrostatic pressure. These roof systems have the strength and capability of spanning structural members such as joists or purlins without being supported by a continuous or closely spaced roof deck and, in most configurations, do not require an underlayment. NRCA recommends  $\frac{1}{2}$  inch per foot (2.4 degrees) as the minimum slope for structural metal panel roof systems, even though numerous manufacturers allow structural systems to be installed on slopes as low as  $\frac{1}{4}$  inch per foot (1.2 degrees). The  $\frac{1}{2}$ -inch-per-foot (2.4 degrees) recommendation helps provide for positive drainage and accommodates the effects of construction tolerances and deflections over time, as well as differences in seam height. Structural metal panel roof systems that can incorporate a sealant in the seam or an anticapillary hem are alternatives to some low-slope membrane roof systems. Structural metal panels typically derive their strength from panel and seam configuration, and the use of heavier gauges of metal. These panels are profiled with high side ribs with stiffening ribs, or intermediate ribs or fluting located in the pan. Structural metal panels also can be used as architectural metal panels.

For more detailed information about structural systems, see Section 5, “Structural Metal Panel Roof Systems.”

### 3.2.3 Metal Shingles and Shingle Panels

There are numerous metal shingles and shingle panels that are marketed for use as steep-slope roof coverings. See Figure 3.1 for some typical configurations of metal shingles and shingle panels. Most metal shingles and shingle panels are press-formed during the manufacturing process to provide a variety of shapes. These products can take the shape of individual or multiple asphalt, tile, slate, or wood shingle configurations. They also can be formed in various shapes and in single or multiple courses.

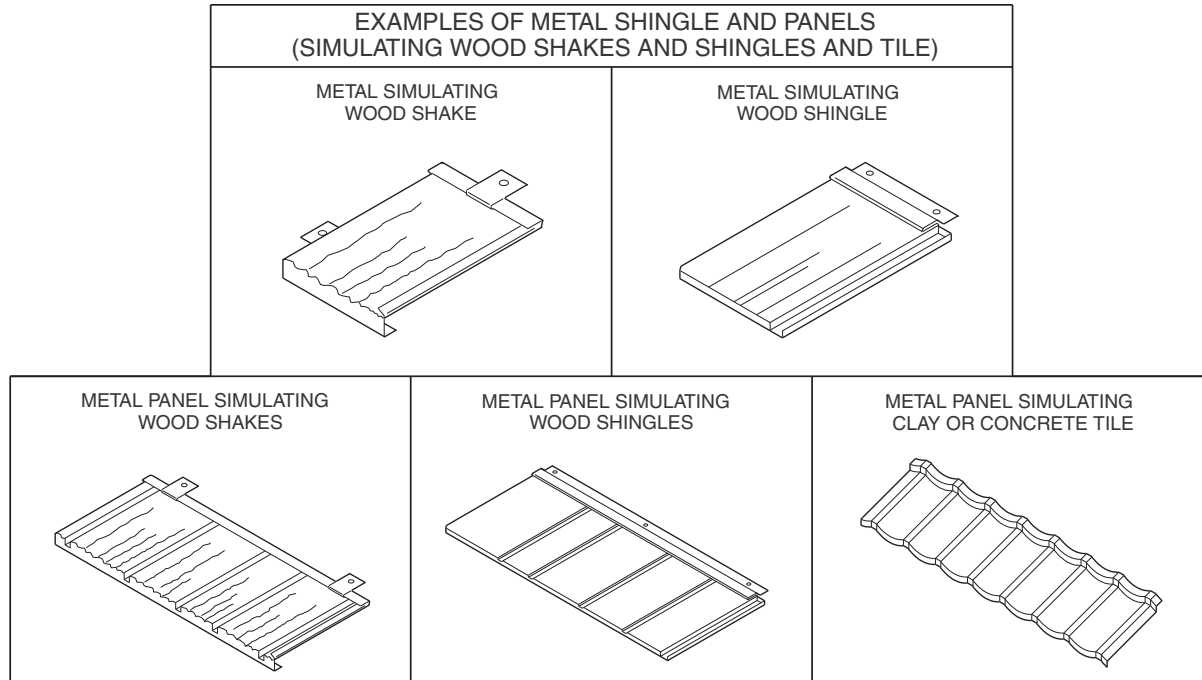


Figure 3.1:  
Examples of  
metal  
shingles and  
shingle  
panels

Metal shingles and shingle panels are interlocked or overlapped and may be clipped or directly fastened to the deck. Metal shingles and shingle panels are typically considered to be watershedding roof systems. They are designed to shed water rapidly over the surface of the panels, so metal shingles and shingle panels are not necessarily considered weatherproof. For metal shingles and shingle panels to shed water rapidly, the roof must have a slope of 3:12 (14 degrees) or greater. For lower slopes, climatic conditions must be carefully considered, particularly the amount of expected ice, snow and debris accumulation.

Wide varieties of metals are used for the manufacture of metal shingles and metal panels. See Section 1, “Fundamentals of Metal Used for Roofing,” for information about various types of naturally weathering metals and metals that required a protective coating.

Metal shingles and shingle panels may be coated with ceramic granules or crushed stone chips that are adhered to the base metal as a protective coating and for aesthetic reasons. They can also be coated with a clear acrylic-based glaze, which is applied to the top finish coating.

Application requirements depend on a product’s profile, type of design and sheet-metal flashing requirements. The product manufacturer’s design and application literature should be consulted.

Metal shingles and shingle panel roof systems are installed over continuous or closely spaced wood decking, wood-furring strips, or metal or wood purlins using a batten or counter-batten system. See Section 3.11, “Substrates for Metal Roofing,” for additional information about deck type and recommendations. Refer to Sections 4.3, “Underlayments,” and 4.3.1, “Ice Dam Protection Membranes,” for additional information.

Metal shingles and shingle panel roof systems have various methods of securement. The types of fasteners and spacing are important for proper installation. The fasteners must be compatible with the base metal of the metal shingle and shingle panel to prevent galvanic corrosion; for example, if copper shingles are installed, copper or stainless fasteners should be used. The service life of a fastener should be equivalent to the desired service life of the secured material.

Wind clips or storm anchors may also be used to secure or fasten the butt, or downslope edge, of the individual metal shingle or shingle panel. Wind clips are made of steel or copper wire, sometimes fashioned with an elongated shaft and disc base.

Most metal shingle and shingle panel roof systems use sheet metal for perimeter metal flashings, valley flashings, hip and ridge coverings, and counterflashings. Manufacturers’ specific requirements for sheet-metal flashing details vary depending on the metal shingle and shingle panel configurations and application requirements.

### **3.3 Panel Configurations**

Metal roof panels are available in a variety of widths, cross-section profiles and seam types. Metal panels can be formed from cut sheets or coils, accommodating many panel lengths and widths. The panel’s pan profile may be flat or ribbed with a variety of raised rib profiles. The ribs vary in size, shape and frequency, depending on the manufacturer, strength and rigidity requirements. The raised rib can highlight a roof’s aesthetics, accommodate thermal movement, facilitate panel interlocking and seaming, and add structural characteristics to the metal panels. Typically, stiffening ribs, when formed in the panel, run the length of the panel, but stiffening ribs or lines may also run perpendicular to the panel’s length within the width or pan of the panel.

### **3.4 Seam Types/Configurations**

Seam types and seaming techniques vary for metal panel roof systems and are a function of roof design criteria. All seams are designed to interlock panels to one another to form a continuous, watershedding or weatherproofing system.

#### **3.4.1 Flat Seam**

Flat seam metal panel roof systems are adaptable to many types of surfaces. Steep-sloped surfaces and vertical walls are often sheathed with metal sheets joined by flat seams, as well as the conical or curved surfaces of spires, domes or cupolas. These conical or curved surfaces are usually covered in this manner because the small sheets can be varied in shape and size to fit curvature and pattern. Clips, located in the seams, provide for the securement of flat seam metal roofing panels. Low-slope flat seam metal panel roof systems traditionally employ the use of soldered joints. See Figure 3.2.

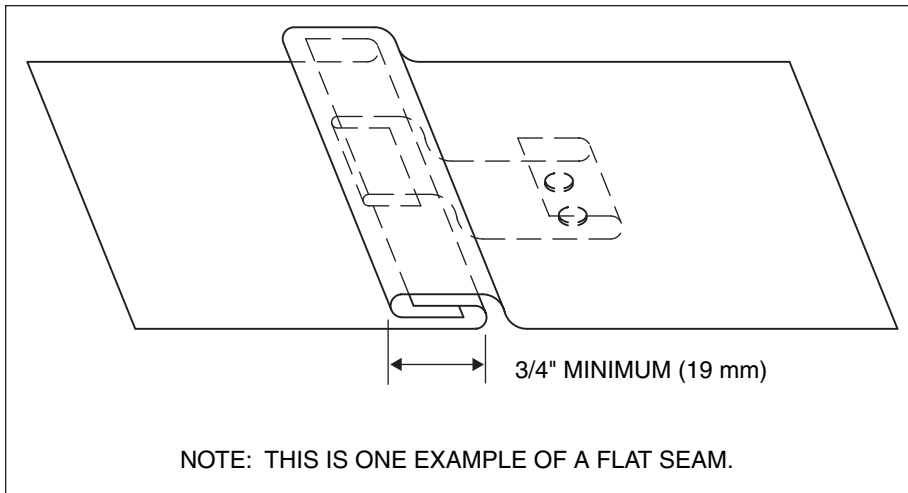


Figure 3.2: Example of flat seam with clip

### 3.4.1.1 Flat Seam, Nonsoldered

A flat seam is created with individual flat-pan panels applied in an overlapped, interlocking shingle fashion. See Figure 3.3. The edges of two adjacent sides of each rectangular sheet are folded over a minimum of  $\frac{3}{4}$  inch (19 mm); the edges of the two other adjacent sides are folded under a minimum of  $\frac{3}{4}$  inch (19 mm). Cleats are engaged in each of the two adjacent over folds and fastened to the deck with two fasteners in each cleat. The clip is folded over the fasteners. Then the next sheet is locked in place by engaging one of its under folds with an over fold of the preceding sheet. This is repeated for sheets both longitudinally and transversely, staggering the transverse seams. Because flat-seamed metal panel roof systems with nonsoldered seams are intended to shed water, they are found in architectural metal applications with slopes of 8:12 (34 degrees) or greater and not recommended for lower-slope applications.

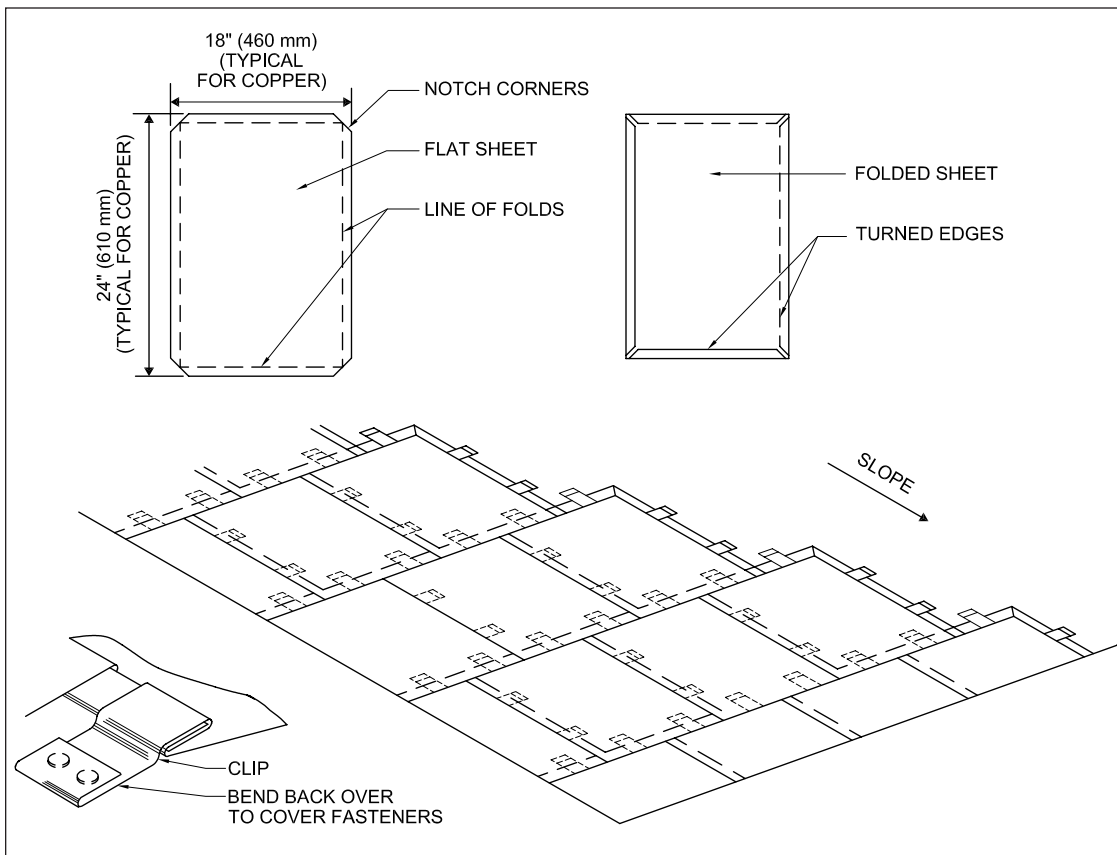


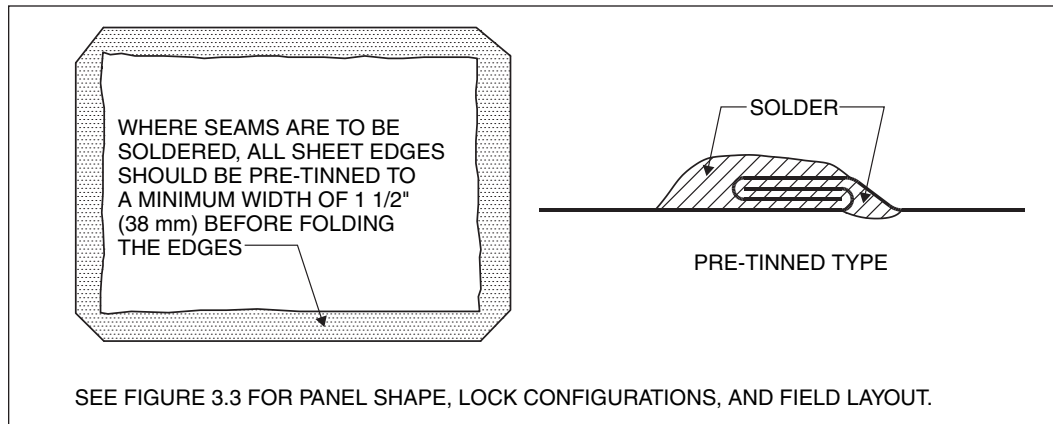
Figure 3.3: Example of flat seam, nonsoldered metal panels

### 3.4.1.2 Flat Seam, Soldered

When the joints of flat seam panels are joined together on low-slope roofs, the joints are soldered to make the system weatherproof. See Figure 3.4. Metals considered for this application need to have the ability to be soldered;

seam edges should be fluxed and pre-tinned (except lead-coated copper) before soldering. For those metals that require pre-tinning (e.g., copper), sheet edges should be pre-tinned to a minimum width of 1½ inches (38 mm) before folding the edges. After the locked seams are engaged, they should be malleted or dressed down and thoroughly sweated full with solder. When using lead-coated copper, the seams should be mechanically cleaned to a bright finish. Liberal amounts of flux should be brushed into the seams before soldering.

Figure 3.4: Example of flat seam, soldered joint

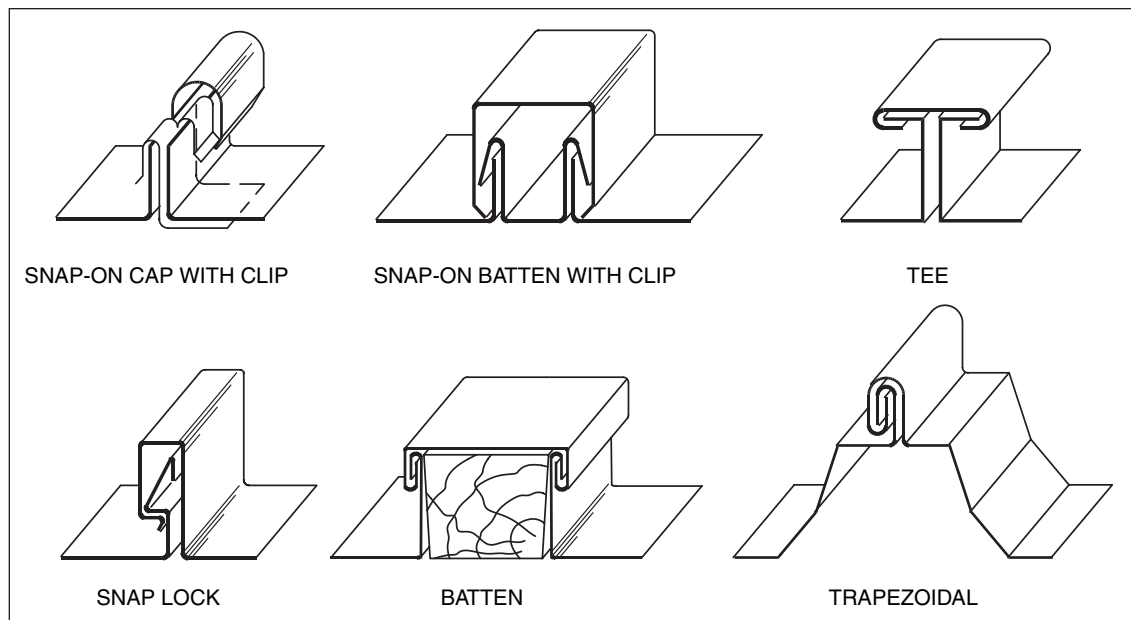


### 3.4.2 Standing Seam

A standing seam is used to refer to almost any kind of metal roof panel with a raised vertical seam. Strictly speaking, however, it refers to those metal panels that interlock or are seamed together vertically above the panel's pan. Standing seams can be used as architectural elements to highlight a roof's aesthetics, accommodate thermal movement, facilitate panel interlocking and seaming, and add structural characteristics to the metal panels. The seaming process varies, depending on the seam profile. However, most common standing seams have a male and a female leg.

There is a variety of seaming, or panel interlocking, methods. Seams may be formed by mechanical seamers or by hand. Seams may be single-locked or double-locked. Other standing seam types are snapped or rolled and locked together, which join together friction-fit components. Common friction-fit seams are snap-on cap and snap-on batten seams. Common standing seam types are illustrated in Figure 3.5, and all are recommended to have a seam height of at least 7/8 inches (22 mm).

Figure 3.5: Common types of standing seams



### 3.5 Seaming Methods

There are four basic panel-to-panel seaming techniques. They are:

- mechanical seam

- snap together seam
- integral (tongue and groove) seam
- hooked Seam

Minimum slope requirements for the various seaming methods should be based on local building codes, regional practices and design requirements.

Mansard-style roof systems generally use a simple seaming method, such as overlapped and snapped on, for joining the panels: the seams typically are not mechanically folded and interlocked. These kinds of standing seams can be easier to install and less weatherproof than the traditional single- or double-locked seams used in many other architectural systems. For this reason, the use of these systems should generally be confined to steeper-slope applications or relatively short spans and for specialty purposes, such as mansard roofs and screen walls. More stringent underlayment requirements are necessary where weatherproof performance is required.

### 3.5.1 Mechanical Seam

A mechanical seam is completed by hand seamers, tongs or electrical seaming devices. These tools can turn a seam completely over itself, producing a weatherproof seam similar to a traditional double-locked seam. Other seam configurations may be partially crimped or folded to produce the desired result. See Figure 3.6.

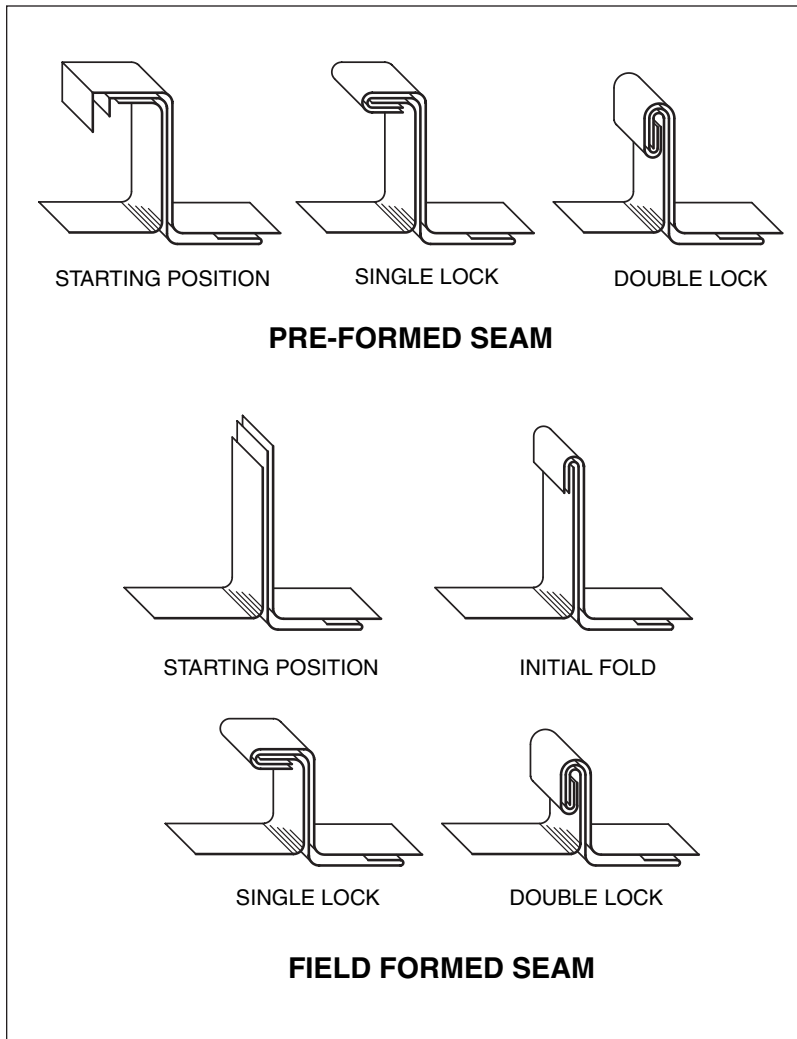


Figure 3.6: Examples of single- and double-locked mechanical seams

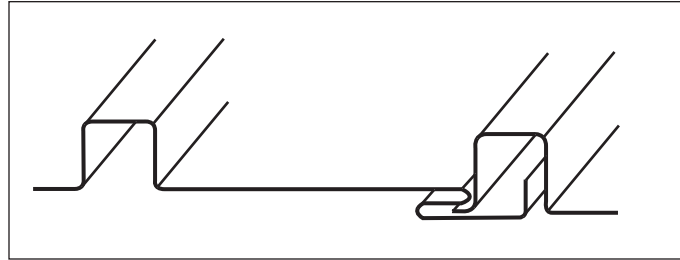
### 3.5.2 Snap Together or Snap-on Seams

A snap-together or snap-on seam is usually simple to install. A separate cap or batten snaps on to a panel's rib or clip to complete the seam. Male and female legs are adjoined to secure the seam in place. Some snap-cap or batten-cap seaming systems have relatively poor water resistance, restricting their use to steep-slope, architectural applications.

### 3.5.3 Integral Seam

An integral seam is normally a tongue-and-groove connection. See Figure 3.7. The first panel is attached to the substrate along its folded receiving edge. The edge of the next adjoining panel is then inserted into the folded receiving edge of the first panel, locking it into position. The water resistance of this seam type is normally accomplished with a hidden channel, which is part of the folded receiving edge. The panel is generally used on steeper-slope applications, such as mansards and mechanical screen walls.

Figure 3.7: Example of an integral seam



### 3.5.4 Hooked Seam

A hooked seam is a flat-lock, flat seam used in some types of architectural metal systems such as Bermuda horizontal panels or metal shingle panels. These seams can be soldered or sealed, depending on slope and design criteria. Bermuda horizontal panels or metal shingle panels hook to the previous course of panels. Hooked-seam panels are installed in shingle fashion and designed to shed water. The Bermuda seam panel profile features a continuous panel that runs perpendicular to the roof slope. It has a shingled appearance and is a watershedding system. See Figure 3.8.

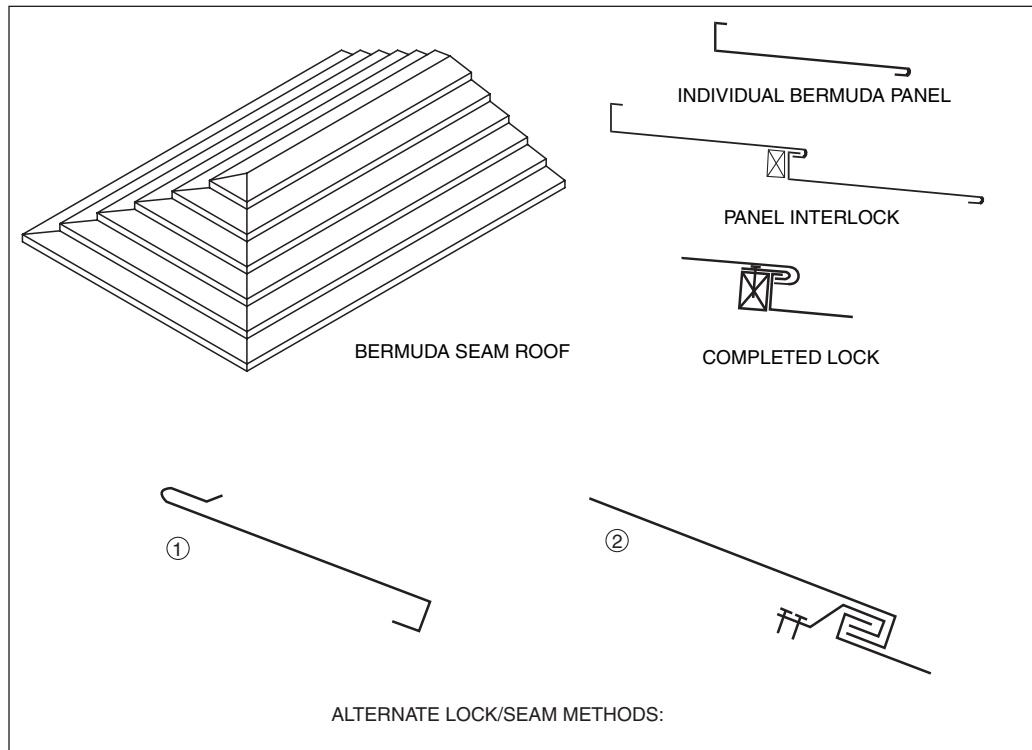


Figure 3.8: Example of Bermuda seam panel profile

### 3.6 Panel Lengths

The length of a premanufactured panel is generally limited by shipping constraints. In the same way, the length of the panels fabricated on site by roll forming is generally limited by lifting and safe handling requirements. In the past, the typical length of shop-formed architectural panels was relatively short—from 8 feet to 10 feet (2.4 m to 3 m). This was because size limitations in the human-powered forming equipment (i.e., press brakes) and the need to control expansion and contraction of the panels once on the roof. However, recently developed computerized brakes can accommodate longer lengths of metal, and with today's factory and portable machine roll forming equipment, it has become practical to form much longer panels. Longer panels make expansion and contraction considerations important factors in the design and detailing of the system.

### **3.7 Panel Widths**

Panel widths typically range from 12 inches to 24 inches (300 mm to 610 mm) for most metal panel roof systems. Concealed clips are located between the ribs. Wider panels may have fewer fasteners and clips per square foot of roof area. With fewer fasteners or clips per square foot, larger wind-uplift forces will be placed on each fastener or clip.

Another factor affected by panel width is the potential for oil-canning, which is visible distortion that may be seen in the flat surface, or pan, portion of the panel. This distortion can be influenced by the metal type, panel width and length, number and spacing of intermediate ribs, and the gauge of the material. For a more complete discussion about oil-canning, see Section 3.16.7.

### **3.8 Underlayment and Slip Sheets**

For applications over continuous or closely spaced decking, an underlayment and slip sheet are recommended as a secondary barrier against water penetration and protection of the underside of the panels from the substrate. For more information about underlayments, refer to Section 4, “Architectural Metal Panel Roof Systems.”

### **3.9 Vapor Retarders**

A vapor retarder may be a necessary component of a metal panel roof system. For information about vapor retarders for architectural metal panel roof systems, refer to Section 4, “Architectural Metal Panel Roof Systems.” For information about vapor retarders for structural metal panel roof systems, refer to Section 5, “Structural Metal Panel Roof Systems.”

### **3.10 Manufacturing Methods**

Metal panel roof systems can be fabricated at manufacturing facilities, roofing contractors’ facilities or job sites. Metal panel roof panels are produced by one of either two methods. One method is to use coiled metal stock (i.e., coil stock) and roll-forming equipment. Roll-forming machinery can be portable, allowing a contractor to produce the panels at the job site. The roll-forming machinery can also be located in a factory, allowing a manufacturer to produce standardized metal panels through mass production for subsequent shipment to contractors or distributors. These panels are referred to as premanufactured. A roll-forming machine can produce panels relatively quickly, and when used at the job site, full-length panels may be produced. However, each machine has limits to the number of profiles it is capable of producing.

The second method of forming metal panels is a bending brake that forms panels from flat stock sheet metal. A bending brake can be a mechanical hand brake, stationary press brake or computer-controlled brake. Flexibility, speed and capacity vary among these types of brakes, and panel lengths are typically 8 feet, 10 feet and 12 feet (2.4 m, 3 m and 3.7 m), depending on the length of the brake’s work deck and bending leaves, but can be longer depending on the equipment. Bending brakes cannot produce panels as fast as a roll-forming machine; however, all brakes are more flexible than a roll former in that they can produce multiple panel profiles. Each method is capable of producing high-quality panels.

### **3.11 Substrates for Metal Panel Roofing**

Metal panel roof systems can be installed over a large variety of substrates. There are two general categories of substrates for metal panel roof systems: one is a continuous or closely spaced roof deck that provides solid support for the metal panel roof panel; and the other is composed of spaced structural supports such as purlins where the metal panels must be fastened to and span between supports.

The most common types of continuous or closely spaced substrates for metal panel roof systems are:

- steel roof decking
- wood-plank and structural wood panel decks

Refer to the Roof Decks portion in the Low-Slope section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition* for more information about attachment, slope and drainage, building movement, expansion joints, precautions and other aspects of common roof decks.

The most common types of spaced structural supports for metal panel roof systems are:

- bar joists
- light gauge framing
- post and purlin
- purlin over continuous substrate

There are continuous substrates and engineered intermittent structural supports available for use with metal panel roof systems other than those listed above. Manufacturers should be consulted for acceptability and requirements.

### **3.11.1 Metal Panel Roof Decks**

Metal panel roof decks are constructed of cold-rolled steel sheets with ribs formed in each panel to provide strength and rigidity. The panels are available in several gauges, rib depths and flute spacings.

NRCA recommends that steel panel roof decks be 22 gauge (0.031 in. [0.79 mm] thick) or heavier and they have factory-galvanized G-90 coating.

See Factory Mutual Research (FM) Loss Prevention Data Sheets and other current publications regarding fasteners and fastening schedules to resist wind uplift. FM field offices and steel deck manufacturers should be consulted for advice on the maximum span and attachment recommendations for various steel decks.

Metal panel roof decks should be designed and installed according to manufacturers' specifications. Deck panel end laps should not be less than 2 inches (50 mm) and should be centered over structural supports. Steel deck panels should be anchored to the supporting members either by using mechanical fasteners or welding.

Spacing of attachment points is recommended to be no more than 12 inches (300 mm) on center to minimize deck rolling and movement under concentrated moving rooftop loads. Roof deck contractors should reweld deficient welds or replace deficient mechanical fasteners before installing other roof components. Additional supports to steel decks should be provided as required at roof penetrations.

Steel deck panels should be installed in a straight line, be properly aligned (not spread) and squarely intersect walls and structural framing. As a guideline for proper alignment of steel deck panels, horizontal variance in the alignment of the panels should not exceed  $\frac{1}{4}$  inch (6 mm) for any 100 feet (30 m) of roof length.

All side laps should be mechanically fastened. Side lap fastener spacing should not exceed 3 feet (1 m). If an interlocking deck is used, fastening may be accomplished by crimping the interlock with a button punch. Fastening through overlapping steel deck panels requires No. 8 or larger self-tapping screws.

### **3.11.2 Wood Plank and Structural Wood Panel Decks**

#### **3.11.2.1 Wood Plank Roof Decks**

A wood plank roof deck is composed of solid-sawn dimensional lumber. It is normally supported by wood beams—often glue-laminated timber, or glulams—and/or solid lumber joists, purlins or rafters. Wood planks may be single or double tongue-and-groove, straight-edged, ship-lapped, or grooved for splines or longitudinal edges. Wood plank decks should have a minimum of 1 inch (25 mm) nominal thickness. The proper thickness of planks and species of wood required for a specific roof is determined by the design loads, including uplift, anticipated for the roof and distance between the supporting members.

#### **3.11.2.2 Structural Wood Panel Roof Decks**

A plywood roof deck is composed of panels made of thin wood layers called veneers that are peeled from logs. The veneers are laid at right angles to each other, then glued together under heat and pressure. This cross-lamination adds strength and stability to the all-veneer panels. Panels consist of a number of cross-laminated layers that vary in number according to the panel's thickness.

An oriented strand board (OSB) roof deck is composed of panels made from layers of compressed, glued wood strands. These strand layers are oriented at right angles to one another before being glued and formed into panels. Oriented strand board for roof decks should be a minimum of  $\frac{1}{2}$ -inch nominal (12-mm) thickness for 16 inches (410 mm) on center rafter spacing. The proper thickness of the oriented strand board panels required for a specific roof is determined by the design loads anticipated for the roof and distance between the supporting members. Space or gap the wood sheathing panels approximately  $\frac{1}{8}$  inch (3 mm) to allow for expansion. Unsupported end joints should be blocked.

All plywood and wood-based panel roof decks suitable for roof application should be made from plywood or wood-based panels rated for structural use as roof sheathing. Most building codes require a label on plywood or wood-based panels, assuring that the plywood or wood-based panel complies with the criteria set forth in PS 1-95, Construction and Industrial Plywood, for all-veneer plywood, or with PS 2-92, Performance Standard for Wood-Based Structural-Use Panels or PRP-108, Performance Standards and Policies for Structural-Use Panels, for structural-use panels, such as OSB, all-veneer plywood, that may not comply with PS 1-95 in certain respects. However, adherence to the criteria set forth in PS 1-95 and PS 2-92 is voluntary, and producers are not required to meet them to sell their products. Although plywood or wood-based panels bearing no label may be acceptable for use, NRCA recommends

that plywood or wood-based panels intended for use as roof sheathing meet or exceed the requirements set forth by PS 1-95, PS 2-92 or PRP-108. However, some roof material manufacturers will allow application of roof products over other wood substrates.

Performance standards PS 1-95 and PS 2-92, which were initiated by APA—The Engineered Wood Association (formerly the American Plywood Association), have been developed under the U.S. Department of Commerce's Procedures for the Development of Voluntary Product Standards. Performance standard PRP-108 was developed by APA—The Engineered Wood Association.

All wood panel roof decks should consist of panels rated for structural use as roof sheathing. For particularly demanding applications, such as prefabricated panelized roof deck systems where cross-panel strength and stiffness or shear properties are critical, designers are recommended to use panels meeting the APA standard for "Structural I Rated Sheathing."

*NRCA is concerned about potential fastener-holding problems and dimensional stability caused by the effects of moisture where oriented strand board and waferboard products are used as roof decking. Refer to metal panel roofing manufacturers' specifications for acceptable wood panel roof deck substrates.*

For some metal panel roof system specifications over solid wood decking where rigid insulation will be placed between the roof deck and the metal panel roof panels, the design of a metal grid or wood batten, a counter-batten system may be necessary. The installation of pressure-treated wood sleepers, battens, counter battens or steel Z-purlins running perpendicular to the metal panel roofing can provide adequate support for the metal panels above the insulation. Typically, the wood or Z-purlins are the height of the insulation or higher to provide a ventilation space, and the insulation is cut to fit between this grid. The grid of wood or steel should be spaced appropriately to accommodate the minimum spacing of the metal panel roofing panel clips and their fasteners. For some metal panel roof systems, this spacing is so close that the installation of a minimum of ½ inch (13 mm) plywood is then needed over the grid system to achieve appropriate attachment of the metal panel roof panels. Generally, the wood panel sheathing is laid so that the long joints run perpendicular to the metal panel roofing panels.

For some metal panel roof systems specified over solid wood decking where the metal panels will be placed directly on the insulation, some panel manufacturers offer bearing plates for through-fastening into the underlying wood roof deck.

### **3.11.2.3 Preservative-treated and Fire-retardant-treated Wood**

Caution should be exercised when roof decks are constructed of wood that has been treated with an oil-borne preservative. Most manufacturers recommend that wood roof decks be constructed with wood that has been treated with a non-oil preservative pressure treatment or with nontreated, air-dried or kiln-dried lumber. The metal panel roof panel manufacturer should be consulted about the specific recommendations for application over preservative-treated decking material. For additional information regarding preservative wood treatment, consult the American Wood Preservers Association.

Because of the deterioration of some fire-retardant-treated (FRT) wood panels caused by chemical reaction, special consideration should be given to investigate existing fire-retardant wood panel decks before design and application of a metal panel roof system. Refer to metal panel roof manufacturers' recommendations for acceptable FRT wood panel roof deck materials.

### **3.11.3 Bar Joist Structural Systems**

Bar joists are prefabricated structural steel members, normally used as beams or horizontal structural members suitable for the support of structural standing seam roof systems. They range in size and length depending on the specific load requirements.

The top and bottom chords are composed of paired angle iron and round bar web members.

Bar joists should be designed and installed according to the manufacturer's specifications. The designer should give particular attention to the load requirements of the building, as well as specific roof loading requirements.

If the bar joists run perpendicular to the roof slope, the roof panel clip may be fastened directly to the top chord of the bar joist. If the bar joists run parallel to the roof slope, intermittent support members must be used for attachment of the roof panel clip.

### **3.11.4 Light-gauge Framing Systems**

Light-gauge framing is a type of intermittent support that is usually made from sheet metal ranging from 14 gauge to 22 gauge.

Some of the most common shapes are:

- hat channel
- square tubing
- standard C channel, eave channel
- Z-purlin (one or two piece)

See Figure 3.9 for examples of these common shapes.

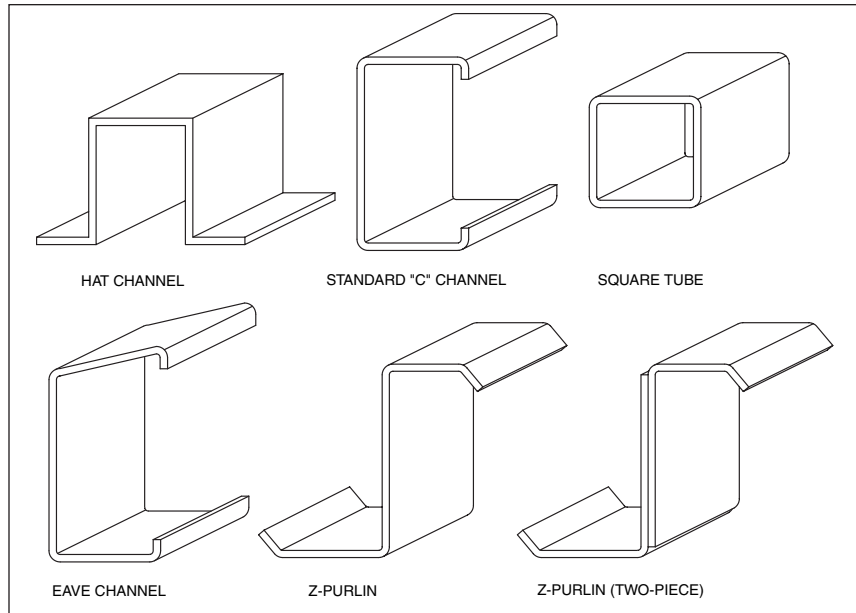


Figure 3.9: Common light-gauge framing shapes

These light-gauge framing shapes are used to offset the metal panel roof system from the substrate for a variety of reasons:

- to provide a location to attach the panel clip
- to provide support for the panels
- to provide space for insulation
- to provide a means to smooth out an irregular substrate via a two-piece Z-purlin
- to permit the underside of the panel to be ventilated

These light-gauge framing shapes must meet design requirements for positive- and negative- pressure loading on the metal panels. Under positive loading, these shapes must retain their shapes and not buckle. Negative-pressure loading places stress at the fastener points of the metal panel roof panels and light-gauge member and at the fasteners of the shape and substrate. Local codes should be consulted for required values of these loads.

### 3.11.5 Post and Purlin Structural Systems

Post and purlin construction is generally used in the design of pre-engineered buildings, such as metal or wood. The system is an open-frame construction using metal Z, C or hat-channel members or wood members to support the metal panel roof system. Spacing can vary from 2 feet to 6 feet (0.6 m to 1.8 m), and gauges can vary from 10 gauge to 20 gauge (0.14 inches to 0.04 inches [3.5 mm to 1.0 mm] thick) depending on design requirements.

Because this is a spaced structural support, a structural metal panel roof panel is required to accommodate the live and dead loads of the building. The panel design and seam shape must be considered to deal with this open spanning and low slope. Panels using a trapezoidal standing-seam profile or corrugated panels are generally used.

When used, fiberglass batt insulation is stretched over the purlins and then the metal panel roof panels are installed directly over the insulation with clips or by direct attachment to the metal purlins. To compensate for the compression of the insulation, spacer blocks should be used.

### 3.11.6 Purlin Over Solid Substrate

Purlins over a solid substrate is a type of spaced structural support that usually consists of light-gauge framing

shapes attached directly to a solid substrate.

These purlins are used to offset the metal panel roof system from the substrate for a variety of reasons:

- to provide a location to attach the panel clip
- to provide support for the panels
- to provide space for insulation
- to provide a means to smooth out an irregular substrate via a two-piece Z-purlin
- to permit the underside of the panel to be ventilated

These purlins must meet design requirements for positive- and negative-pressure loading on the metal panels. Under positive loading, these purlins must retain their shapes and not buckle under the load. Negative-pressure loading places stress at the fastener points of the metal panels and purlin and at the fasteners of the purlin and substrate. Local codes should be consulted for required values of these loads.

### **3.12 Roof and Metal Panel Layout**

Because to beginning panel layout and installation, it is recommended to check the levelness and squareness of the roof deck or substrate. Corrections to the deck can only be made before panel installation.

When installing metal panel roof systems on highly visible roof areas, it is generally preferred to balance the width of the panels at each end of a roof section. For low-slope roof applications or on roof areas where, for example, a rake or wall detail exists at one end and a hip or valley condition exists at the other end, there is generally no need to balance the panels.

At hips and valleys, it is generally preferable to align the seams at the point of intersection. This is only possible when the intersecting roof areas have the same roof slope. When they do not, custom-width panels may need to be considered to compensate for the difference in slope. The visual difference of the panel widths may not be a desirable trade off. Also, it may not be possible to obtain custom-width panels.

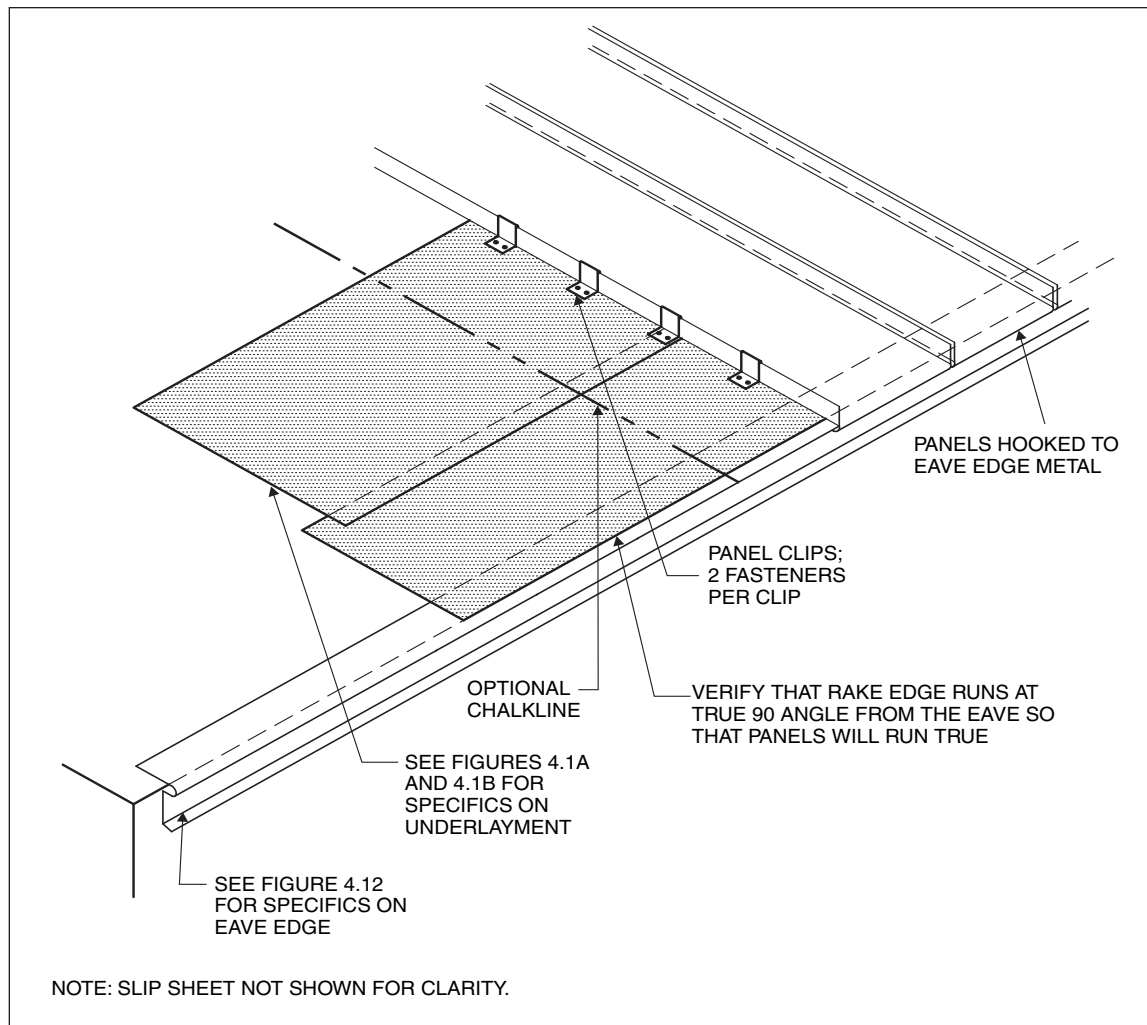
When having a balanced panel layout is not a visual concern, a contractor will typically start laying panels at the rake edge beginning with a full-width panel. Panel installation generally has to proceed in one direction (i.e., from left to right or right to left across the roof area) based upon the seam type, unless a special starter panel is used. It is sometimes feasible to lay out full panels trying to gain a fraction of an inch per panel if the width of the total roof is not an exact multiple of the width of each panel. However, most panel systems have a small tolerance for how tightly the panels may be laid together. Manufacturers' instructions for panel width adjustment tolerance should be consulted and closely followed to avoid potential seam deficiencies and excessive oil-canning.

When a roof is laid out for equal size end panels, the midpoint of the roof is typically determined first. Depending on the relationship of the roof width and the panel module width, either a seam or the midpoint of the center pan can be located on the center point line while still keeping the end panels equal in size. This will help maximize or minimize the end panel size as desired. Manufacturers' installation instructions, seam types, job conditions and other considerations may dictate panel start points and/or layouts as some panel configurations require installation in a single direction.

A layout plan can help to verify the correct panel size and number of panels that will be required for the job. Planning the layout before installation can also help the designer to aesthetically blend the roof with building lines, shapes and symmetry.

The roof may be laid out using story poles, tape measures or chalk lines. Making marks on the substrate helps to ensure the panel widths balance at each end of the roof and the panels will be installed perpendicular to the eave. Consistent installation of panels, perpendicular with the eave, will prevent side camber or bowing along the edges of the panels. See Figure 3.10.

Figure 3.10: Chalk lines, underlayment and clips



### 3.13 Fastening/Attachment Requirements

Consideration must be given to fastening requirements during roof design. If the metal system is being installed as a Factory Mutual Approvals- (FM-) or Underwriters Laboratories- (UL-) approved roof assembly, the prescribed fastening schedule and substrates should provide adequate anchorage to resist wind-uplift pressures. However, if the metal panel roof is an architectural system other than an FM- or UL-approved assembly being designed for use over a continuous or closely spaced roof deck, the designer should consider the need to conduct fastener pull-out tests to determine whether the substrate and metal panel system will meet the design wind-uplift requirements. Wind-uplift requirements will vary depending on local building codes that consider the design wind speed for the area, topography, roof slope, fastener type and pattern, roof deck or substrate type, height of building, panel width, and metal thickness and type.

With metal panel roof systems, it is critical that fasteners and clips and their densities be designed to meet the wind-uplift requirements for the project. It is important to select the correct fasteners relative to the substrate, fastener size, point or tip type, thread type, shank type, compatibility and corrosion resistance. If panels are being roll formed with portable or mobile equipment, fastening requirements may be available from equipment manufacturers, together with the results of wind-uplift tests that may have been conducted on specific metal panel roof assemblies. It is important to adhere to the fastening specifications so that the metal panel roof system attachment is not compromised.

### 3.14 Fixed Points

Metal panel roof system design must accommodate thermal movement of the metal panels and must resist sliding forces, typically called “drag loads.” Thermal movement is caused by changes in temperature. Drag loads are caused by gravity and snow loads that force the metal panels to move downslope. Typical metal panel roof systems need to be fixed to resist drag loads but must allow for movement because panel expansion and contraction. Panel movement is typically allowed to occur in one of two directions: upslope or downslope. This can occur by providing a fixed point of attachment either at the hip and ridge or eave and valleys. See Figure 3.11. For long panels, it may be desirable to fix the panels at the midpoint so movement occurs at each end of the panel; each end of the panel will move

one-half of the total panel movement. It is easier to accommodate 2 inches (50 mm) of movement at each panel end than 4 inches (100 mm) of movement at one end.

When a metal panel is fixed at the ridge, the fasteners can be concealed under ridge or hip caps. Concealed fasteners can be more aesthetically acceptable to building owners, in lieu of having exposed fasteners at the eaves. When panels are fixed at the ridge, panels cannot be fixed at valleys. When a metal panel is fixed at the eaves and valleys, fasteners at the ridge cannot be attached to the structure to create a fixed point. Care must be taken at penetrations, roof curbs and vent stacks so that panels are not fixed to the substrate at these locations. Providing more than one fixed point in a metal panel system restricts panel movement and can result in oil-canning or panel damage.

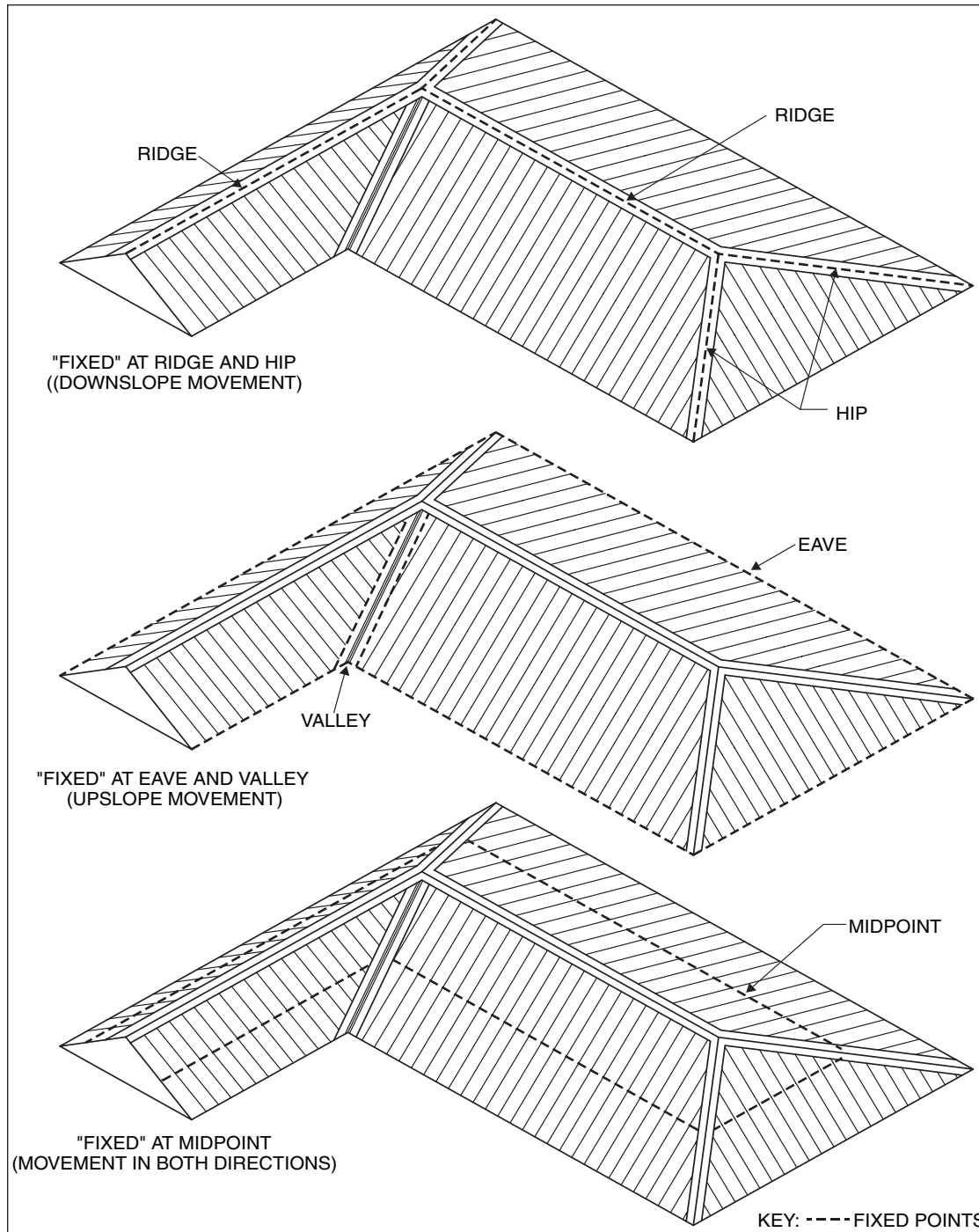


Figure 3.11: Possible fixed-point locations

### 3.15 Flashings and Accessories

Because metal panel roof systems are frequently interrupted by the intersection of adjoining roof sections, adjacent walls and/or penetrations such as curbs and plumbing soil-pipe stacks, all of which create potential locations for

leakage, special provisions for weather protection must be made at these locations. Flashings are used to control water entry at these locations. Careful attention to flashing details is essential to successful long-term roof performance regardless of the type of metal panel roof system construction. The number of roof penetrations should be kept to a minimum. Refer to the Construction Details section for examples of flashing conditions commonly encountered with architectural and structural metal panel roof systems.

For information about eaves and rakes, gutters and downspouts, valleys, penetrations, slope transitions, ridges and hips, end laps, snow guards and wall panels, see Section 4.9, “Flashing and Accessories,” Section 5.12, “Sheet Metal Flashing,” Section 5.13, “Accessories,” and Section 5.14, “Wall Panels.”

### 3.16 Additional Information About Metal Panel Roof Systems

#### 3.16.1 Expansion and Contraction Considerations

The expansion and contraction of metal that takes place with temperature changes can cause many problems for metal panel roof systems when expansion and contraction are not accommodated for in the design of the metal panel roof system. Expansion and contraction can cause flashings to become distorted and possibly loosen from the substrate. Expansion and contraction not correctly allowed for can cause leaks and make a roof system more vulnerable to storm and wind damage. The system design must consider expansion and contraction as they relate to panel-to-panel connections, panel-to-structure or -substrate attachment, panel-to-flashing junctures, and flashing-to-structure or -substrate attachments. In all these situations, materials will move differentially with temperature change for one of the following reasons:

- different materials will have different coefficients of expansion. See Figure 3.12
- some components may be exposed to a greater degree of temperature change than others; for example, the exterior panels will have a greater temperature range exposure than the interior structure to which attachment is made
- movement of two components occurs in different directions; for example, panel lengths must accommodate vertical, or ridge-to-eave, movement, while ridge flashing must accommodate horizontal movement

Metal Type	Coefficient of Thermal Expansion	Increase in 10-Foot Lengths per 100°F Temperature Change
Galvanized Steel	0.0000067 in./in./°F	0.080 in.
Steel	0.0000067 in./in./°F	0.080 in.
Terne	0.0000067 in./in./°F	0.080 in.
Copper	0.0000094 in./in./°F	0.113 in.
Stainless Steel	0.0000096 in./in./°F	0.115 in.
Aluminum	0.0000129 in./in./°F	0.155 in.
Lead	0.0000161 in./in./°F	0.193 in.
Zinc	0.0000174 in./in./°F	0.209 in.
Fir Parallel to Grain	0.0000021 in./in./°F	0.025 in.
Pine Parallel to Grain	0.0000031 in./in./°F	0.037 in.
Brick Masonry	0.0000031 in./in./°F	0.037 in.
Limestone	0.0000044 in./in./°F	0.053 in.
Glass	0.0000047 in./in./°F	0.056 in.
Marble	0.0000056 in./in./°F	0.067 in.
Concrete	0.0000078 in./in./°F	0.094 in.
Plaster	0.0000092 in./in./°F	0.110 in.

Figure 3.12: Coefficient of thermal expansion

Movement along the length of the panel from ridge to eave is an important concern with most standing seam metal panel roof systems. Horizontal movement of a panel is less of an issue because the seam-to-seam width of most standing seam panels is relatively small. Some standing seam panels have small interspersed inter-panel ribs referred to as stiffening ribs. The flat pan portion of the panel can absorb some movement by bowing or distorting. Significant movement through the pan, however, is not the preferred method of accommodating movement because of its effect on the appearance of the roof and there can be a loss of watertight integrity at the eave or ridge when the metal bows.

Movement along the length of the panel is generally not of great concern if the panels are short in length. Clips can

accommodate some of the expansion and contraction of shorter panels by rolling and flexing. Connections with flashings may also flex or roll sufficiently to accommodate movement stresses. Conversely, long panel lengths can move several inches or more, depending on the type of metal, actual length and temperature change. Clips must either be designed to allow the panels to slide back and forth or accommodate the movement of the panels within their design by flexing, rolling or sliding, such as with two- or three-piece clips. With expansion clips, the base portion of the clip is fastened to the deck or structural member and allows the upper portion of the clip, which is attached to the panel, to slide, or “float,” with the panel movement.

The amount a panel can move from expansion and contraction can be calculated by multiplying the metal's coefficient of expansion by the maximum length from the point where the panel movement is fixed to the end of the panel by the expected temperature change. In some cases, panel movement may be fixed in the middle of the panel with both ends free to move; maximum movement at each end of the panel will therefore be one-half of what it would be if the panel were fixed at one end and all movement were directed to the other end. Where to fix a panel, in any metal panel roof system, is a design consideration that must be well thought out. Panels may be fixed at the eave, midpoint or ridge or at an intermediate line of penetration. The location should be a horizontal point shared in common by all panels so the panel movement is consistent from one panel to another.

Flashing attached to a building or structure must be either securely fastened to restrain movement or designed to provide for movement without damaging the metal or fasteners. Flashings that are attached to the metal panel roof panels, structure or another panel must be installed with a slip-type connection or must be designed with a multiple-bend profile that allows the flashing to flex and accommodate metal movement.

### **3.16.2 Drainage**

Metal panel roof systems use both internal and external drainage systems in a fashion similar to other low- and steep-slope roof systems. External drainage systems include, for example, exterior gutters and scuppers. Internal drainage systems include built-in gutters with drains and should be avoided where possible. See Section 2, “Architectural Sheet Metal,” for more information on internal gutters.

### **3.16.3 Deck Considerations**

For new construction, the roofing contractor's only responsibility for the deck is to ensure that its surface condition is suitable for the application of roofing materials. Before the application of the roof system, the deck should be inspected to make sure it is smooth, straight and free of irregularities. If the deck is composed of panels or planks, the roofing contractor should check to see that adjacent deck sections are aligned horizontally on the same plane. The deck must provide a substrate that will accommodate the application of the specified roofing materials. For additional information, see the General Roofing Project Considerations section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*.

In the design of a roof system, especially in reroof situations, developing pull-out values specific to deck and fastener type may be prudent to determine the uplift resistance of the roof system and components. When pertinent to the design of a roof system or components, these values should be determined by the roof system designer during the design stage. Local building codes should be consulted for the appropriate methodology for developing wind loads.

### **3.16.4 On-site Storage**

Panels stored on site should be protected from standing water, which can stain or discolor paint finishes and naturally weathering metals. If water does come in contact with stored panels, the panels should be sloped so that one end is higher than the other, which will allow water to drain off.

### **3.16.5 Protective Films**

Some metal coil stock or premanufactured panels incorporate a protective film. This protective film should be removed once the panels are installed so it does not degrade from ultraviolet exposure. In certain situations, the protective film may be difficult to remove if the panels have been stored on site for some time.

### **3.16.6 Hoisting Panels**

The way that roof panels are hoisted to the point of installation is an important consideration for the installer. The panels should be supported so that the stack or individual panels don't bend significantly or crease, as creases may render the creased portions of the metal panel unusable.

### **3.16.7 Oil-canning**

Oil-canning is an inherent phenomena prevalent in light-gauge, cold-formed metal products. Oil-canning refers to

physical distortions in the flatness of the metal; however, this condition is only aesthetic in nature and it does not have any adverse effect on the structural integrity or the weatherproofing capability of the panel. Because some paint finishes, clear coats and metals are highly reflective and bright, distortions can be quite apparent. The visual effects of oil-canning can be exacerbated by changing or varying light conditions. Many metal panel roof panel manufacturers issue disclaimers regarding oil-canning, yet it can nevertheless become a customer-acceptance issue. If a specifier intends to reduce the severity of oil-canning, careful design consideration should be given to the width, gauge and profile of the specific product. NRCA does not consider oil-canning alone to be a cause for rejection.

There are a number of potential causes of oil-canning; however, all are attributable to residual stresses, either induced or redistributed, for different reasons.

- Residual stress during coil production can contribute to camber, the deviation of a side edge from a straight line. This longitudinal curving will place additional stress on the metal as it is pulled through the roll-forming machine, which attempts to form a straight edge on the panel.
- Slitting a master coil can release and redistribute stresses, especially if the slitter blades are out of adjustment or dull.
- The roll-forming equipment itself can cause oil-canning. As metal is run through the rolling stations, it is placed under stress and can stretch, particularly if the equipment is out of adjustment or operated beyond its limitations.

Despite having a properly adjusted, well-maintained roll-forming machine and good quality metal, oil-canning can still occur when panels are installed. It can result from temperature fluctuations and cycles, an uneven substrate or irregular bearing on the structural framing, structural movement or over-torquing of the mechanical fasteners.

The following precautions and considerations should assist in the reduction of oil-canning and its visual effects.

- Specify that coil stock be tension-leveled to ensure flatness of material.
- Use a heavier-gauge metal that is more rigid and less likely to oil-can than lighter-gauge material.
- Limit individual panel pan widths.
- Limit face dimensions on the fascia metal.
- Use stiffening ribs or striations in the field of the metal panel.
- Use stiffening ribs in the fascia metal, or use two-piece fascia metal when the face dimension is greater than 8 inches (200 mm).

Following are considerations to reduce the visual effects of oil-canning:

- Use low-gloss finishes or special surface textures such as embossing or striations
- Consider using metals that weather naturally, as these metals typically dull or fade over time with the development of a layer of oxidation.

### **3.16.8 Standards Applicable to Metal Panel Roof Systems**

The following ASTM standards are applicable to metal panel roof systems.

ASTM E 283, “Standard Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen.”

ASTM E 330, “Standard Test Method for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference.”

ASTM E 331, “Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference.”

ASTM E 1514, “Standard Specification for Structural Standing Seam Steel Roof Panel Systems.”

ASTM E 1592, “Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference.”

ASTM E 1637, “Standard Specification for Structural Standing Seam Aluminum Roof Panel Systems.”

ASTM E 1646, “Standard Test Method for Water Penetration of Exterior Metal Roof Panel Systems by Uniform Static Air Pressure Difference.”

ASTM E 1680, “Standard Test Method for Rate of Air Leakage Through Exterior Metal Roof Panel Systems.”

## **4. Architectural Metal Panel Roof Assemblies**

### **4.1. Description**

Architectural metal panel roof systems are typically hydrokinetic, or watershedding, roof systems. They are designed to shed water rapidly over the surface of the panels, so the seams are not necessarily watertight. For panels to shed water rapidly, the roof must have adequate slope. Architectural metal roof panel systems perform well on slopes of 3:12 (14 degrees) or greater. For lower slopes, climatic conditions must be carefully considered, particularly the amount of expected ice, snow and debris accumulation, because sealant or sealant tape, such as butyl, may need to be incorporated in the interlocking ribs.

Architectural metal panel roof systems require continuous or closely-spaced decking. A minimum underlayment of a No. 30 asphalt-saturated felt underlayment and separate slip sheet, such as rosin-sized sheathing paper or an underlayment with slip-sheet capabilities are recommended. Metal panel manufacturers should be consulted for specific underlayment requirements. With architectural metal panel roof systems, an ice dam protection membrane is recommended where the January mean temperature is 30° F (-1° C) or less or as required by local codes. Also, for some types of metal, ventilation of the undersides of the architectural metal panels may be necessary.

Architectural roof panels are usually characterized by a flat pan with a  $\frac{7}{8}$ -inch to 1½-inch (22-mm to 38-mm) high rib on each side. The absence of intermediate ribs and large side ribs provides the panels with a clean appearance, but these panels typically do not have adequate strength to be used without a continuous or closely spaced substrate.

There is, however, a hybrid type of metal panel roof system described as a flat-seam, soldered metal panel roof system (typically 18 inches by 24 inches [460 mm by 610 mm]) that incorporates the hydrostatic characteristics of structural metal panel roof systems but requires a continuous or solid deck as is required with an architectural metal panel roof system. See Section 3.4.1.2.

Structural metal roof panels can also be used in architectural applications, that is, over continuous or closely spaced substrates. Structural metal panel roof systems are used in architectural applications generally for increased uplift resistance. Structural panels used in architectural applications typically have flat pans and vertical seams (i.e., non-trapezoidal) to allow for simpler flashing installation. In addition, these types of panels have different seam aesthetics and shadow lines that can be more appealing for roofs that are visible. It is important to note that detailing methods for structural metal roof panel systems used in architectural applications may differ from typical detailing methods used for architectural metal roof panel systems because of differences in panel gauges, seam types, panel profiles, manufacturers' requirements and geographic differences. When structural metal roof panels are used in architectural applications over continuous or closely spaced roof decks, refer to Section 4, "Architectural Metal Panel Roof Systems," for design considerations and application information.

Although metal panels classified as "structural panels" can also be used as architectural metal roof panels, the reverse is not necessarily true. See Section 5, "Structural Metal Panel Roof Systems," for more information about these types of metal panels.

### **4.2 Substrates**

Metal panel roof systems can be installed over a large variety of substrates. There are two general categories of substrates for metal panel roof systems: one is a continuous or closely spaced roof deck or rigid insulation that provides solid support for the metal roof panel, and the other is composed of spaced structural supports such as purlins where the metal panels must span between supports. The purlins also provide a point of attachment for the panels. Architectural metal panels are required to be installed over continuous or closely spaced roof decks.

The most common types of continuous or closely spaced substrates for architectural metal panel roof assemblies are:

- steel roof decks
- wood-plank and structural wood panel decks

See Section 3, "Fundamentals of Metal Panel Roof Systems," for a more detailed description of the most common types of continuous or closely spaced roof decks.

### **4.3 Underlayments**

Underlayment is primarily used to separate the roof covering from the roof deck or substrate, shed water and provide secondary weather protection. Underlayment should be vapor-permeable unless designed to act simultaneously as a vapor retarder. The use of underlayment requires a continuous substrate to support the underlayment material. Because they need to be supported, underlayments typically are not used with structural metal panel roof systems when intermittent supports are used to carry the roof systems. For example, structural metal panel roof systems

installed over bar joists, light-gauge framing, post and purlins, or purlins over solid substrate should not include underlayment. For metal panel roof assemblies where the spaces between purlins over a solid substrate are filled with a solid material (e.g., polyisocyanurate insulation), underlayment should be used.

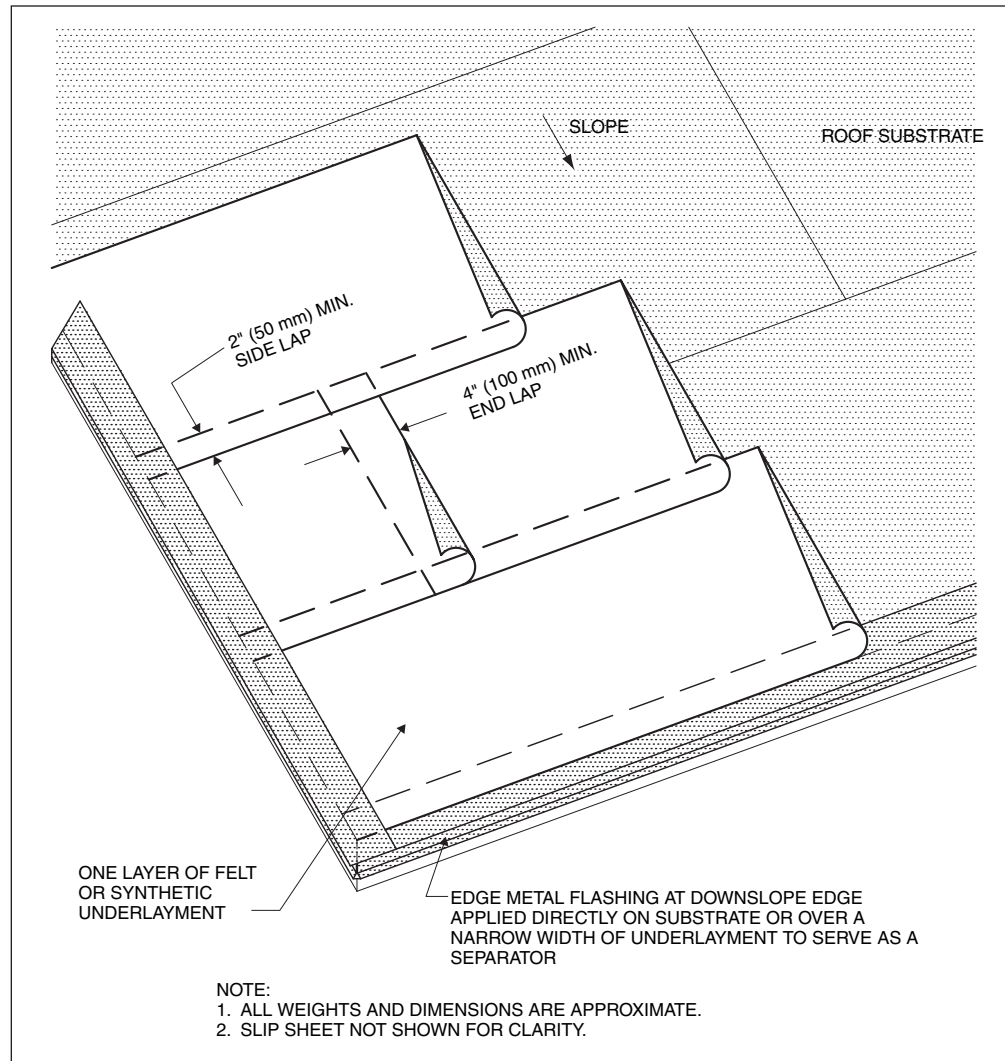
For applications over continuous or closely spaced decking, an underlayment and slip sheet are recommended as a secondary barrier against water penetration and protection for the backsides of the panels from the substrate. In addition to the underlayment, an ice dam protection membrane at downslope perimeters, transitions, valleys and around penetrations is recommended in cold regions.

If underlayment is used as a temporary watershedding system, the underlayment should be inspected for proper installation and integrity because the installation of the metal panels.

The following underlayment guidelines are recommended by NRCA:

A. For single-layer underlayment, a minimum of one layer of No. 30 asphalt-saturated, nonperforated felt, or laminated or reinforced polyethylene- or polypropylene-based synthetic underlayment should be applied horizontally, or perpendicular to the slope of the roof. Heavier underlayment may be required by local code or by specifications according to local conditions and requirements of the designer or manufacturer of the roof system. All felt sheets should have a minimum side lap of 2 inches (50 mm) over the preceding felt, and end laps should be a minimum of 4 inches (100 mm). The felts should be fastened as necessary to hold the felts in place until the metal roofing panels are applied. See Figure 4.1A.

Figure 4.1A: Single layer underlayment



B. When a double layer underlayment is specified, two layers of a No. 15 or No. 30 asphalt-saturated, nonperforated felt, or laminated or reinforced polyethylene- or polypropylene-based synthetic underlayment should be applied horizontally. A 19-inch (480-mm) wide starter sheet should be applied at the eaves. A full-width sheet should be applied covering the starter sheet. Succeeding sheets should be lapped approximately 19 inches (480 mm) leaving an approximate 17-inch (430-mm) exposure over the preceding sheets. End laps should be a minimum of 4 inches

(100 mm). The felts should be fastened as necessary to hold them in place until the metal roofing panels are applied. See Figure 4.1B.

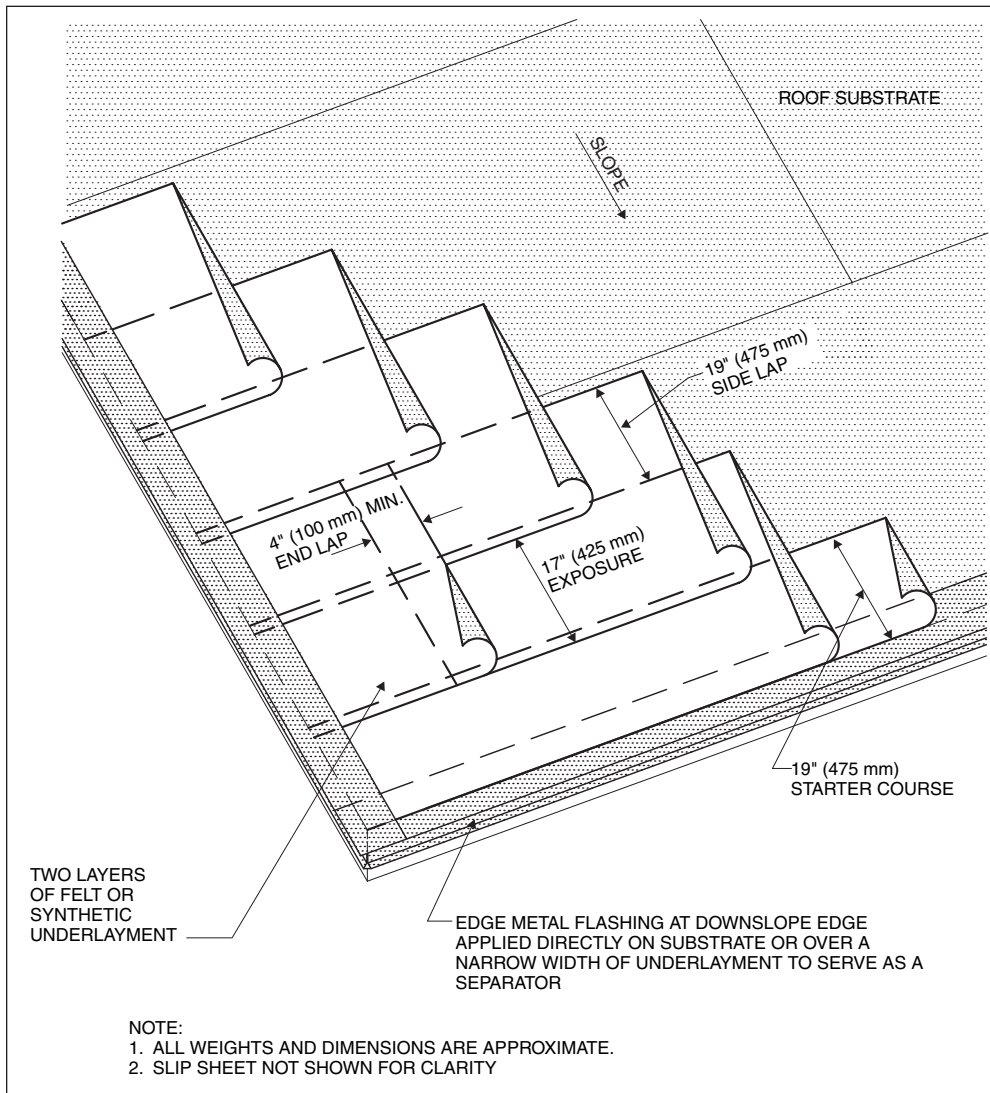


Figure 4.1B: Double layer underlayment

C. Regardless of the type of underlayment required or slope of the roof, in locations where the January mean temperature is 30° F (-1° C) or less or where the possibility of ice formation at the eaves is anticipated, NRCA suggests installation of an ice dam protection membrane. See Figure 4.2. Some building codes require the use of ice dam protection membranes in areas where the mean January temperature is 25° F (-2° C) or less. Designers and contractors are urged to consult the applicable building code. Also, in these same regions, NRCA does not recommend the use of gutters that have front faces higher than the bottom edge of the roof panels, thus increasing the potential for ice dam formation.



Figure 4.2: Average January temperature map (below 30° F [-1° C])

### 4.3.1 Ice-Dam Protection Membranes

An ice-dam protection membrane may consist of:

- a single layer of self-adhering polymer modified bitumen membrane. See Figure 4.3A.
- two plies of No. 30 asphalt-saturated, nonperforated felt where the upslope half of each ply sheet is fastened to the deck and the downslope half is set in hot steep asphalt, roof cement or cold adhesive. See Figure 4.3B.
- a combination of one heavyweight coated base sheet and one ply of No. 30 asphalt-saturated, nonperforated felt where the heavyweight coated base sheet is fastened to the deck and the ply sheet is set in hot steep asphalt, roof cement or cold adhesive. See Figure 4.3C.

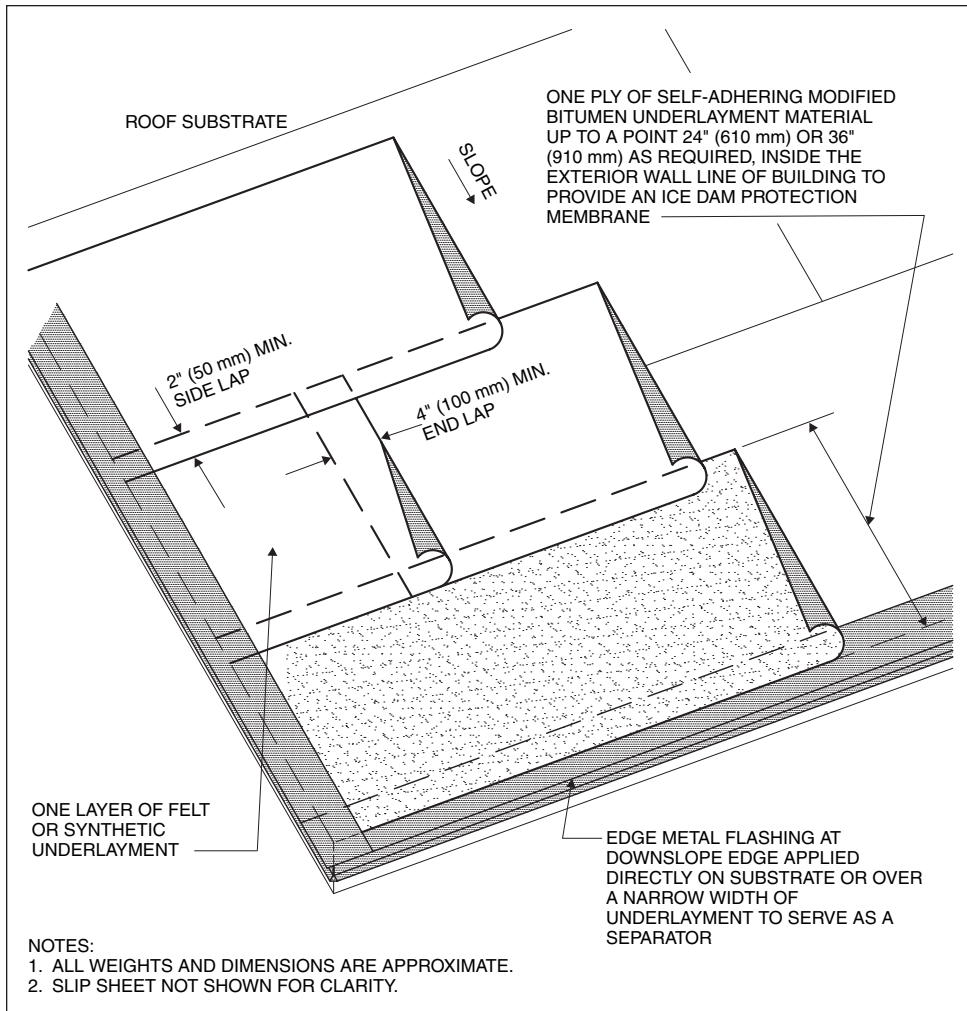


Figure 4.3A: A single layer of self-adhering polymer modified bitumen membrane as ice-dam protection

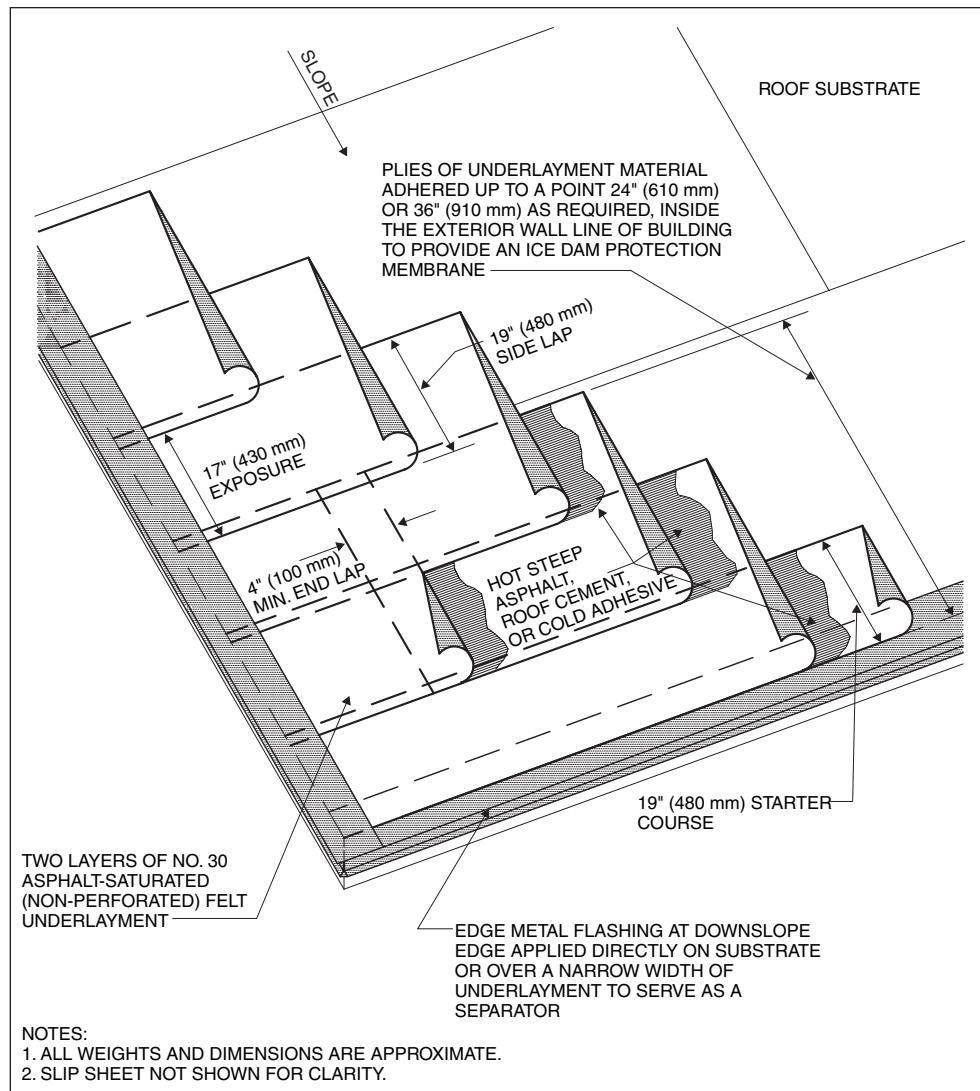


Figure 4.3B: Two plies of No. 30 asphalt-saturated non-perforated felt as ice-dam protection

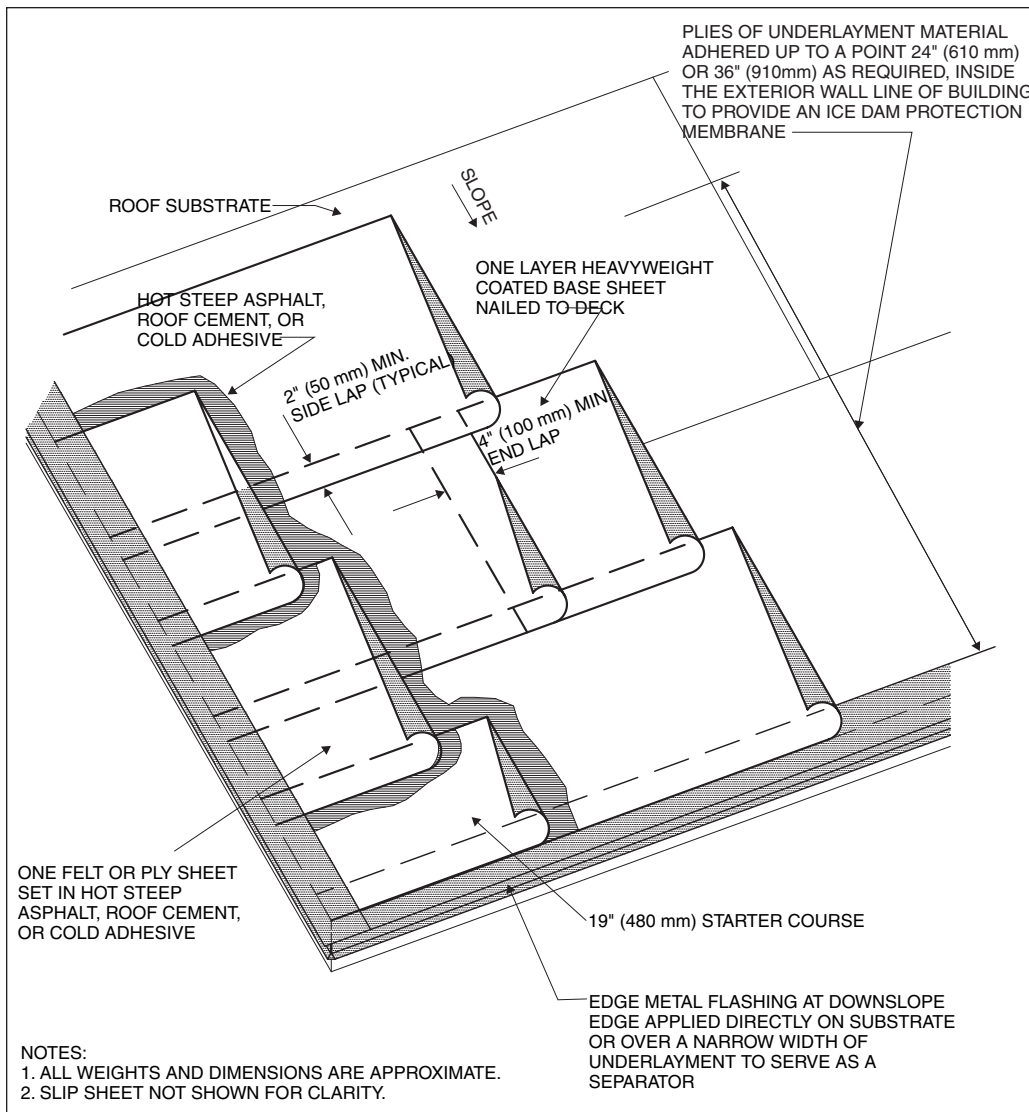


Figure 4.3C: A combination of one heavy-weight coated base sheet and one ply of No. 30 asphalt-saturated, non-perforated felt as ice-dam protection

The ice-dam protection membrane should be applied starting from the downslope roof edge, or eave, and extending upslope a minimum of 24 inches (610 mm) from the inside of the exterior wall line of the building. On slopes less than 4 inches per foot (18 degrees), NRCA recommends that the ice-dam protection membrane be extended a minimum of 36 inches (910 mm) upslope from the inside of the exterior wall line of the building. Ice-dam protection membrane at downslope perimeters, transitions and valleys and around penetrations is recommended in cold regions.

In climates where ice damming can be severe, consideration should be given to extending the ice-dam protection membrane farther up the slope.

Ice-dam protection membranes by themselves cannot be relied upon to keep leaks or moisture problems from occurring. Careful consideration of roof insulation, ventilation and project- and climate-specific detailing is vital. Also, self-adhering modified bitumen underlayment must not be left exposed for long periods of time. Self-adhering modified bitumen underlayments should be covered with the primary roofing material as soon as practical to prevent premature degradation of the modified bitumen material.

Local codes should be consulted for any additional requirements for the use of ice-dam protection membrane.

Underlayments that incorporate a granule surfacing are available to provide a more slip-resistant surface for workers. When using these types of underlayments, precautions should be taken to prevent abrasion or damage to the undersides of the metal panels.

Also available are underlayments that incorporate a nonwoven fleece-type surface to act as a separator between the metal panels and underlayment material.

Several manufacturers offer a range of asphalt-saturated felts and asphalt-saturated and coated felts. The following ASTM standard specifications apply to these materials:

- ASTM D 224, “Standard Specification for Smooth-Surfaced Asphalt Roll Roofing (Organic Felt).”
- ASTM D 226, “Standard Specification for Asphalt-Saturated Organic Felt Used in Roofing and Waterproofing.”
- ASTM D 2626, “Standard Specification for Asphalt-Saturated and Coated Organic Felt Base Sheet Used in Roofing.”
- ASTM D 4869, “Standard Specification for Asphalt-Saturated Organic Felt Shingle Underlayment Used in Roofing.”
- ASTM D 1970, “Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment Protection.”

### **4.3.2 Slip Sheets**

A slip sheet is a layer of smooth building paper (e.g., rosin-sized or unsaturated building paper). NRCA recommends that one layer of rosin-sized sheathing paper or other slip sheet material be specified. Before metal panel application, a rosin-sized slip sheet may be necessary to protect the underlayment from damage, as the panels can adhere to and tear the underlayment.

## **4.4 Vapor Retarders, Insulation and Ventilation**

Some vapor retarder, insulation and ventilation issues are unique to architectural metal panel roof assemblies. For additional information refer to the following sources:

- “Moisture Control for Low-slope Roof Assemblies” and “Rigid Board Roof Insulation” in the Low-slope Text section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*.
- “Moisture Control and Ventilation for Steep-slope Roof Assemblies” in the Steep-slope Text section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*.

Because every building is in some way unique, building owners and designers may need to consult with appropriate design professionals who are familiar with the complexities of vapor retarder, insulation and ventilation issues.

### **4.4.1 Vapor Retarders**

For architectural metal roof systems installed over attic spaces, or “cold roof” systems, the vapor retarder is typically located at the ceiling level, typically the attic floor. For architectural metal panel roof systems installed over cathedral, or vaulted ceiling construction, careful consideration should be given to proper design, placement and installation of vapor retarders.

Insulation can be designed for placement above or below the substrate over which an architectural metal panel system is to be installed. For constructions in which the insulation is placed above the substrate, a vapor retarder may be needed between the substrate and insulation. For constructions in which the insulation is placed below the substrate, a vapor retarder may be needed below the insulation, on the warm side of the roof assembly.

For insulations with lower compressive strengths, metal or wood grid, such as a batten/counter-batten systems or plate-bearing systems, should be used for attachment of the metal panels. This will help prevent the compression and deformation of the insulation. A metal or wood batten, counter-batten system can also be used to create a ventilation space below the metal panels where needed.

A composite insulation board, such as a wood panel laminated to rigid insulation, is also a substrate used under architectural metal panel roof systems. Consideration must be given during design to the type of fastener used for securement of the composite board panels to the supporting structure and to the fastening schedule.

### **4.4.2 Insulation**

Insulation can be a vital part of a metal roof system. A properly insulated building uses less heating and cooling energy to maintain a comfortable interior environment than a poorly insulated building. Designers should determine the insulation requirements of the metal roof system. Several thermal design concepts are used to determine insulation requirements, as well as condensation, air infiltration and sound-control requirements.

When rigid insulation is installed over a solid roof deck, panel clips are typically fastened to wood or metal batten, counter batten grid, Z-purlin or metal hat channel, which is usually placed over the deck and between the insulation boards. Specially designed clips and bearing plates are available for installation directly over rigid insulation boards, but battens are suggested because of the relatively low compressive strength of most rigid insulation. The battens are typically the same thickness or thicker as the rigid insulation boards which creates a ventilation cavity. Where increased R-value is desired, an additional layer of insulation may be installed over the first layer. When this is done, additional battens are installed over and perpendicular to the first layer of battens. Not only does this two-layer arrangement provide a higher R-value, it is quite effective in minimizing thermal bridging that occurs at gaps between

adjacent insulation boards and/or between insulation boards and battens. See Figure 4.4.

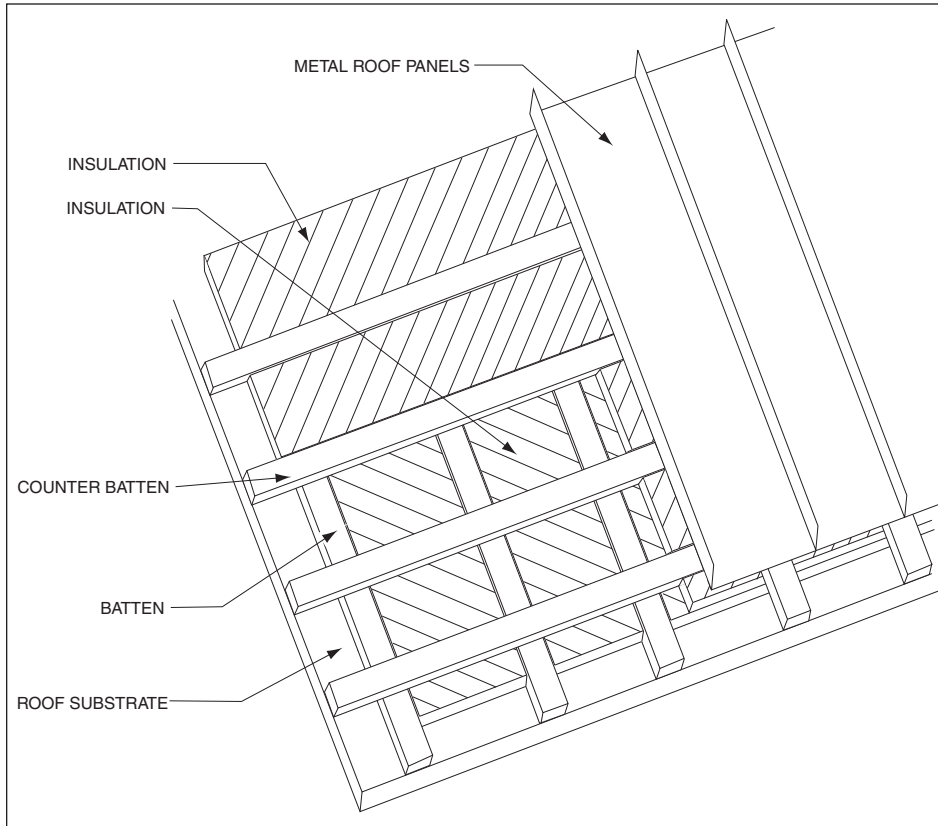


Figure 4.4: Counter batten system with two layers of insulation

When two layers of battens are used in a metal panel roof system, it is important to design the connection between the intersecting battens so it has sufficient strength to carry the wind-uplift design loads of the metal panel roof system. It is also important to adequately design the connection between the deck and the first layer of battens, and particular attention should be paid to connections where battens are spliced. NRCA recommends the use of decay-resistant, treated wood battens for longevity. When treated wood is used, the following recommendations are suggested:

- Carbon steel, aluminum and electroplated galvanized steel fasteners and connectors should not be used in contact with treated wood. Hot-dipped galvanized fasteners complying with ASTM A153 and connectors complying with ASTM A653, Class G185, generally are acceptable. Type 304 or Type 316 stainless-steel fasteners and connectors are recommended for maximum corrosion resistance.
- Fasteners with proprietary anti-corrosion coatings may be acceptable for use with treated wood. When considering the use of such proprietary coated fasteners and connectors, consult fastener manufacturers for specific information regarding the performances of their products in treated wood and any precautions or special instructions that may be applicable.
- Aluminum fasteners, flashings and accessory products should not be used in direct contact with any treated wood. ACQ-treated wood is not compatible with aluminum.
- Uncoated metal and painted metal flashings and accessories, except for 300-series stainless steel, should not be used in direct contact with treated wood. Metal products, except stainless steel, may be used if separated from treated wood by a spacer or barrier, such as single-ply membrane or self-adhered polymer-modified bitumen membrane material.

Additionally, a separator sheet, such as vinyl or self-adhering underlayment, is needed between the treated wood battens and the bottom of the metal panels to prevent corrosion of the bottom side of the metal panels.

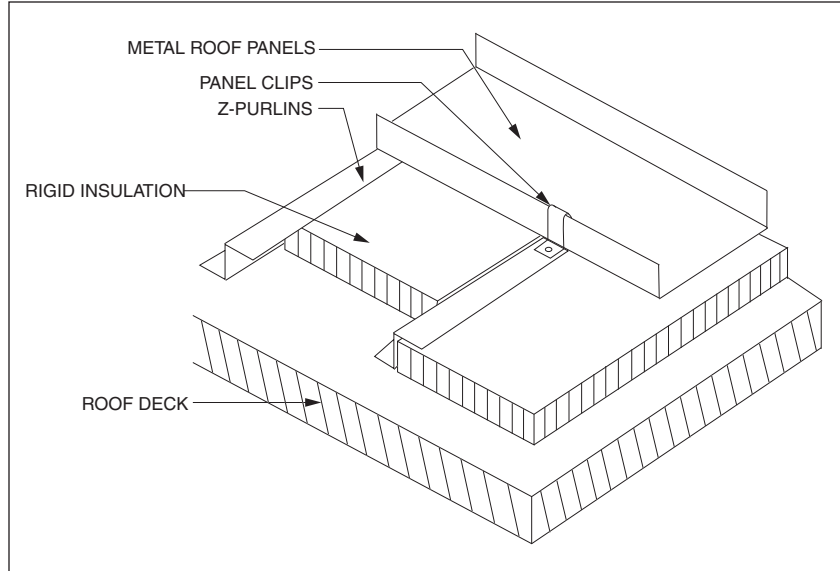
Rigid roof insulation can be installed over continuous or closely spaced roof decks under an architectural metal panel roof system. The type of roof insulation used and whether a vapor retarder is required will depend on such things as dew-point location, climatic conditions, interior conditions and owner's requirements. The potential for condensation to occur between the metal panels and rigid insulation must not be overlooked. Ventilation between the underside of metal panels and roof insulation may be required.

An underlayment should be installed on top of the rigid roof insulation in a similar fashion as previously described for

a continuous or closely spaced decking. Refer to Figure 4.1A. Attachment of the underlayment can vary depending on the roof system requirements.

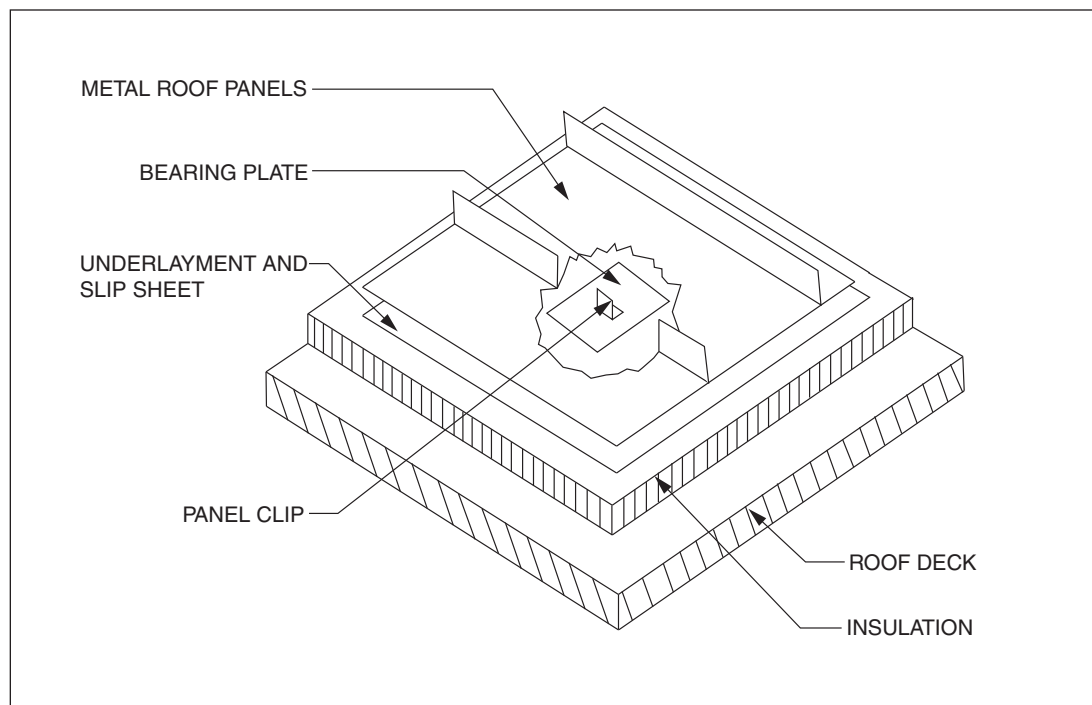
Attachment of metal roof panels over rigid insulation can be accomplished by installing purlins, metal hat channels or wood nailers to the deck. These members should run in a direction perpendicular to the roof slope or parallel to the eave line. Spacing for these members will be based on the spacing requirements for the panel clips. Rigid roof insulation is then installed between the framing members. For an example of this type of construction using Z-purlins, refer to Figure 4.5.

Figure 4.5: Z purlins with rigid insulation



Another method of attaching metal roof panels over rigid insulation is by the use of bearing plates on top of the insulation. When using bearing plates, the rigid roof insulation is installed over the deck with an underlayment and slip sheet on top of the insulation. The metal panels are then installed over this assembly. At each clip location, a metal bearing plate is placed over the insulation and underlayment. The clip can be either attached through the bearing plate and into the deck below, or the clip can be attached to the bearing plate if the bearing plate is attached separately to the deck and is of adequate strength and thickness to meet code requirements. Fasteners must also meet the minimum pull-out resistance required by building codes. An example of bearing plate construction is shown in Figure 4.6.

Figure 4.6: Bearing plate and panel clip over rigid insulation



### 4.4.3 Ventilation

Regardless of the effectiveness of a vapor retarder and the amount of insulation used in areas where condensation development is possible, condensation should be expected to develop on the undersides of the metal panels. Accordingly, the clips and fasteners should be corrosion-resistant. The desired degree of resistance is determined by climate—for example, more resistance will be needed in coastal or industrial areas. The type of ventilation and the design of the ventilation system is the responsibility of the designer and should be determined during the initial design of the building and roof assembly.

#### 4.4.3.1 Cold Roof Construction

Ventilation between the underside of metal roof panels and the substrate may be required because of the potential for condensation on the underside of the metal roof panels, regardless of the effectiveness of the vapor retarder and amount of insulation used. Condensation in metal roof systems can be problematic because the panels themselves are excellent thermal conductors and the temperature of the panels often falls below the dew point temperature.

Where condensation is anticipated, an air space between the panel and substrate is needed. The depth of this ventilation space is determined by the climate, interior relative humidity, effectiveness of the vapor/air retarder, roof slope and air-flow efficiency of eave, hip and ridge details—or other means of providing air exchanges from the roof cavity. Accordingly, the clips and fasteners should be corrosion-resistant. The desired degree of resistance is determined by the climate; is more resistance will be needed in coastal or industrial areas and the building owner's or designer's degree of conservatism.

If zinc or terne metal panels, except terne-coated stainless steel, are used, ventilation of the underside of the panels is critical to avoid corrosion. Additionally, terne metal panels may require a coat of paint on the underside to prevent corrosion. The manufacturer or supplier should be consulted for more information about any requirements for the painting of the underside of the panels.

#### 4.4.3.2 Compact Roof Construction

Where insulation is located between the deck and metal panels and the conditions for condensation development is anticipated, the use of an appropriate underlayment over the insulation should be considered. The underlayment can protect the insulation from condensate water, thereby limiting the chance of R-value reduction. Also, if a small quantity of ice develops on the undersides of the panels and rapidly melts, the underlayment can effectively shed melted ice and preventing leakage into the interior of the building.

### 4.5 Panel Profiles (Seam Types)

Panel profiles vary from manufacturer to manufacturer depending on the different methods used for forming the panels. The metal panels can have different physical characteristics and aesthetic appearances. The choice of the profile is often based on performance, as well as aesthetics. Seam height not only affects aesthetics, it also affects performance. Generally, taller seams can accommodate greater densities (i.e., greater depths) of water runoff. The seam type (e.g., double lock) also will affect the ability of a metal panel roof system to accommodate water runoff. Seam height and type should be appropriate for the job specifics (e.g., slope) and according to manufacturer's recommendations.

The flat pan with a vertical rib is the most common profile for traditional architectural metal panel roof systems. It is a design that uses an assortment of vertical ribs styles. These ribs dictate the actual panel profile, extent of weatherproofing and finished seam profile. These profiles include double-lock, snap-on caps, battens, T's, snap-lock seams and integral seams. See Figure 4.7.

A hybrid type of metal panel roof system is flat-seam, soldered metal panel roof system that incorporates the hydrostatic characteristics of structural metal panel roof systems but requires a continuous or closely spaced, solid deck as is required with an architectural metal panel roof system.

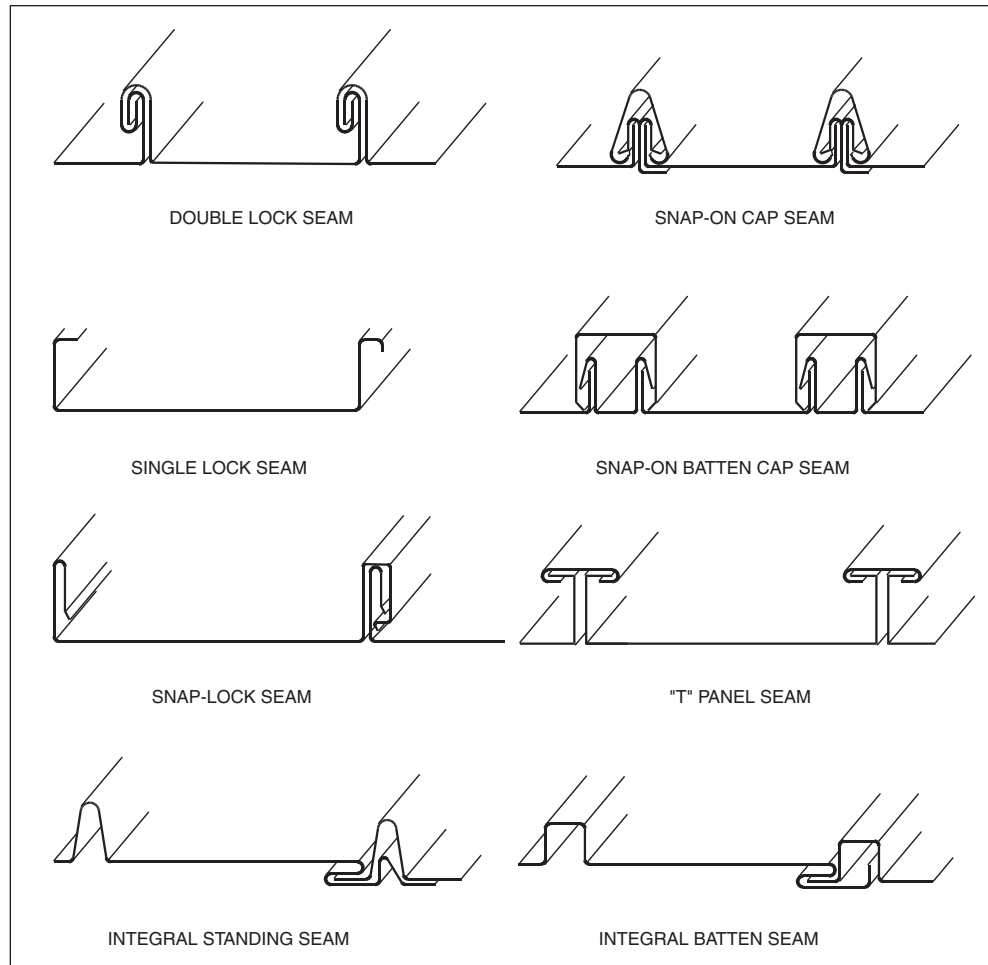


Figure 4.7: Examples of common architectural metal roof panel profiles (based on seam type)

## 4.6 Panel Installation

With most metal panel roof systems, metal edge flashing is installed first, along the downslope edge, then an underlayment and ice dam protection membrane, if required, is installed. See Figures 4.3A, 4.3B and 4.3C. The roof flange of the edge metal should extend back up the slope of the roof a minimum of 3 inches (75 mm) or more to rest smoothly on the roof deck. The edge flashing is secured with appropriate fasteners spaced approximately 3 inches (75 mm) on center, staggered. The underlayment or ice dam protection membrane should overlap the metal edge flashing flange. Before metal panel application, a rosin-sized slip sheet may be necessary to protect the underlayment from damage because the panels can adhere to and tear the underlayment.

Once all underlying components have been installed, the metal panel application may begin. The downslope ends of panels should hook onto the metal edge flashing or be secured in another manner along the perimeter to resist wind-uplift and water infiltration. See Figure 4.8.

Architectural metal panels are attached to the roof substrate with a series of individual clips. These clips are sometimes one-piece and can allow for some panel movement along the clip's engaged edge. Two-piece expansion clips may be installed and can allow for more thermal movement. When using two-piece clips and metal panel roll formers, architectural roof panels can be formed in long, typically full-length, eave-to-ridge, panels. Depending on the system, the clips are installed at various intervals, and the panels are intended to move back and forth under thermal loads without loosening or breaking the clips.

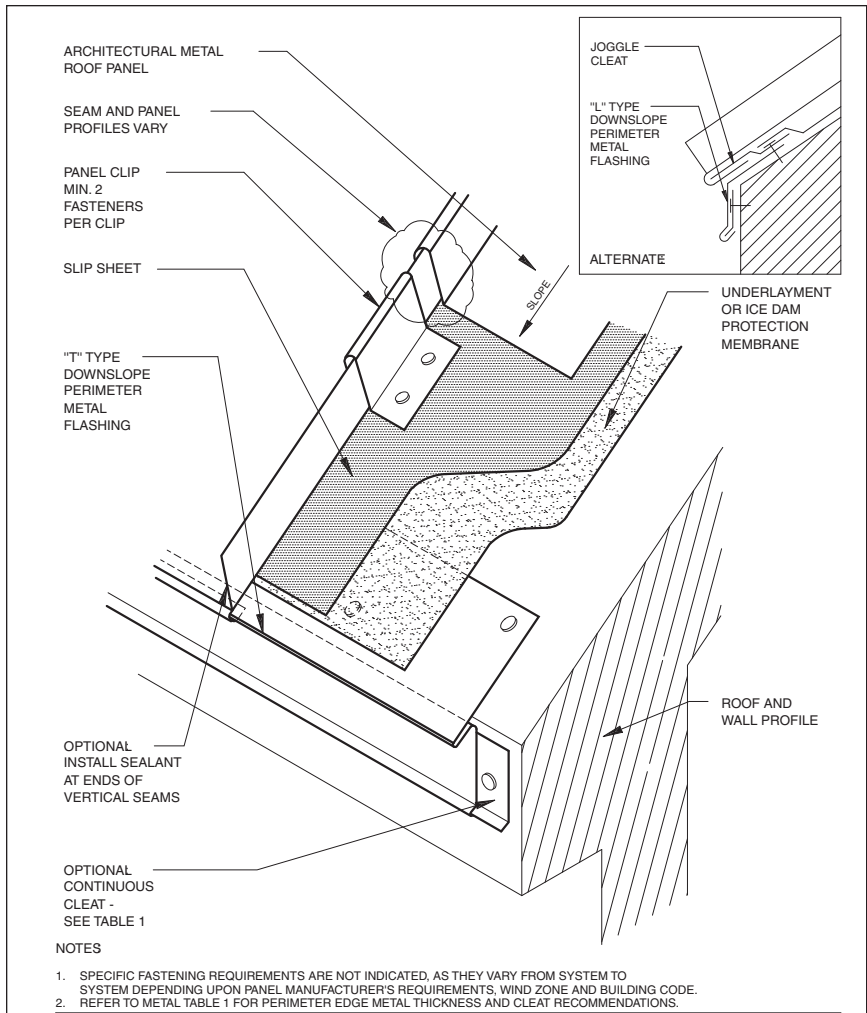


Figure 4.8: Downslope perimeter edge securement

Once a section of the roof panels is secured, the seaming process can begin. If the panels are of a mechanical interlock design, it is good practice to crimp the panels together with hand seamers before using a mechanical seamer. This should be done close to the location of the clips so that there will be less likelihood of a panel disengaging from a clip and adjacent panels before being seamed. It will also keep the panels firmly nested together for seaming, which may prevent the seamer from disengaging from or damaging the seam.

Refer to Section 3.5 for information about seam types and seaming methods. Manufacturers should be consulted for specifics about seaming.

Expansion clips are needed to accommodate thermal movement in long panels. During installation, correct positioning of clips is important. During warm-weather application, clips should be installed with the sliding position near the maximum point of panel movement. When a panel contracts from cooler temperatures, it will have adequate space to move so that stress will not be transferred to the clip. During cold-weather applications, clips should be installed near the minimum point of panel movement. See Figure 4.9. Manufacturer specifications should be referred to for proper settings for expansion clips.

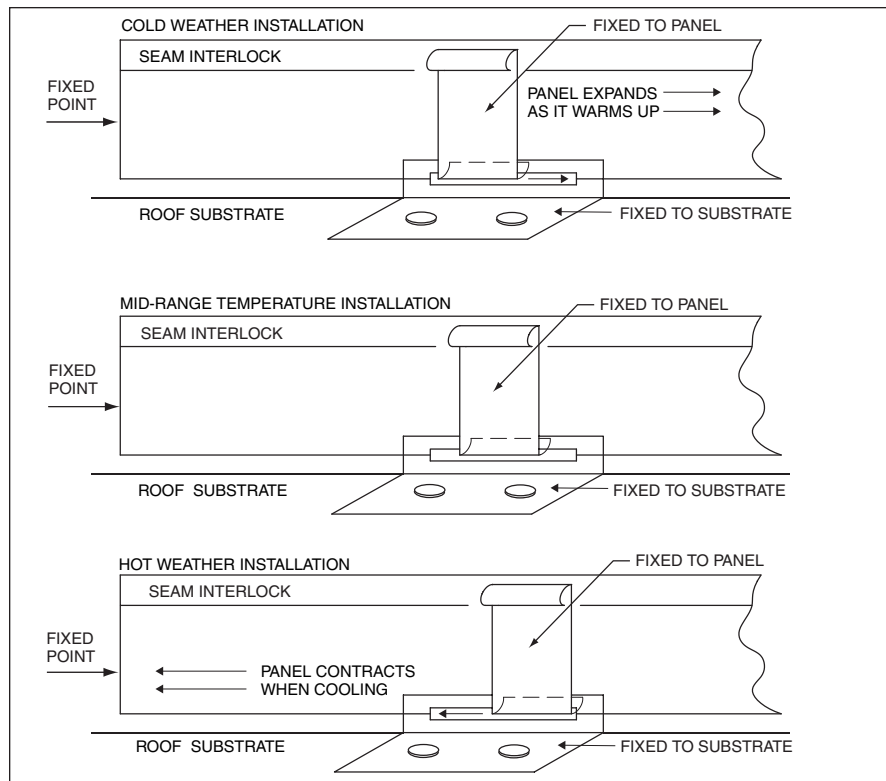


Figure 4.9: Clip location with respect to temperature

## 4.7 Fastening/Attachment Requirements

During design of a metal panel roof system, consideration must be given to the fastening requirements. If the metal system is being installed as a Factory Mutual Approvals- (FM-) or Underwriters Laboratories- (UL-) approved roof assembly, the prescribed fastening schedule and substrates should provide adequate anchorage to resist wind-uplift pressures. However, if the metal roof system is an architectural system—other than an FM or UL approved assembly—being designed for use over a solid structural roof deck, the designer should consider the need to conduct fastener pull-out tests to determine whether the substrate and metal panel system will meet the design wind-uplift requirements. Wind-uplift requirements will vary depending on local building codes that mandate the design wind speed for the area, topography, roof slope fastener type and pattern, roof deck or substrate type, height and geometry of the building, panel width, and metal thickness and type.

With metal panel roof systems, it is critical that fasteners and clips and their densities be designed to meet the wind-uplift requirements for the project. It is important to select the correct fasteners appropriate for the substrate, fastener size, point or tip type, thread type, shank type, compatibility and corrosion resistance. If panels are roll-formed with portable or mobile equipment, fastening requirements may be available from equipment manufacturers together with the results of wind-uplift tests that may have been conducted on specific metal panel roof assemblies. It is important to adhere to the fastening specifications so that the metal roof system attachment is not compromised.

Care must be taken to drive fasteners straight and not under- or over-drive them. Misalignment of fasteners can create a wear point on the underside of the overlying panel, which invites degradation—with some panels, corrosion—and can eventually lead to perforation of the panel. Low-profile (i.e., “pancake”) fastener head design is recommended for clip attachment unless otherwise recommended by manufacturers to minimize wear points and potential damage or perforation of the panel. See Figure 4.10.

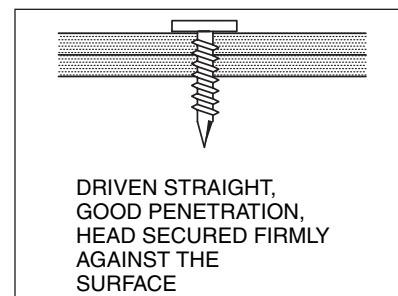


Figure 4.10: A properly installed fastener

Metal panel roof system attachment design should consider the number of clips needed at the roof perimeters and corners because increased fastening at the perimeters and corners may be necessary to accommodate increased wind-uplift loads.

#### **4.8 Fixed Points**

Metal panel roof system design must accommodate thermal movement of the metal panels and must resist sliding forces, typically called “drag loads.” Thermal movement is caused by changes in temperature. Drag loads are caused by gravity and snow loads that force the metal panels to move downslope. Typical metal panel roof systems need to be fixed to resist drag loads but must allow for movement because of panel expansion and contraction. Panel movement is typically allowed to occur in one of two directions: upslope or downslope. This can occur by providing a fixed point of attachment either at the hip and ridge or eave and valleys. For long panels, it may be desirable to fix the panels at the midpoint so movement occurs at each end of the panel; each end of the panel will move one-half of the total panel movement. It is easier to accommodate 2 inches (50 mm) of movement at each panel end than 4 inches (100 mm) of movement at one end.

When a metal panel is fixed at the ridge, the fasteners can be concealed under ridge or hip caps. Concealed fasteners can be more aesthetically acceptable to building owners in lieu of having exposed fasteners at the eaves. When panels are fixed at the ridge, panels cannot be fixed at the valleys. When a metal panel is fixed at the eaves and valleys, fasteners at the ridge cannot be attached to the structure to create a fixed point. Care must be taken at penetrations, roof curbs and vent stacks so that panels are not fixed to the substrate at these locations. Providing more than one fixed point in a metal panel system restricts panel movement and can result in oil-canning or panel damage. See Figure 4.11.

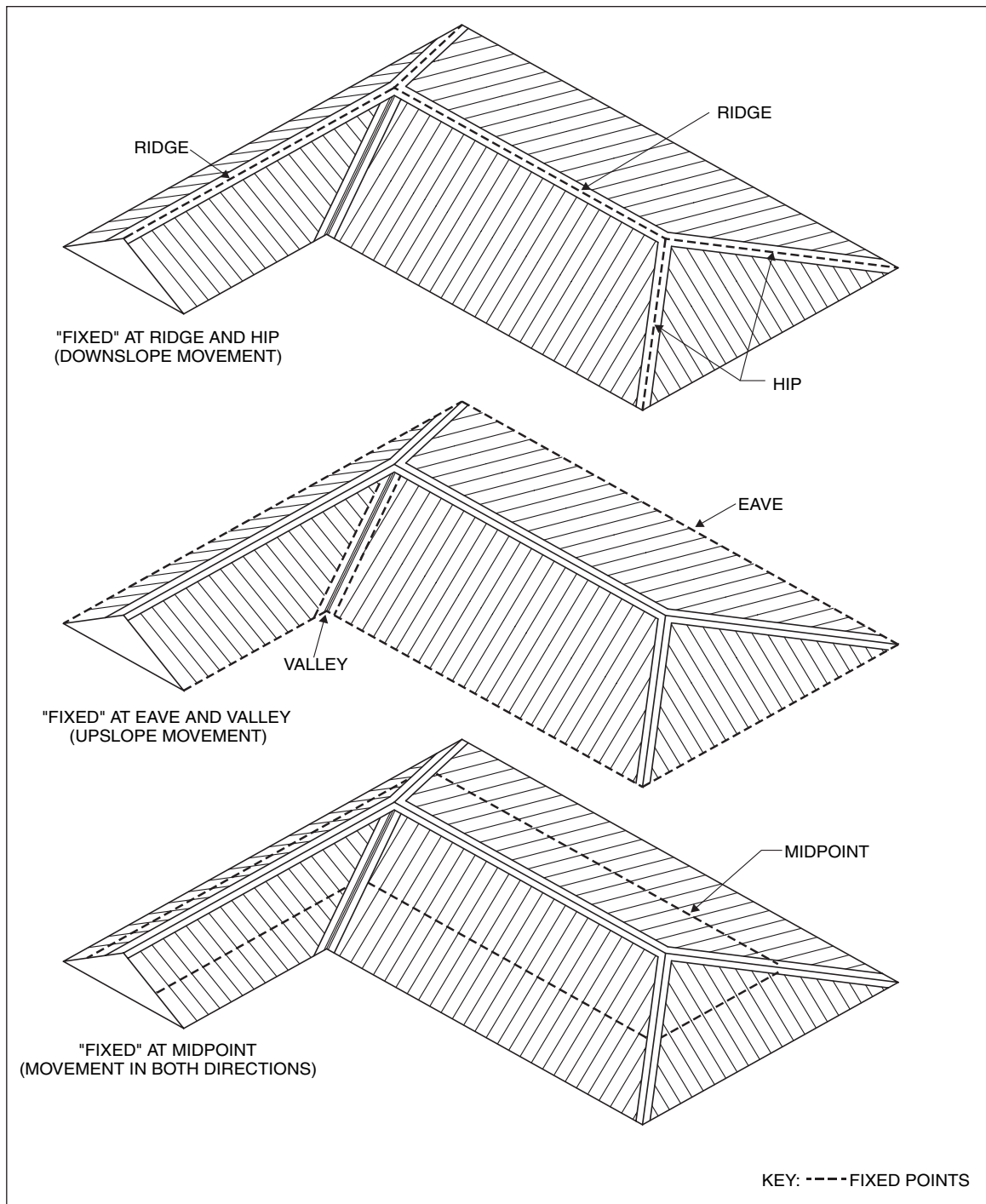


Figure 4.11: Possible fixed point locations

## 4.9 Flashing and Accessories

Because metal panel roof systems are frequently interrupted by the intersection of adjoining roof sections, adjacent walls and/or penetrations such as curbs and plumbing soil-pipe stacks, all of which create potential locations for leakage, special provisions for weather protection must be made at these locations. Flashings are used to control water entry at these locations. Careful attention to flashing details is essential to successful long-term roof performance regardless of the type of metal panel roof system. The number of penetrations should be kept to a minimum. Refer to the Construction Details section for examples of flashing conditions commonly encountered with architectural metal roof systems.

Designers should consider the following factors for proper detailing:

- type of substrate

- roof slope
- roof insulation
- proper flashing securement in relation to the location of fixed panel point
- panel profile
- panel radius
- vented vs. non-vented
- valley end points
- dormers

#### **4.9.1 Eaves**

Flashings used at the eaves are made of equal or heavier gauge metal than the roof panels to achieve proper panel securement. When a T-type drip edge metal is used at the eave, it can serve as a securement point for the roof panel. If this type of detail is used, the fixed point location will be at the ridge/hip or panel midpoint. In this detail, the panel is hooked to the T-type drip edge to allow movement and secure the panel edge. This type of eave flashing may be used with a vertical leg structural panel but is not typically used with a trapezoidal rib structural panel.

Eave flashings installed over an L-type metal edge requires a continuous bead of sealant between the drip edge and panel. At the seam ends, metal and/or foam closures, set in continuous sealant, are required to seal the open ends of the seams. Structural metal roof panels can be attached at the eaves with clips in the seams or with exposed, gasketed fasteners through the panel and drip edge. Use of through-panel fasteners will fix the panels at the fastener location.

#### **4.9.2 Rakes**

Flashings used at rakes are made of equal or heavier gauge metal than the roof panels to achieve proper panel securement. When a Z-closure is used at the rake, it often serves as a securement point for the roof panel, as well. The rake is hooked to the top of the Z-closure to allow movement. This type of rake flashing may be used with a vertical leg structural panel as well, as a trapezoidal structural panel.

Rake flashings for structural metal panel roof systems are typically installed over the metal panels and extend down the face of the wall or structure. The lower edge of the rake flashing is secured with continuous cleats or exposed, gasketed fasteners. The Z-closure is installed on top of the metal panels must be set in a continuous bead of sealant and should only be attached to the metal panel, not to the framing system or substrate. Attachment to the framing or substrate will fix the panel and rake flashing. See Figure 4.12

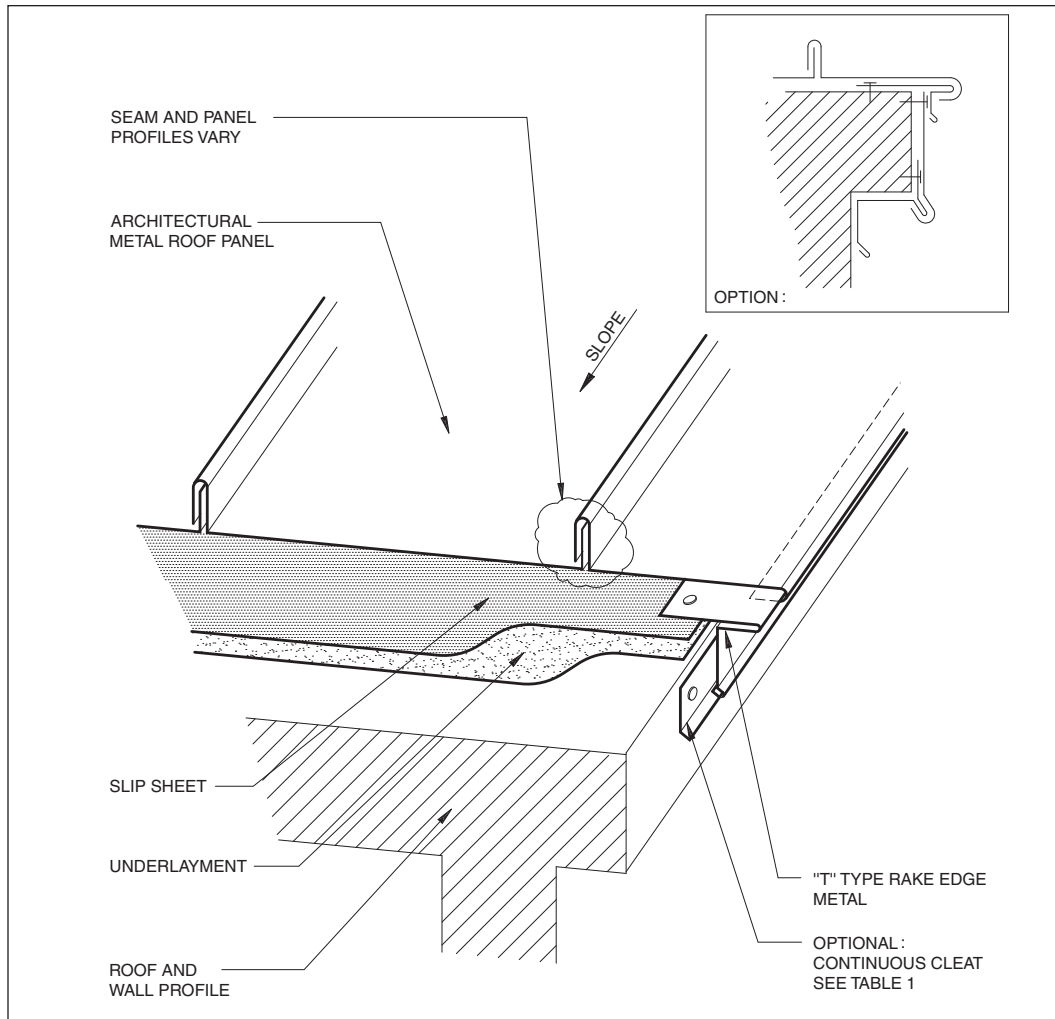


Figure 4.12: Example of a rake edge

### 4.9.3 Gutters and Downspouts

Drainage of architectural metal panel roof systems may be controlled by the use of gutters and downspouts. The size, style, attachment, location, climatic conditions and construction should be considered by designers when using gutters and downspouts. Gutters and downspouts used in conjunction with architectural metal panel roof systems are typically fabricated from the same metal type as the metal panels.

There are two types of gutters: built-in and externally attached (i.e., hanging). Gutter assemblies must be able to support themselves and the weight of debris, water and ice. Gutters must also remain leak free while enduring the stress of expansion and contraction.

When possible, built-in gutters at valleys and parapet walls should be avoided by designers and building owners; considering alternative roof drainage designs is strongly recommended by NRCA. When these built-in gutter types are used, overflow protection, that is secondary devices, is critical, and consideration should also be given to using a secondary waterproofing membrane.

For more information, see Section 2.3, “Gutters and Downspouts.”

### 4.9.4 Valleys

When designing a metal roof system valley, the designer should consider several factors, including:

- angle of adjoining roof slopes and resultant slope of the valley
- severity of the topography and climate, such as possibilities of debris and snow buildup, ice damming or strong wind-driven rains
- the need for a valley liner based on whether the metal panel roof system is hydrokinetic—a watershedding roof system, often referred to as architectural—or hydrostatic—a water-barrier roof system, often referred to as structural

- type and profile of the adjacent metal roof panels that will overlap the valley metal
- proximity of hips, dormers, chimneys, skylights, penetrations or other valleys
- size of the roof areas that will contribute runoff into the valley
- number and type of surrounding trees that will deposit debris onto the roof, which can eventually create a buildup or blockage, hampering drainage through the valley
- total length of the valley
- type of metal used, expected amount of thermal movement and required dimensions of hem to account for thermal movement

For the valley to perform successfully, it has to readily shed water at all locations throughout its length.

Depending on their length, metal valleys are not usually made from one continuous section of metal—typically they are made from two or more sections. As a result, a designer should consider how individual sections of valley metal must be joined and how valley metal will interface with the metal roof panels and other adjacent components making up the roof assembly, such as dormers and penetrations. Designers should carefully consider how laps are joined so the valley remains in place, resist drag-load, and still shed water, and how the center, sides and edges of the valley metal must be configured to perform in the needed location. For some architectural systems, such as mansard/screenwall systems and valley section lengths less than 10 feet (3 m), a straight, flat flange that is through-fastened may suffice. However, for many valleys, where greater thermal movement is anticipated, the edges of the valley metal flanges may be folded over for clip and panel securement. See Figures 4.13A, 4.13B and 4.13C. A raised center rib in the valley metal is helpful to control the flow of water runoff and helps prevent the water flow from running across the valley from one side to the other. This is especially true for steeper-sloped areas that intersect lower-sloped areas forming a valley and areas where large ridge-to-valley distances occur.

Where roofs of two equal slopes join to form a valley, the slope of the valley is less than that of the two adjacent fields of the roof. For example, where two slopes of 3 inches per foot (14 degrees) intersect at a valley, the actual valley slope is only about 2 inches per foot (9 degrees). This fact is important to bear in mind when considering which type of valley is specified, as each valley type has specific advantages. Enhancing the valley's detailing and underlayment requirements may also be appropriate.

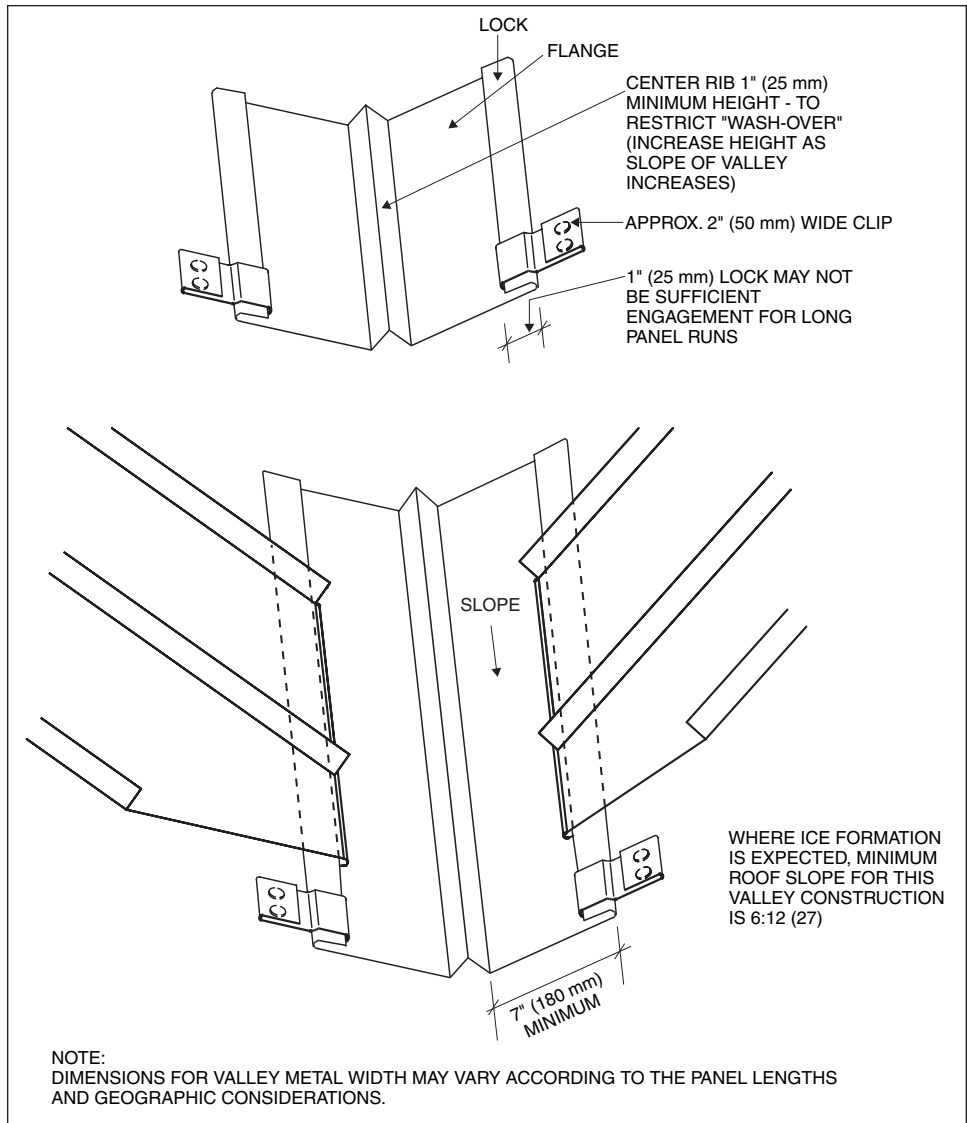


Figure 4.13A: Example of typical valley metal profile

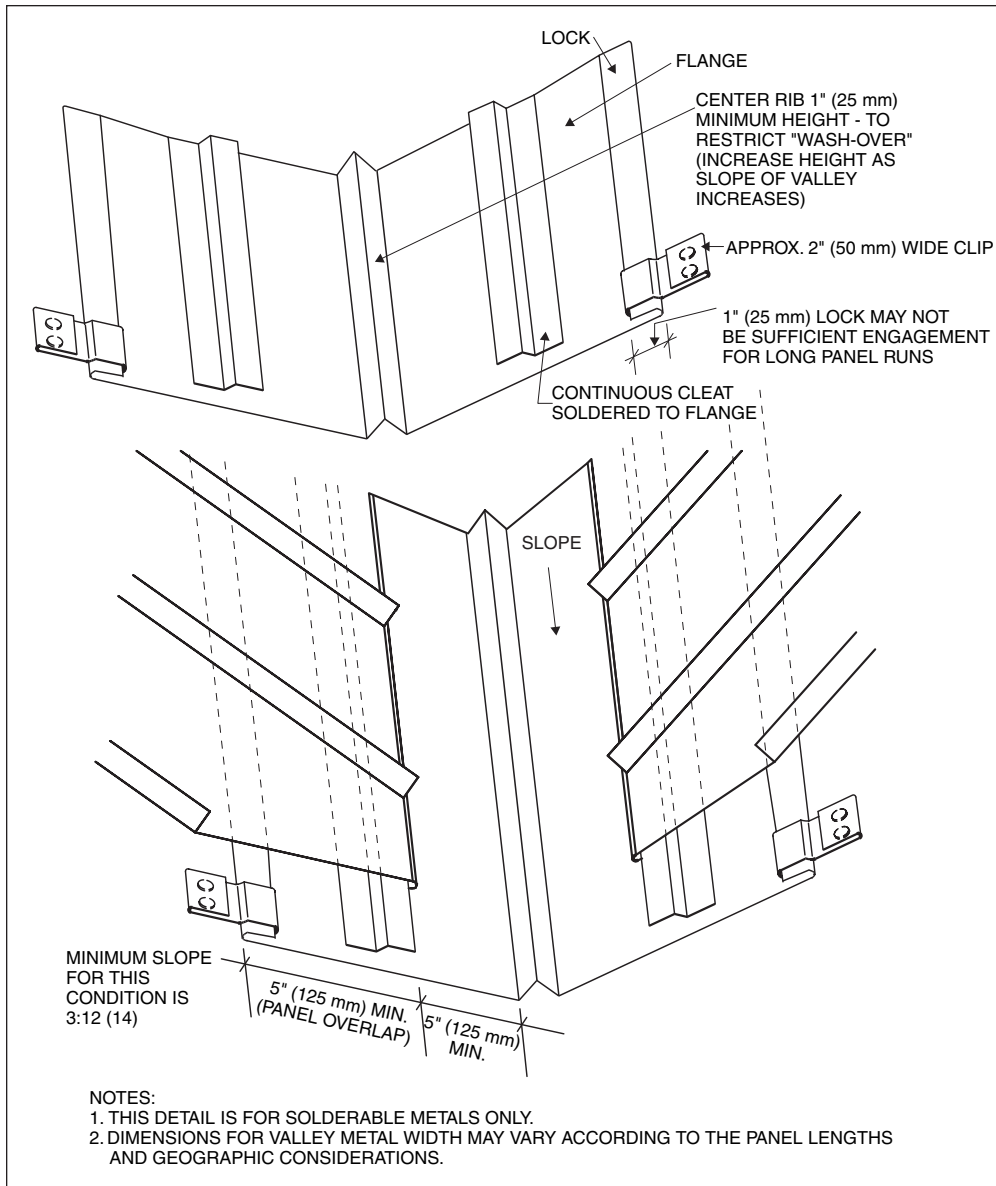


Figure 4.13B: Example of typical valley profile for solderable metals

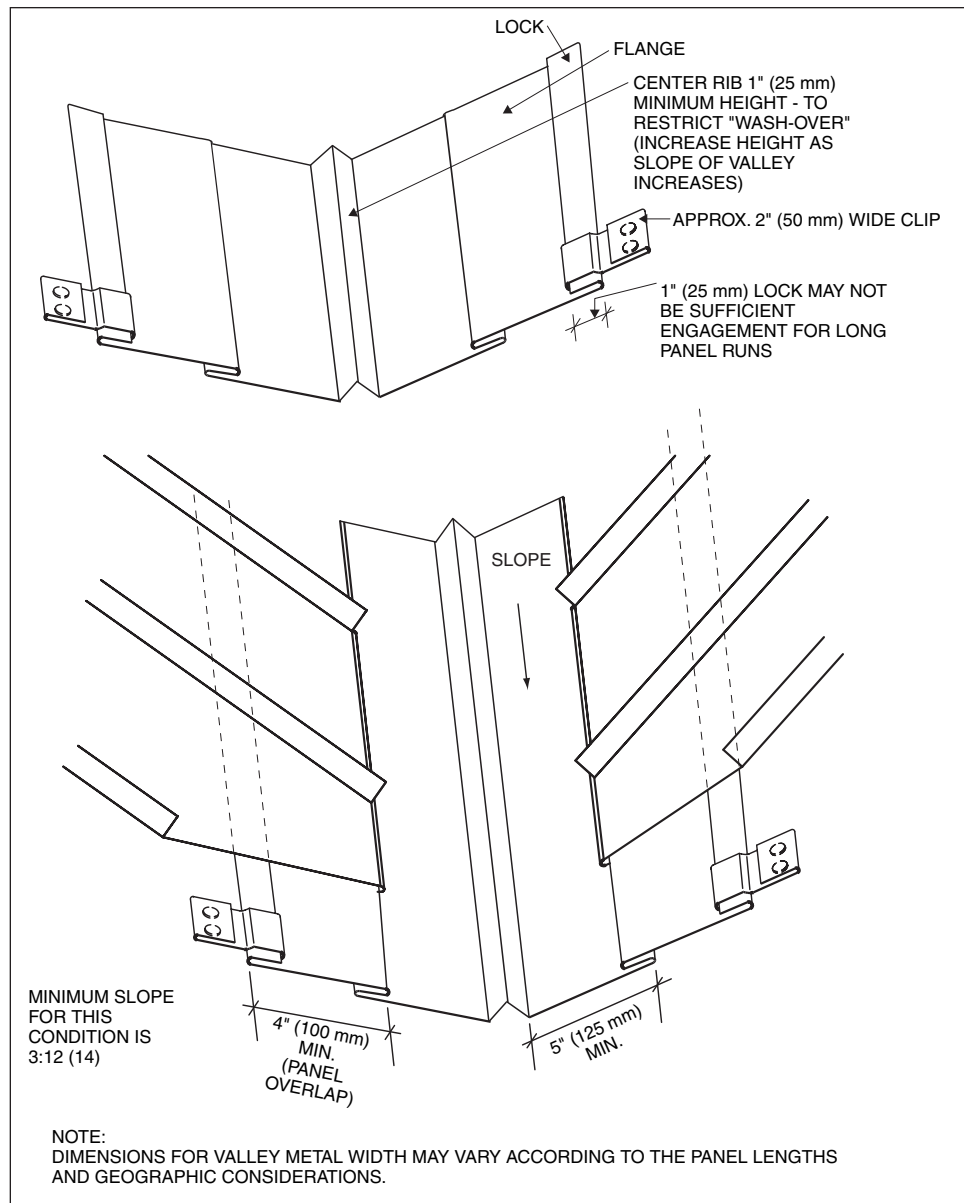


Figure 4.13C: Example of typical valley profile for non-solderable metals

When determining clip size for valley metal securement, a designer should select clips wide enough so that a minimum of two fasteners, installed parallel to the valley, may be used to attach the clips. The clips should be formed from at least the same gauge metal as the valley metal flashing. When clips are fastened with just one fastener, the cyclical thermal movement of the valley metal can loosen the fastener. A loose fastener results in a loose clip, and sections of the valley metal can bind against the misaligned clips.

Securing clips with two fasteners, set side by side, holds the clips in place more securely than using one fastener per clip. NRCA recommends the back tab of a clip be bent over the fastener heads and the tab hammered flat to help keep the fasteners from backing out and from damaging the underside of the metal roof panels. However, many pre-fabricated clips do not allow the base of the clip to be bent over the head of the fasteners.

In a nonstructural metal panel roof system where valley metal is clipped to the roof deck, the upslope end of each section of valley metal should be securely attached to the substrate. Valley metal attached with clips placed along the edges can move within the clips—because of thermal expansion and contraction—and slip downslope with time. In climates with heavy snow, drag loads of accumulated snow and ice in the valleys can also pull the valley metal downslope.

Therefore, individual sections of valley metal need to be anchored. Fastening each section of valley metal in a staggered pattern along the upslope end keeps the metal in place. Generally, concealed fastening with fasteners installed approximately 3 inches (75 mm) on center and staggered is adequate for most valley metal sections. See Figure 4.14.

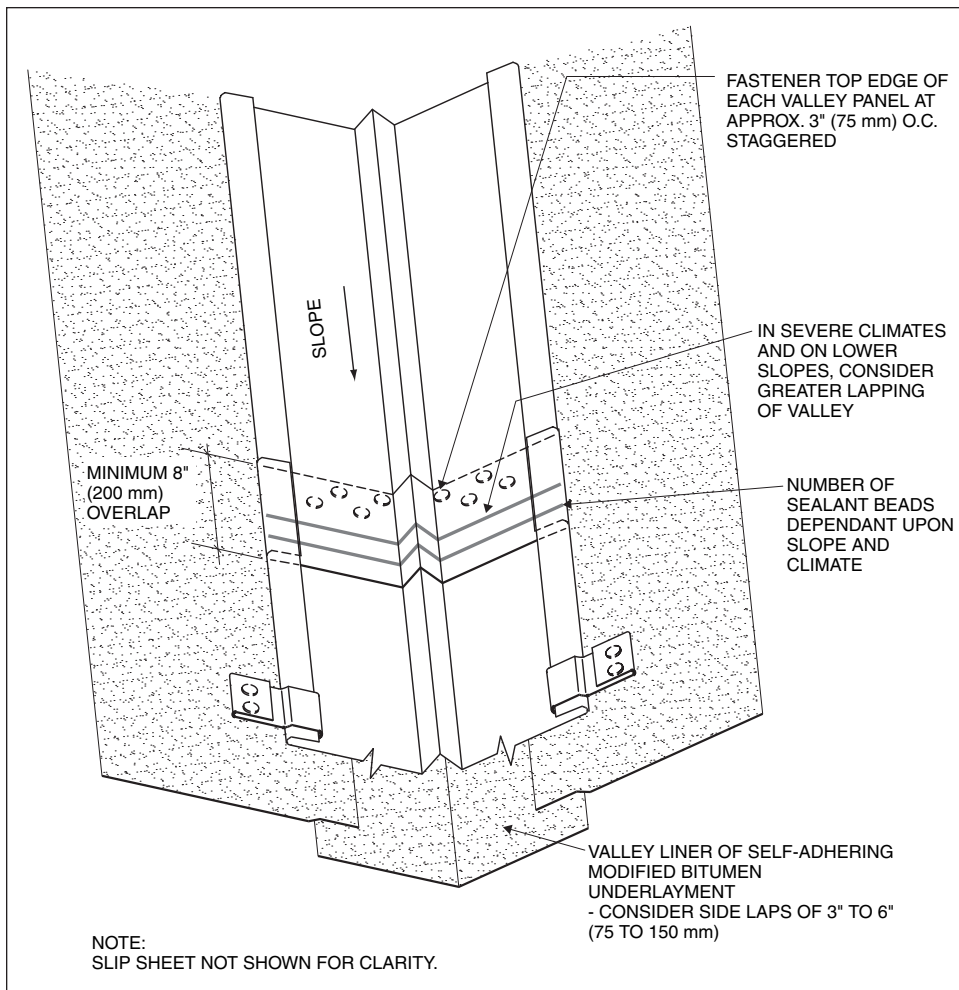


Figure 4.14: Valley metal overlap and upslope attachment of valley metal

#### 4.9.4.1 Valley Enhancements

Some metal panel roof system manufacturers' "standard" valley details may need to be enhanced for projects in severe climates, in areas of high intensity rainfall or where valleys are relatively low-sloped.

At a location where a basic valley design may not readily shed water during certain situations such as wind-driven rain or ice damming conditions, NRCA suggests the valley design be enhanced to accommodate the expected situations that may cause problems.

For example, if, because of the relatively low slope of a roof and severity of climatic conditions, a particular valley may be expected to dam regularly with ice during freeze-thaw cycles, the valley flashing flanges on either side of the valley should be specified wide enough to accommodate this expected occurrence. That is, they should be made wider than the typical flange specified with other metal panel roof systems.

The following are examples for enhancing valley details:

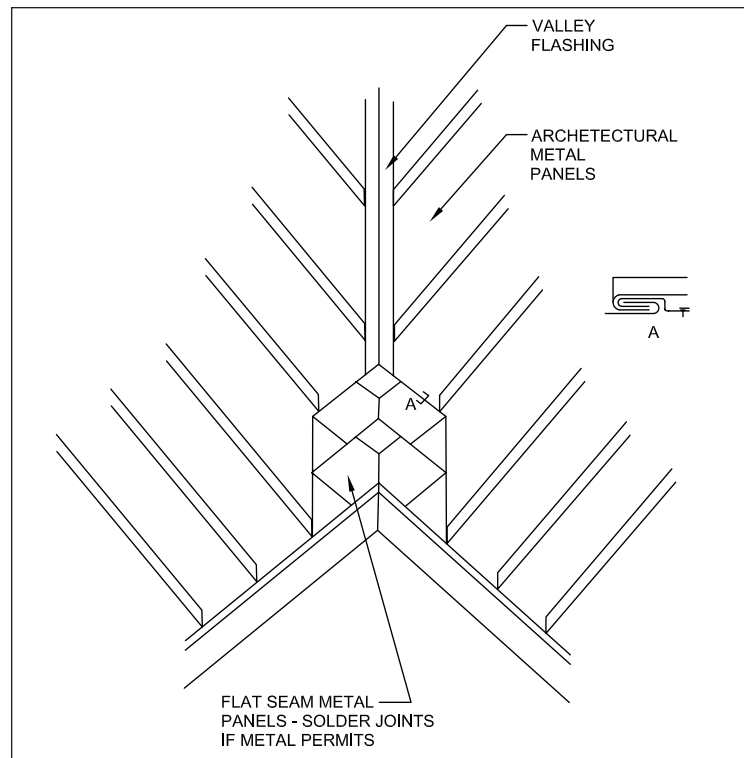
- Valley Width

Widening a valley metal provides an opportunity to improve the valley's performance. For example, wider valley metal allows more taper to be built into the valley so that the opening or exposed portion through the valley can be wider at the bottom.

If a valley needs to be tapered, it is suggested to taper the opening width about  $\frac{1}{8}$  of an inch per foot (0.6 degrees). Tapered valleys can handle greater quantities of runoff water nearer the lower end where runoff increases from larger contributing area. Tapered valleys better alleviate the buildup of debris, snow and ice.

Another option to accommodate the buildup of snow and ice is to install a gusset. The gusset opens the end of the valley significantly keeping the seams back from the typical ice dam area allowing the ice dam to free itself from the valley. The gusset can be formed of flat seam soldered pans or from larger/wider valley metal. See Figure 4.15.

Figure 4.15: Gusset at the end of a valley



- Flange Dimension and Roof-panel Overlap

The distance that adjacent metal roof panels must overlap the flanges on either side of the valley is another consideration. One of the most important reasons for widening the flashing flanges on either side of the valley centerline is that it allows for a greater flange overlap—lateral upslope—under the adjacent metal roof panels. The result is that the metal panels can further overlap the valley metal, providing a more positive mechanical lap.

With metal roof systems used as watershedding systems in moderate to severe climates, NRCA suggests that valley flange widths be exposed a minimum of 5 inches (125 mm) and lapped a minimum of 4 inches (100 mm) by the field panels. See Figures 4.13A, 4.13B, 4.13C.

- Individual Valley Metal Section Overlap and Sealing

The individual sections of valley metal must be overlapped by the adjacent upslope section for the valley to shed water. For successful valley performance, it is critical to provide sufficient overlap between valley sections. Metal valley sections should be overlapped a minimum of 8 inches (200 mm). The number of sealant beads is dependent upon the roof slope and climate. When sealant is required, a minimum of two continuous beads of sealant are recommended in metal valley laps. However, in severe climates, three continuous beads of sealant are not uncommon. For concealed sealing applications, such as valley metal laps, sealants that remain flexible and retain their adhesive properties for extended periods of time should be used.

- Underlayment and Valley Liner Material

With watershedding metal panel roof systems, the valley metal is typically laid over a minimum No. 30 asphalt-saturated felt or other underlayment sheet and rosin-sized paper that lines the valley. However, if the slope is not adequate and climatic conditions will expose the valley to severe wind-driven rains or extended freeze-thaw cycles, enhancing the valley underlayment is necessary.

Instead of using an asphalt-saturated felt underlayment, it may be beneficial to first line the valley with an ice dam protection membrane. Self-adhering polymer modified bitumen membranes can work well as a valley liner material. These membranes should extend past the edge of the valley metal on both sides and be covered with a slip sheet.

- Stripping in Valley Flanges

Folding the edges of a metal valley helps to turn migrating water back from the edges of a valley. But with various metal roof panel profiles where the panel will lap onto a valley that is oriented into anticipated prevailing wind-driven rain or exposed to extended freeze-thaw cycles, water sometimes can enter the roof system. The use of a membrane valley liner, such as a self-adhering modified bitumen underlayment, can help limit this migrating moisture from reaching the interior.

Stripping in the valley flanges along both sides of a metal valley can help to ensure the valley detail is weatherproof. Membrane valley liner material should be extended beneath and beyond the edges of the valley metal to facilitate stripping in of the metal valley flanges to the membrane valley liner. See Figure 4.16A and 4.16B. This detail restricts valley metal movement at the clips.

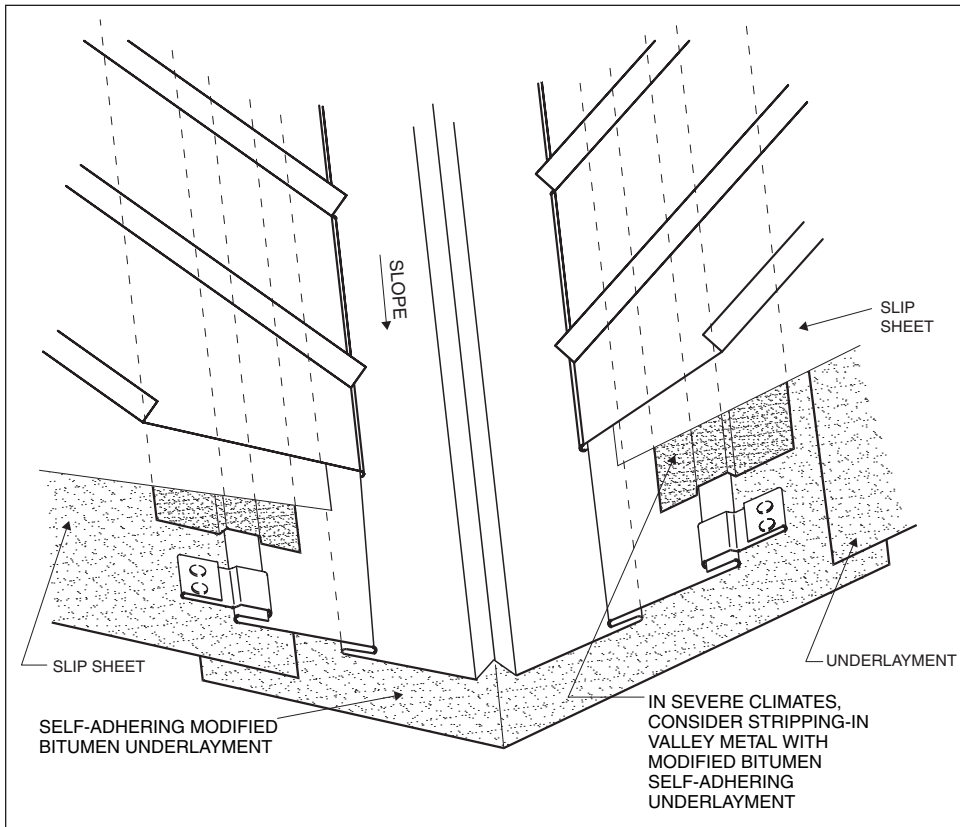


Figure 4.16A: Stripping in valley flanges

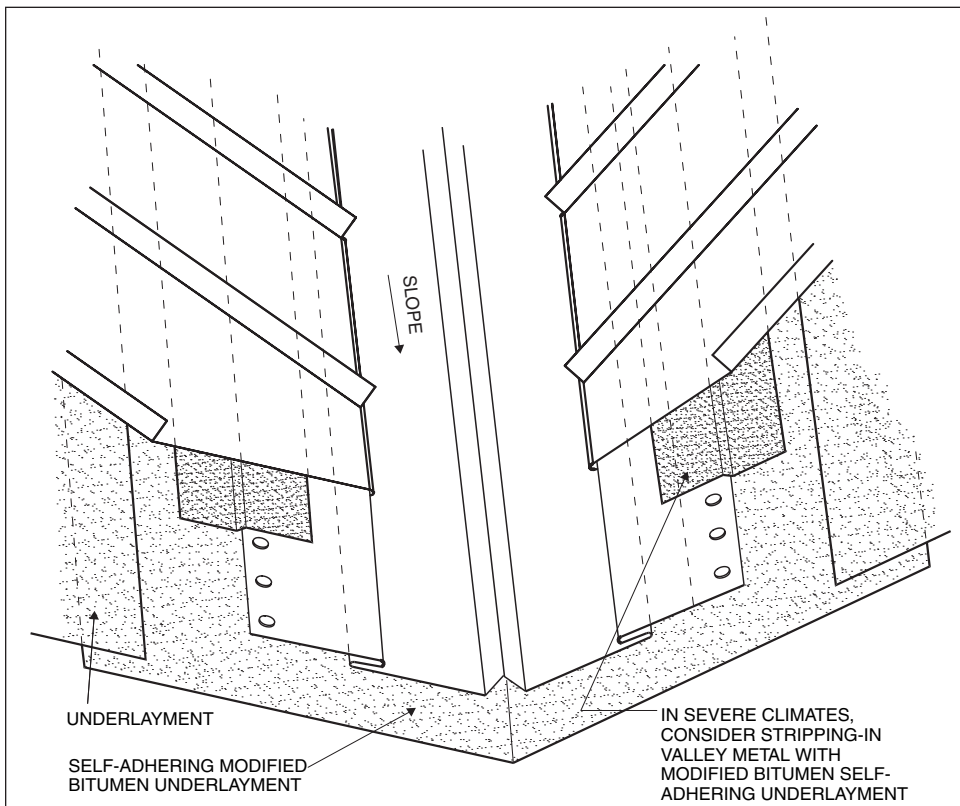


Figure 4.16B: Stripping in valley flanges

### 4.9.5 Penetrations

Flashing of any penetration can best be facilitated when the penetration is less than the width of a panel. Large penetrations are more complex and require additional considerations during design and installation. There are two types of roof panel penetrations, which are based on size. Small penetrations are less than *one-half* the width of the metal panel; large penetrations are greater than *one-half* the width of the metal panel. However, regardless of the penetration size, weatherproof characteristics and independent movement must be accounted for.

Small penetrations that can be installed within the width of the individual roof panel use a shop fabricated or premanufactured flashing component, such as a premanufactured flexible pipe collar. Small pipe penetrations should not penetrate seams and should be centered within the panel to allow for drainage.

For flashings that include full-panel-width sized shop-fabricated or prefabricated flashings, NRCA recommends that the top flange upslope of the flashing piece be installed under the roof panels, and the bottom flange downslope of the flashing piece be installed over the roof panels. Proper installation of the flashing will allow for both panel movement and vertical movement of the penetration. Care should be taken not to allow the flashing fasteners to restrict panel movement.

Shop-fabricated flashings typically consist of metal shapes formed to fit the item to be flashed and may require a metal rain collar. A flexible pipe collar includes a rubber type bellows with a metal flashing flange at the base and is set in a bed of sealant and fastened to the roof panel. An adjustable metal clamping collar is required to be installed at the top of the boot in sealant to terminate the flashing. A metal rain collar may also be installed above the flexible pipe collar.

The designer is responsible for coordinating the penetration location to avoid an installation that would interrupt the panel seams. Consideration should be given to using only round penetrations and should include only single units. Aesthetic requirements may involve the painting of the flashing and penetrations or the addition of a skirt to hide the flexible boot. Panel manufacturers should be consulted for their requirements for small and large penetrations.

Large penetrations can be installed in a single panel width as long as they do not prevent adequate drainage. Large penetrations such as mechanical vents and HVAC units that require flashing through the panel ribs involve the use of curbs, a sleeve, or a flat sheet that eliminates the seam and allows for drainage. These curbs may be pre-manufactured, shop-fabricated, or field-fabricated. The size, weight, type and other requirements determine how the curb and equipment is to be supported. Sub-framing may be required for support.

Panel-supported flashings are used for light loads and move with the roof panels when thermal movement occurs. They are attached to the roof panels and sealed in a weatherproof manner. Smaller units can be centered on one or two panels so that water can flow past the sides of the curb.

When larger curbs are used, the panel ribs must be stopped short of the upslope face of the curb so that water can flow past the ends of the ribs and not be trapped against the curb. If a raised curb is wider than 24 inches (600 mm), it is recommended that the designer detail a metal cricket on the upslope side of the curb to help divert water flow to either side of the curb. The cricket should be made of the same metal type and gauge as the metal panel. Depending on the metal type, the cricket should be welded, soldered or fastened and set in sealant. Curb heights should be a minimum of 8 inches (200 mm).

A column penetration may be considered a small or large penetration and should be flashed appropriately. When heavy equipment must be supported by a building's structure, differential movement between the support elements and roof panels must be accommodated. If the equipment includes the use of a separate frame supported by vertical supporting elements attached to the building structure, the vertical supporting elements are flashed as small penetrations. The clearance height measured from the metal panel to the bottom of the equipment support member should increase as the equipment width increases. The following chart is also provided in the Construction Details section of the Manual. See A-MTL-11.

Width of Equipment	Clearance Height of Legs
Up to 24 inches (610 mm)	24 inches (610 mm)
24 inches (610 mm) to 48 inches (1.2 m)	36 inches (910 mm)
48 inches (1.2 m) and wider	48 inches (1.2 m)

Penetrations may require the use of insulation to provide thermal resistance or reduce condensation. Penetration details will vary greatly from system to system. The designer should consult the manufacturer for specific information about the metal roof system, penetration type, panel configuration, attachment, and wind-uplift and code requirements.

### 4.9.6 Slope Transitions

There are two types of slope transitions: gambrel-style transitions, where the upper roof area has less slope than the adjacent lower roof area, and the opposite, where the upper roof area has more slope than the adjacent lower roof area. Transition-metal flashings therefore need to incorporate the attributes of eaves and ridges to provide closures at the ends of the upslope panel runs and the beginnings of the downslope panel runs.

When designing a metal roof transition, a designer should consider several factors including:

- angle of adjoining roof slopes
- severity of the topography and climate, such as possibilities of snow buildup, ice damming or strong wind-driven rains
- type and profile of the adjacent metal roof panels that will overlap the transition components
- proximity of hips, dormers, chimneys, skylights, penetrations or valleys
- size of the roof areas that will contribute runoff over the transition
- number and type of surrounding trees that will deposit debris onto the roof, which can eventually create a buildup or blockage, hampering drainage above or below the transition
- type of metal used and anticipated thermal movement
- supporting deck/sub-framing for slope change

Depending on their length, metal transitions are not usually made from one continuous section of metal—typically they are made from two or more sections and several components. As a result, the designer should consider how individual sections of transition metal are to be joined and how transition metal will interface with the metal roof panels and other adjacent components making up the roof assembly, such as dormers and penetrations. The designer should carefully consider how laps are joined for the transition to remain in place, that is not block waterflow or deform, and still shed water and how the edges of the transition metal should be configured to perform in the assigned location.

Depending on the slopes of the two roof surfaces and type of metal roof system flashing, the transition may be accomplished by using a metal cover, “knee joints” or “knuckles,” metal closures, or up-turned panel ends and sealants. Foam closures should be used only in conjunction with metal closures and up-turned panel ends. For a lesser-sloped metal roof below a steeper-sloped roof, all these components may be used to flash transitions. The practice of cutting panel seams and bending the panel pan into or over the transition and only caulking the seam is not recommended.

Transition covers and closures are made of equal or heavier gauge metal to achieve proper panel securement along the transition. Transition metal often serves as a securement point for the eave flashings of the upslope panel run. Therefore, it typically is not directly attached to the panel because of differential expansion and contraction of the materials. Instead, the panel is hemmed around the transition closure to allow movement. Transition metal may also serve as a securement point for the lower panel run. Therefore, design decisions about where and how securement points will function in relation to transitions are important.

#### 4.9.6.1 Slope Transition Enhancements

Some metal panel roof system manufacturers’ “standard” transition details may need to be enhanced for projects in severe climates or areas of high-intensity rainfall. For a transition to perform successfully, it has to shed water at all locations along its length.

At a location where a basic transition may not readily shed water during certain situations such as wind-driven rain or ice damming conditions, NRCA suggests the transition design be enhanced to accommodate the expected conditions.

For example, if, because of the relatively low slope of a roof and severity of climatic conditions, a particular transition may be expected to dam regularly with ice during freeze-thaw cycles, the transition flashing components should be specified with enough overlap to accommodate this expected condition.

The following are examples for enhancing slope transition details:

- Flange Dimension and Roof-panel Overlap

The distance that adjacent metal roof panels must overlap the flanges on either side of the transition should be considered. One of the most important reasons for widening the flanges on either side of the transition is that it allows for a greater overlap under the upper metal roof panel and over the lower metal roof panel.

For metal roof systems that will be used as watershedding systems in moderate to severe climates, NRCA suggests

that transition metal overlap the lower roof panels a minimum of 6 inches (150 mm) and be overlapped by the upper metal roof panels a minimum of 4 inches (100 mm).

- Underlayment and Liner Material

With watershedding metal panel roof systems, the transition metal is typically laid over a minimum No. 30 asphalt-saturated felt or other underlayment sheet and rosin-sized paper that is continuous across the change in slope. However, if the slope is not adequate and climatic conditions will expose the transition to severe wind-driven rain or extended freeze-thaw cycles, enhancing the transition underlayment is necessary.

Instead of using an asphalt-saturated felt underlayment, it may be beneficial to first line the change in slope with an ice dam protection underlayment. Self-adhering polymer modified bitumen membranes can work well for this purpose. These membranes should extend past the edges of the transition metal on both sides.

- Stripping in Transition Metal Flanges

Stripping in the transition metal flanges along the upslope side of the metal transition can help to ensure a successful transition detail. The membrane transition liner material should be extended beneath and beyond the edges of the transition metal to facilitate stripping in the upslope metal transition flange.

- Slope Transition Support

In snow and ice regions, transition metals may need support. The use of decay-resistant treated wood blocking, installed above the lower metal panel closures, between the panel seams and at the same height as the seam, will provide support to the transition metal cap/cover.

When treated wood is used, the following recommendations are suggested:

- Carbon steel, aluminum and electroplated galvanized steel fasteners and connectors should not be used in contact with treated wood. Hot-dipped galvanized fasteners complying with ASTM A153 and connectors complying with ASTM A653, Class G185, generally are acceptable. Type 304 or Type 316 stainless-steel fasteners and connectors are recommended for maximum corrosion resistance.
- Fasteners with proprietary anti-corrosion coatings may be acceptable for use with treated wood. When considering the use of such proprietary coated fasteners and connectors, consult fastener manufacturers for specific information regarding the performances of their products in treated wood and any precautions or special instructions that may be applicable.
- Aluminum fasteners, flashings and accessory products should not be used in direct contact with any treated wood. ACQ-treated wood is not compatible with aluminum.
- Uncoated metal and painted metal flashings and accessories, except for 300-series stainless steel, should not be used in direct contact with treated wood. Metal products, except stainless steel, may be used if separated from treated wood by a spacer or barrier, such as single-ply membrane or self-adhered polymer-modified bitumen membrane material.

Additionally, a separator sheet, such as vinyl or self-adhering underlayment, is needed between the treated wood blocking and the bottom of the metal panels to prevent corrosion of the bottom side of the metal panels.

In many instances, the use of nontreated, construction-grade wood is suitable for use in roof assemblies as blocking or nailers, provided reasonable measures are taken to ensure the nontreated wood remains reasonably dry when in service. Where a specific construction detail provides for a secondary means of waterproofing, NRCA now considers the use of nontreated, construction-grade wood to be an acceptable substitute for treated wood.

#### **4.9.7 Ridges and Hips**

Ridges and hips occur along the intersection of two adjacent roof slopes. Ridge and hip assemblies use similar detailing techniques. Flashing at the ridges and hips is needed to provide a closure for the tops of the metal panels. Proper flashing and securement of the metal cap and panel assembly at these intersections are essential for a long-term, weather-tight detail. Depending on the slope of the roof and type of metal panel roof system, flashing of the ridge or hip may be accomplished by using metal closures or up-turned panel ends and sealant.

NRCA suggests that along each side of the ridge and hip, the ends of the roof panels be turned up to form a pan. See Figure 4.17. This pan acts as a secondary barrier against water intrusion. Some metal panel profiles may not allow panel ends to be turned up to form a pan. To terminate these panel ends, NRCA recommends a preformed metal closure be secured between each rib and set in sealant.

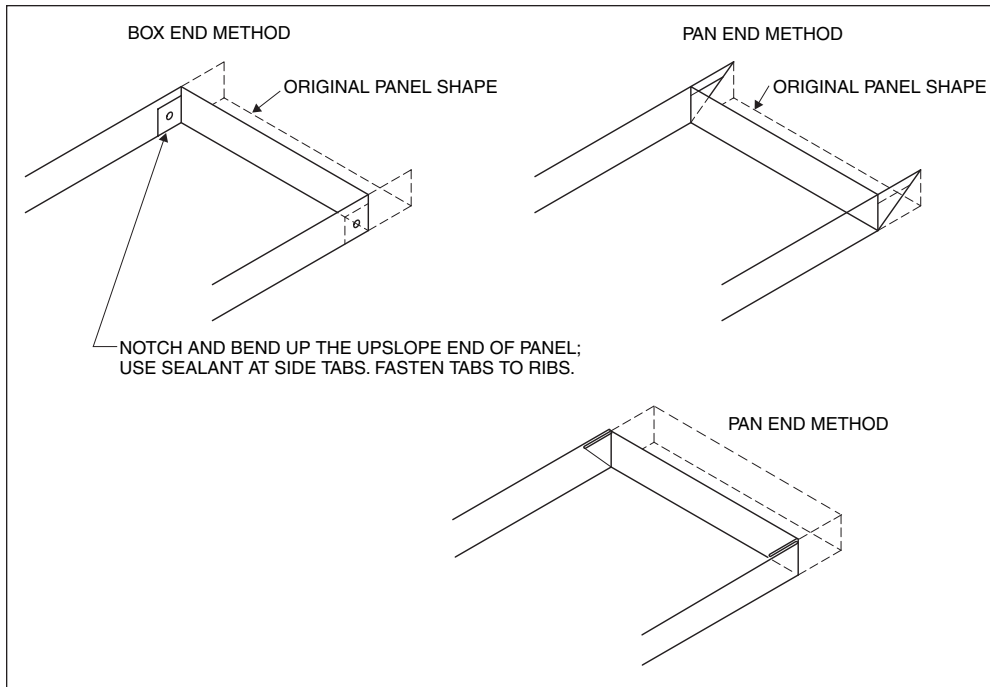


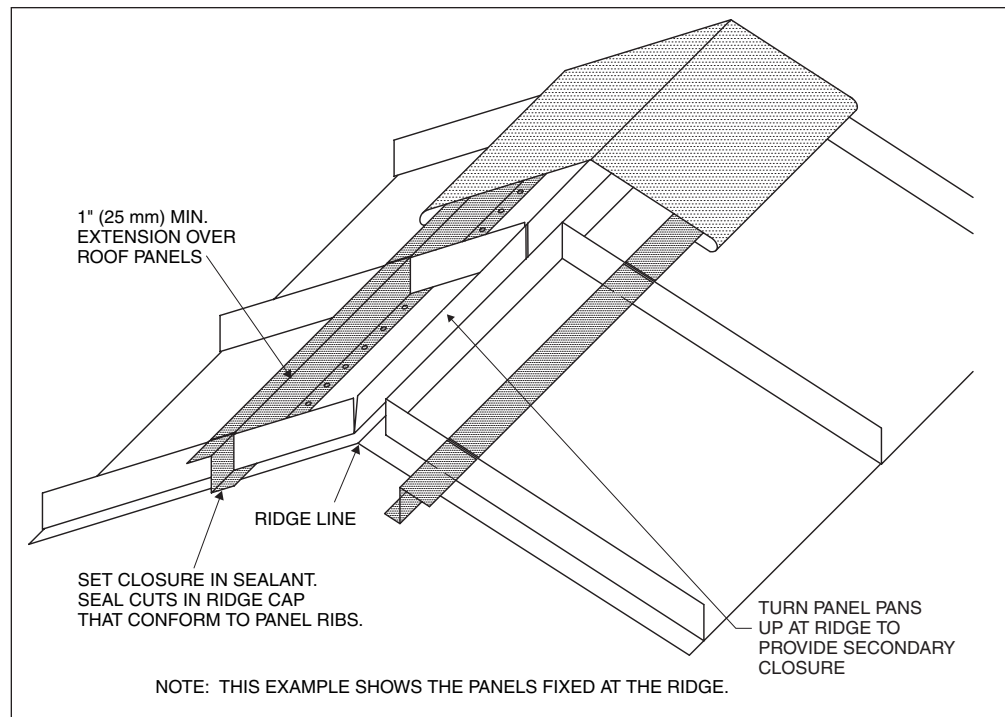
Figure 4.17: Examples of up-turned panel ends

Metal Z-closures are placed between each panel rib and fastened and set in sealant or soldered to the metal panels. The metal cap is then mechanically attached or clipped to the top of the Z-closure. See Figure 4.18. NRCA recommends the Z-closure and cap be the same metal gauge or heavier and the same type of metal as the metal panel. Foam closure strips should not be used as primary closures but only in conjunction with the metal closures and up-turned panel ends.

With some vertical seam panels, techniques have been developed where it is possible to turn up panel ends at ridges and hips without cutting the panel end. A Z-closure is then attached in the field of the panel downslope from the panel end and is aligned with the outer edge of the hip or ridge cap to provide the primary closure for wind-driven rain and snow. This procedure is unique to vertical leg panels and not necessarily applicable to other panel configurations.

Lap joints for metal ridge and hip caps should be overlapped a minimum of 4 inches (100 mm) and set in two beads of sealant. For long ridge and hip lengths, a designer should detail the ridge or hip cap to allow for thermal movement. Laps for hip caps should be lapped in watershedding fashion.

Figure 4.18: Example of ridge closure



Where venting is required, ridge assemblies must be detailed to provide airflow but not allow water migration into the building. In most cases, the vented ridge cap includes the same components as a nonvented cap but additionally incorporates the use of an air space and/or perforated material to provide airflow. For proper venting, the deck, underlayment, insulation and metal panel should have a properly sized continuous opening for airflow along the ridge line, as well as a distinct airspace under the panels to allow air to move from eave to ridge. This can be accomplished by installing longer clips. Hips are typically not vented because of the potential for leakage.

Panel manufacturers' vented ridge and hip cap details should be consulted for specific requirements.

For additional information, refer to the following sources:

- "Moisture Control for Low-slope Roof Assemblies" in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*.
- "Moisture Control and Ventilation for Steep-slope Roof Assemblies" in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*.

The designer and owner are encouraged to discuss these details with professional roofing contractors experienced with metal panel roof systems for specific recommendations based on roof slope, climatic conditions and regional practice.

### 4.9.8 End Laps

End laps in metal panel roof systems occur where a metal panel overlaps and rests on top of a panel that is down-slope. End laps are necessary in architectural metal roof panel designs when the dimension of the roof slope (eave to ridge) is longer than the length that factory panels can be feasibly shipped or a manufacturer does not offer on-site roll forming.

End laps can be designed as a fixed or nonfixed point of the roof system depending on the roof assembly design. End laps can also be shop-notched or field-formed. End laps of adjoining panels should be offset.

For end-lap construction, the lower panel is notched on the vertical ribs and panel material is removed to receive the upper panel. This prevents a buildup of material and provides continuity for sealant details.

All end-lap components and detailing will vary with each manufacturer and material type, but certain criteria must normally be met to complete a weatherproof end lap condition. Panel manufacturers should be consulted for their design criteria. A properly completed end-lap detail will perform as a continuous member of an architectural metal panel roof system.

### 4.9.9 Snow Guards

In locations where ice and snow occur frequently, snow guards may be desirable over the entire roof, but particularly when a metal roof's eave is positioned over pedestrian or vehicular traffic areas. Because of the smooth surface of metal panels and how quickly metal panels transfer heat, snow and ice tend to loosen suddenly from panels. If snow guards are used, it is strongly recommended not to penetrate the metal panels with exposed fasteners, thus avoiding potential leakage. Snow guards should be attached with manufacturer-recommended sealants at flat-pan areas or nonpenetrating fastening at vertical ribs that are typically accomplished through clamping methods. Nonpenetrating attachment is preferable to penetrating the metal panels. The installation of snow guards creates a potential location for the buildup of snow, debris and ice, and water dams can occur, which may result in leakage. The installation of ice dam protection membrane is recommended under and upslope of the areas with snow guards.

There may be a need for additional clips where snow guards are installed because of the expected weight of ice and snow. Snow guard manufacturers should be consulted for specific requirements. If snow guards are used, designers must be aware that the buildup of snow on a roof will add additional weight to the roof system and structure.

### 4.9.10 Wall Panels

Metal wall panels can be used where a parapet wall intersects the roof line or extends from one roof elevation to another. Metal wall panels can have a standing seam profile, an interlocking flat-seam profile or a sealed lap-seam profile. They can be installed over a continuous or closely spaced substrate or over a framing system. Insulation and underlayment may be installed behind the panels.

The upper edge of the metal wall panels is typically made weatherproof by using metal flashings or closures. All inside and outside corners require metal flashings to seal this junction of the metal wall panels. All penetrations through the wall panels must be flashed in a weatherproof manner. Ventilation of any air space should be considered when installing metal wall panels.

The bottom of metal wall panels should be installed over a positively-sloped through-wall flashing that provides drainage from the wall panels onto a lower roof section or other appropriate location. All laps in metal wall panels should be sealed. When exposed fasteners are used to attach the flashing, corrosion-resistant materials should be used.

## 5. Structural Metal Panel Roof Systems

### 5.1 Description

Structural metal panel roof systems are typically hydrostatic, or water-barrier, roof systems. They are designed to resist the passage of water at joints, laps and junctures under hydrostatic pressure. These roof systems have the strength and capability of spanning structural members, such as joists or purlins, without being supported by continuous or closely spaced decking and, in most configurations, do not require underlayment. NRCA recommends  $\frac{1}{4}$  inch per foot (2.4 degrees) as the minimum slope for structural metal panel roof systems, even though numerous manufacturers will allow structural systems to be installed on slopes as low as  $\frac{1}{8}$  inch per foot (1.2 degrees). The  $\frac{1}{2}$ -inch-per-foot (2.4 degrees) recommendation helps provide for positive drainage when considering the effects of construction tolerances and deflections over time, as well as differences in seam height. Structural metal panel roof systems that incorporate a sealant in the seam or anti-capillary hem are alternatives to some low-slope membrane roof systems. Structural metal panels derive their strength from panel and seam configuration and the use of heavier gauges of metal. These panels are profiled with high-side ribs and stiffening ribs, intermediate ribs or fluting located in the pan.

Predominately, steel (i.e., Galvalume® and galvanized) and aluminum are used for the fabrication of structural metal roof panels. Other metal types, such as stainless steel, can be used but require special consideration for their design and use for structural metal applications. A structural metal panel roof assembly's capacity is influenced by metal type, gauge/thickness, panel width, seam height, use of stiffening or intermediate ribs in the pan of the panel, and purlin spacing. See Section 1, "Fundamentals of Metal Used for Roofing," for discussion about metal types and common gauges/thicknesses of metals used in the fabrication of metal roof panels.

Structural metal panels also can be used as architectural metal panels. However, the reverse is not necessarily true. See Section 4, "Architectural Metal Panel Roof Systems," for more information about these types of metal panels.

### 5.2 Substrates

Metal panel roof systems can be installed over a large variety of substrates. There are two general categories of substrates for metal roof systems: one is a continuous or closely spaced roof deck or rigid insulation that provides solid support for the metal roof panel, and the other is composed of spaced structural supports, such as purlins, where the

metal panels must span between supports. The purlins also provide the points of attachment for the panels. Structural metal roof panels are typically installed directly over spaced structural supports without the use of a continuous or closely spaced roof deck.

Spaced structural supports can be categorized into two categories: widely spaced supports without a solid substrate and closely spaced supports with a solid substrate between supports. An example of closely spaced supports with a solid substrate between supports is light-gauge purlins attached to a solid deck (e.g., concrete) with rigid insulation between the purlins above the solid deck.

The most common types of spaced structural supports for structural metal panel roof systems are:

- Bar joists
- Light-gauge framing
- Post and purlin
- Purlin over solid substrate

Spaced structural supports (i.e., framing systems) need to be compatible with the panels. Specifically, the panels, fasteners and framing system need to be compatible to avoid any potential galvanic reaction between the metal types.

### **5.2.1 Bar Joist Structural Systems**

Bar joists are prefabricated structural steel members, normally installed as horizontal structural members suitable for the support of solid decking or structural standing seam roof systems. They range in size, length and spacing depending on the specific load requirements and building design.

Typically a bar joist consists of top and bottom chords composed of paired angle iron and/or round bar web members.

Bar joists should be designed and installed according to plans and specifications. The building designer should give particular attention to the load requirements of the building, as well as specific roof loading requirements.

If the bar joists run perpendicular to the roof slope, the roof panel clip may be fastened directly to the top chord of the bar joist. Designers should determine the clip size giving consideration to the size of the top chords. If clips are fastened with two fasteners, one fastener should be installed in each of the two pieces of the top chord. Therefore, the clip will need to be large enough to cover the entire top chord to allow for fastening. If the bar joists run parallel to the roof slope, intermittent support members must be used for attachment of the roof panel clip.

### **5.2.2 Light-gauge Framing Systems**

Light-gauge framing is a type of intermittent support that is usually made from sheet metal ranging from 14 gauge to 22 gauge (0.078 inches to 0.031 inches [2.0 mm to 0.8 mm]). The gauge of the material is based on the design of the framing system, the framing members spacing, and wind uplift and seismic requirements.

Some of the most common shapes are:

- hat channel
- square tubing
- standard C-channel and eave channel
- C-purlin
- Z-purlin (one or two piece)

See Figure 5.1 for examples of these common shapes.

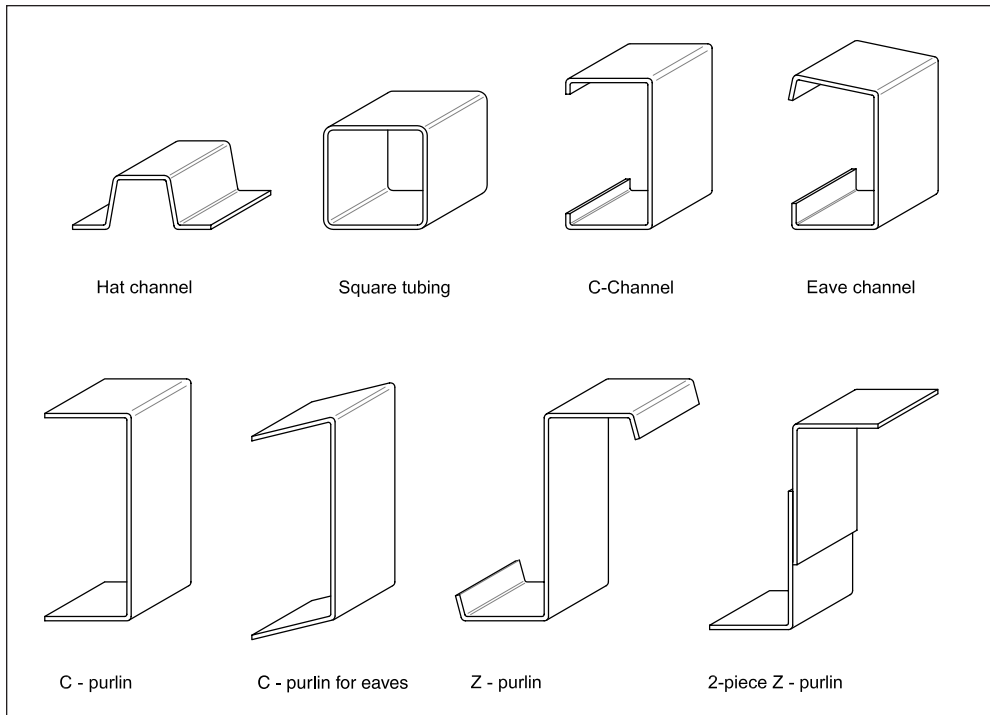


Figure 5.1: Common light-gauge framing shapes

Light-gauge framing shapes are used to separate the metal roof system from the substrate for a variety of reasons:

- to provide a location to attach the panel clip
- to provide support for the panels
- to provide space for insulation
- to provide a means to smooth out an irregular substrate via a two-piece Z-purlin
- to permit the underside of the panel to be ventilated
- to create slope

Light-gauge framing shapes must meet design requirements for positive- and negative-pressure loading on the metal panels. Under positive loading, these shapes must retain their shape and not buckle. Negative-pressure loading places stress at the fastener points of the metal roof panels and light-gauge member, and at the fasteners of the light-gauge member and substrate. Local codes should be consulted for required values of these loads.

Retrofit metal panel roof systems are reroofing systems that incorporate light-gauge framing systems and structural metal panel roof systems. The light-gauge framing is attached to an existing structural substrate and is the support and anchorage for the structural metal panel roof system. See the Reroofing Section of The NRCA Roofing and Waterproofing Manual, for additional information about retrofit metal roof systems.

### 5.2.3 Post and Purlin Structural Systems

Post and purlin construction is generally used in the design of pre-engineered buildings, such as metal or wood. The system is an open-frame construction using light-gauge metal Z-, C- and/or hat-channel members and/or wood members to support the metal panel roof system. Spacing can vary from 2 feet to 6 feet (0.6 m to 1.8 m), and gauges can vary from 10 gauge to 20 gauge (0.14 inches to 0.04 inches [3.5 mm to 1.0 mm] thick) depending on design requirements.

Because this is a spaced structural support, a structural metal roof panel is required to accommodate the live and dead loads of the building. The panel design and seam shape must be considered to address these open spans and low slope.

### 5.2.4 Purlins Over Solid Substrate

Purlins over a solid substrate is a type of spaced structural support that typically consists of light-gauge framing shapes attached directly to a solid substrate.

Purlins are used to offset a metal panel roof system from the substrate for a variety of reasons:

- to provide a location to attach the panel clip
- to provide support for the panels
- to provide space for insulation
- to provide a means to smooth out an irregular substrate via a two-piece Z-purlin
- to permit the underside of the panel to be ventilated
- to create slope

These purlins must meet design requirements for positive- and negative-pressure loading on the metal panels. Under positive loading, purlins must retain their shape and not buckle under the load. Negative-pressure loading places stress at the fastener points of the metal panels and purlin and at the fasteners of the purlin and substrate. Local codes should be consulted for required values of these loads.

Structural metal roof panels can also be used in architectural applications, that is, over continuous or closely spaced substrates. Structural metal panel roof systems are used in architectural applications generally for increased uplift resistance. Structural panels used in architectural applications typically have flat pans and vertical seams (i.e., non-trapezoidal) to allow for simpler flashing installation. In addition, these types of panels have different seam aesthetics and shadow lines that can be more appealing on roofs that are visible. It is important to note that detailing methods for structural metal roof panels used in architectural applications may differ from typical detailing methods used for architectural metal roof panel systems because of differences in panel gauges, seam types, panel profiles, manufacturers' requirements and geographic differences. When structural metal roof panels are used in architectural applications over continuous or closely spaced roof decks, refer to Section 4, "Architectural Metal Panel Roof Systems," for design considerations and application information.

The most common types of continuous or closely spaced substrates for structural metal roof panels used in architectural applications are metal and wood roof decks.

### **5.2.5 Steel Roof Decks**

Steel roof decks are constructed of cold-rolled steel sheets with ribs formed in each panel to provide strength and rigidity. The panels are available in several gauges, rib depths and flute spacings.

NRCA recommends steel roof decks be 22 gauge (0.031-inches [0.79-mm] thick) or heavier and have factory-galvanized G-90 coating. It is the designers responsibility to select the appropriate gauge, rib depth and flute spacing based on the required capacity of the metal roof deck.

The designer or decking contractor should see Factory Mutual Approvals (FM) Loss Prevention Data Sheet 1-28, Steel Deck Institute (SDI) requirements, Underwriters Laboratory or other current publications regarding fasteners and fastening schedules to resist wind uplift. FM field offices and steel roof deck manufacturers should be consulted for advice on the maximum span and attachment recommendations for various steel decks.

A steel deck may be the structural support for a different material, such as rigid insulation or gypsum boards. These types of materials require a solid substrate (e.g., the steel deck) while providing other useful characteristics. Gypsum boards above steel decks can be used to provide increased fire-resistance properties for the roof assembly and the use of rigid insulation will provide additional thermal resistance for the roof assembly. Structural metal panels can be installed directly over these substrate configurations. Attachment requirements are discussed in Section 5.10.

### **5.2.6 Insulation**

Insulation used as a component of a metal panel roof system is either rigid or batts. Rigid insulations are used over solid decks (e.g., plywood, metal) with or without the use of intermittent channels or battens. When channels or battens are used, they are spaced so that the clips can be fastened to the channel or batten. When rigid insulation boards are used without channels or battens, clips are installed on top of the rigid insulation board, generally with a base plate to support the clip and keep it from crushing the insulation boards.

Rigid insulation is considered a supporting substrate for a metal panel roof system, not a structural substrate such as plywood or metal deck which provide adequate pull-out resistance of fasteners. It is adequate to support the metal panels and general rooftop traffic but can only be used above a structural roof deck.

Fiberglass batt insulation is not a supporting substrate for a metal panel roof system. When used, fiberglass batt insulation is stretched over the purlins and then the metal roof panels are installed directly over the insulation with clips or by direct attachment to the metal purlins. To compensate for the compression of the insulation and subsequent

loss of thermal value, spacer blocks or stand-off clips should be used.

For additional information about insulation for structural metal panel roof systems, see Section 5.5, Insulation.

### **5.2.7 Other**

Cementitious wood fiber deck panels and concrete roof decks may be used as substrates for structural metal panel roof systems. For these types of roof decks, it is generally not appropriate to attach clips directly to the deck. Installation of a purlin, attached appropriately to the bulb tees or concrete deck, is recommended. Use of the purlin accommodates attachment of the structural metal panel's clips. See Section 5.2.4, "Purlins over solid substrate," for additional information.

## **5.3 Underlayments**

Underlayment performs two primary functions: it provides temporary weather protection until a roof covering is installed, and it provides a secondary weatherproofing barrier should moisture infiltrate the metal roof system. For metal roofing, underlayment is also used to separate the roof covering from the roof deck or substrate. Underlayment should be vapor-permeable unless designed to act simultaneously as a vapor retarder. The use of underlayment requires a continuous substrate to support the underlayment material. Because they need to be supported, underlayments typically are not used with structural metal panel roof systems when intermittent supports are used to carry the roof systems. For example, structural metal panel roof systems installed over bar joists, light-gauge framing, post and purlins, or purlins over a solid substrate should not include underlayment. For metal panel roof assemblies where the spaces between purlins over a solid substrate are filled with a rigid material (e.g., polyisocyanurate insulation), underlayment should be used.

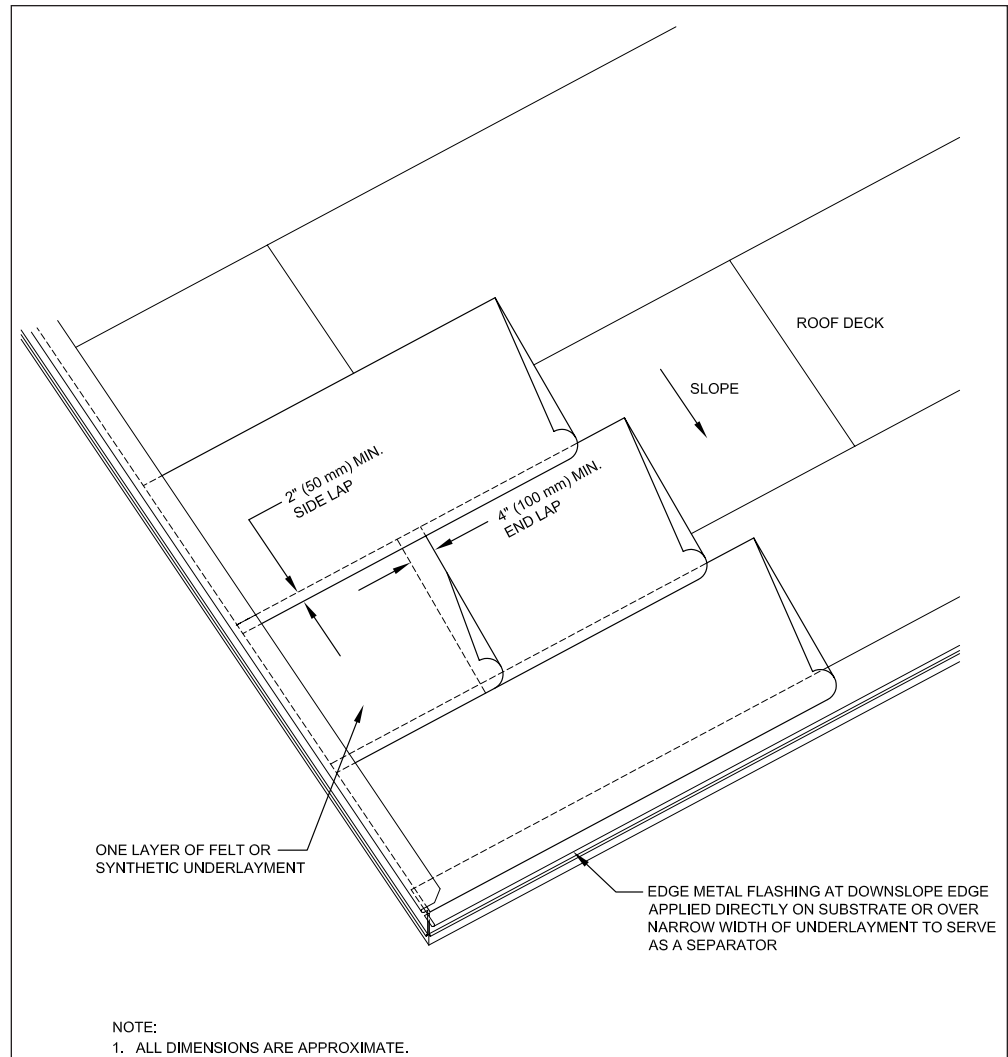
On applications over continuous or closely spaced substrates (solid substrates), an underlayment is recommended as a secondary barrier against water penetration and protection for the backsides of the panels from the substrate. In addition to the underlayment, an ice dam protection membrane at downslope perimeters, transitions, valleys and around penetrations is recommended in cold regions where ice dams can occur.

If underlayment is used as a temporary watershedding system, the underlayment should be inspected for proper installation and integrity before the installation of the metal panels.

The following underlayment guidelines are recommended by NRCA:

- For single-layer underlayment, a minimum of one layer of No. 30 asphalt-saturated, nonperforated felt, or laminated or reinforced polyethylene- or polypropylene-based synthetic underlayment should be applied horizontally, perpendicular to the slope of the roof. Heavier underlayment may be required by local code or specifications according to local conditions and requirements of the designer or manufacturer of the roof system. All sheets should have a minimum side lap of 2 inches (50 mm) over the preceding sheet, and end laps should be a minimum of 4 inches (100 mm). The sheets should be fastened as necessary to hold them in place until the metal roof panels are applied. See Figure 5.2

Figure 5.2: Single-layer underlayment



- When a double-layer underlayment is specified, two layers of No. 15 or No. 30 asphalt-saturated, nonperforated felt or laminated or reinforced polyethylene- or polypropylene-based synthetic underlayment should be applied horizontally. A 19-inch (480-mm) wide starter sheet should be applied at the eaves. A full-width sheet should be applied covering the starter sheet. Succeeding sheets should be lapped approximately 19 inches (480 mm) leaving an approximate 17-inch (430-mm) exposure over the preceding sheets. End laps should be a minimum of 4 inches (100 mm). The sheets should be fastened as necessary to hold them in place until the metal roof panels are applied. See Figure 5.3.

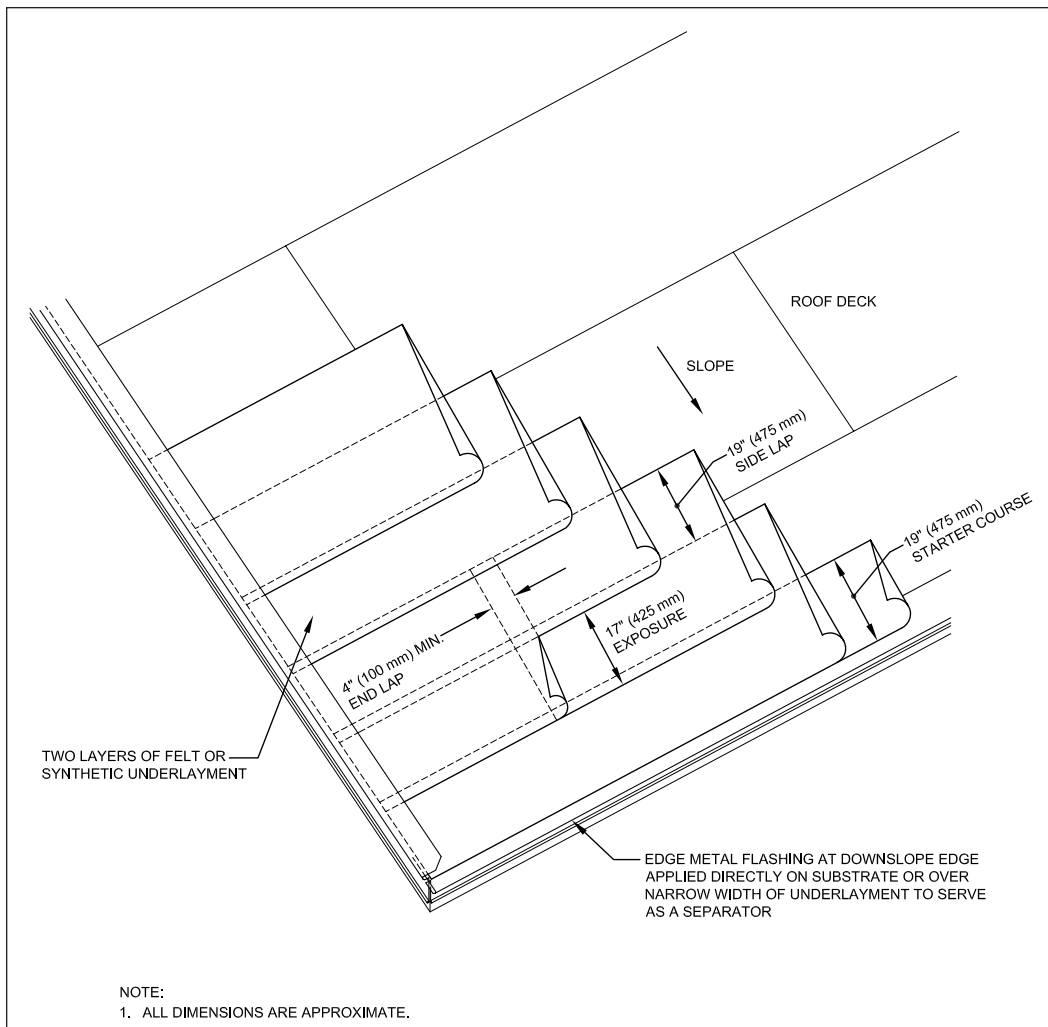


Figure 5.3: Double-layer underlayment

- Regardless of the type of underlayment required or slope of the roof, in locations where the January mean temperature is 30 F (-1° C) or less or where the possibility of ice formation at the eaves is anticipated, NRCA recommends installation of an ice dam protection membrane. See Figure 5.4. Some building codes require the use of ice dam protection membranes in areas where the mean January temperature is 25° F (-2° C) or less. Designers and contractors are urged to consult the applicable building code. When batt insulation is used, protection against ice dam formation is difficult because of the lack of a solid surface to apply ice dam protection membrane. Also, NRCA does not recommend the use of gutters that have front faces higher than the bottom edge of the roof panels to avoid increasing the potential for ice dam formation.

See Section 4, "Architectural Metal Panel Roof Systems," for more information about ice dam protection membrane installation.



Figure 5.4: Average January temperature map (below 30° F [-1° C])

## 5.4 Vapor Retarders

Vapor retarders are intended to prevent or reduce moisture migration into roof assemblies by means of minimizing both air leakage and diffusion and therefore reducing the amount of moisture that can condense within the roof assembly. Proper use of vapor retarders in conjunction with insulation and ventilation can significantly reduce or even eliminate condensation problems.

Information on vapor retarders and the four methods of determining the need for a vapor retarder can be found in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.

Regardless of the method used to determine the need for a vapor retarder, it is important to realize actual relative humidity and dew-point temperature values are constantly changing in normal building environments as the ambient temperature and/or water vapor pressure in the air change. Values for design relative humidity and design dew-point temperature are theoretical constant values based upon design assumptions and are used for calculation purposes. These design values should be based upon conservative assumptions of probable conditions.

The use of vapor retarders in roof assemblies has been debated in the roofing industry for years. NRCA considers the determination of whether a vapor retarder is necessary to be included in roof assemblies to be the responsibility of the designer of the roof system.

Vapor retarders may be necessary in structural metal panel roof systems. In many instances, such as open purlin design and pre-engineered metal buildings, the batt insulation incorporates a film vapor retarder on the underside of the insulation. Even in climates that do not require vapor retarders, the insulation for these buildings typically incorporates the film to support the insulation and provide an aesthetically pleasing and light-reflecting surface. This film can offer acoustical benefits. The films can also provide different finishes and may be fire-retardant. Product manufacturers should be consulted for information about the permeability of the film and its ability to perform as an effective vapor retarder.

For additional information, refer to the following sources:

- “Moisture Control for Low-slope Roof Assemblies” in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.
- “Moisture Control and Ventilation for Steep-slope Roof Assemblies” in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.

Because every building is in some way unique, building owners and designers may need to consult with appropriate design professionals who are familiar with the complexities of vapor retarder, insulation and ventilation issues.

See Sections 5.5, Insulation and 5.6, Ventilation for additional information.

## **5.5 Insulation**

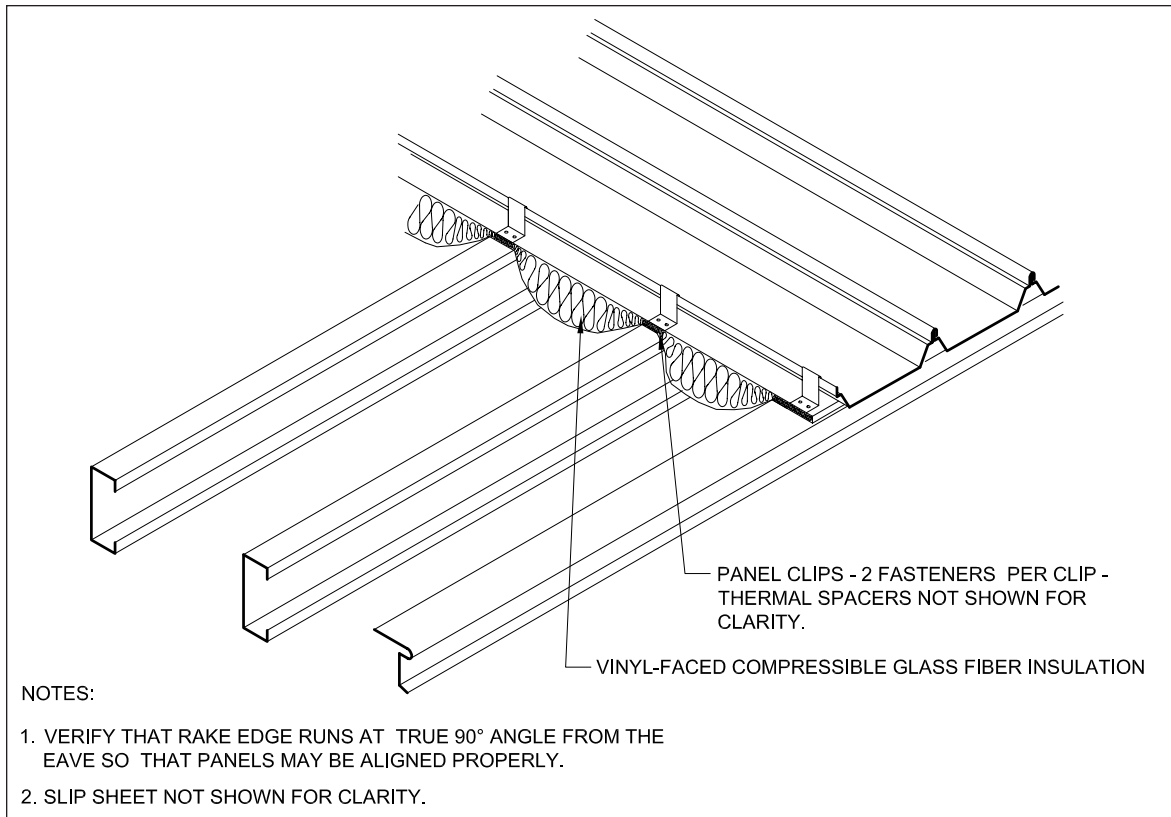
The primary purpose of roof insulation is to provide thermal resistance. A roof is generally one of the largest surface areas of a building envelope through which interior heat escapes. Insulation within a roof assembly will help to maintain the inside temperature of a building at a more constant, comfortable level. Building codes have requirements for the minimum amount of thermal insulation required.

Insulation can be a vital part of a structural metal roof system. A properly insulated building uses less heating and cooling energy to maintain a comfortable interior environment than a poorly insulated building. Designers should determine the insulation requirements of the metal roof system as a part of the overall building envelope’s thermal insulation requirement. Several thermal design concepts are used to determine insulation requirements, as well as condensation, air infiltration and sound-control requirements.

### **5.5.1 Batt Insulation**

Batt insulation, installed with a structural metal panel roof system, will typically be installed over open purlins or other spaced structural members. See Figure 5.5. Batt insulation is typically made from glass- fiber insulation and may have a polypropylene, vinyl or aluminum facer. The facer may act as a vapor retarder. It can also provide acoustical benefits by minimizing the noise associated with panel movement and rainfall.

Figure 5.5: Metal panels installed over batt insulation over purlins



When metal roof panels are installed over batt insulation that is located over purlins or other structural members, the insulation is compressed, particularly at the clips. This compression results in a reduction of the R-value at this location. In cold climates, this R-value reduction can cause the dew point to fall below the vapor retarder. In these cases, condensation can occur on the inside of a building and drip into the building's interior. The proper selection and installation of vapor retarders and thermal spacers at purlins will reduce the loss of R-value where batt insulation is used.

Typically, batt insulation over open purlins or other structural members is installed perpendicular to the purlins and typically runs from the eave edge to ridge. However, there are methods used where batt insulation is installed from rake edge to rake edge. When a vapor retarder film is used, the side tabs of the film should be lapped, then stapled or taped together to ensure the continuity of the vapor retarder and help minimize sagging of the insulation at the side laps. Additionally, the facing tabs of the batt insulation should be carried over the purlins or other structural members and lapped and then stapled or taped together. This should occur at nonvented ridges, hips, valleys and end joints.

A second layer of batt insulation can be installed on top of the first layer. The second layer should be an unfaced layer of insulation, that is, without a vapor retarder, to prevent condensation or trapping moisture. The second layer of batt insulation is typically installed in a direction perpendicular to the slope of the roof or perpendicular to the first layer of insulation.

After the batt insulation is in place, the metal roof panels are installed and attached to the purlins with metal clips. Insulation spacer blocks should be installed between the panels and insulation, over the purlins, to enhance the insulating value and minimize the potential for condensation. Proper clip height should be used to accommodate insulation thickness and spacer block height to help prevent upward bulging of the metal panels between the seams.

### 5.5.2 Rigid Insulation

Rigid roof insulation can be installed over continuous (solid) or a closely spaced roof deck under a structural metal panel roof system. The type of roof insulation used and whether a vapor retarder is required will depend on such things as dew-point location, climatic conditions and interior conditions, owner's requirements and building code requirements. The potential for condensation to occur between the metal panels and rigid insulation must not be overlooked. A ventilation space and/or a slip sheet between the underside of metal panels and roof insulation may be required. The common types of rigid insulation used in structural metal panel roof systems over solid decks are polyisocyanurate, extruded polystyrene, expanded polystyrene and fiberglass.

An underlayment should be installed on top of the rigid roof insulation in a similar fashion as previously described for continuous or closely spaced decking. Refer to Figures 5.2 and 5.3. Attachment of the underlayment can vary depending on the roof system requirements.

Attachment of the structural metal roof panels over rigid insulation can be accomplished by installing purlins, metal hat channels or wood nailers to the deck. These members should be run in a direction perpendicular to the roof slope or parallel to the eave line. Spacing for those members will be based on the spacing requirements for the panel clips. Rigid roof insulation is then installed between the framing members. An example of this type of construction using Z-purlins is shown in Figure 5.6. Attachment requirements should be determined by the designer or structural engineer.

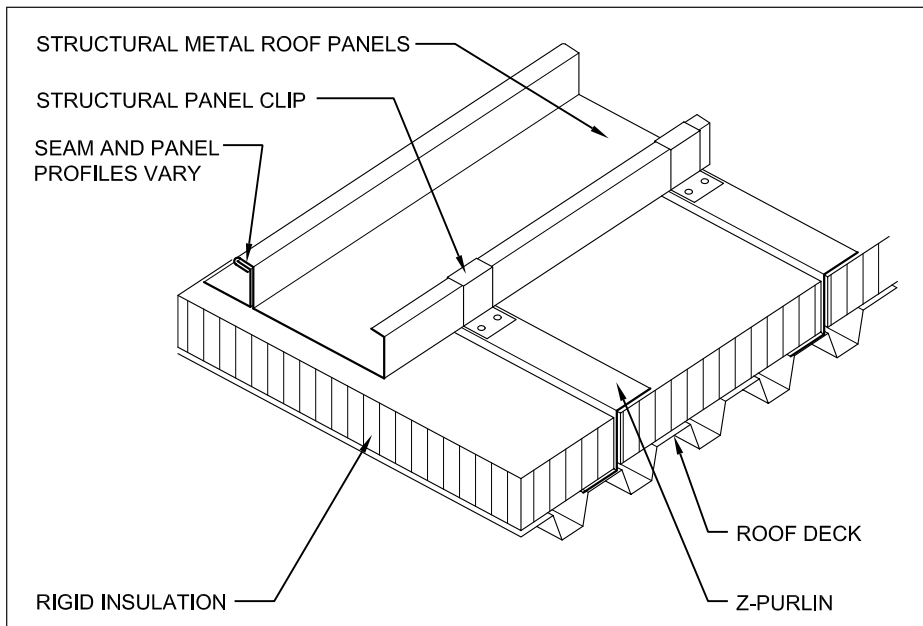


Figure 5.6: Z-purlins with rigid insulation

Another method of attaching structural metal roof panels over rigid insulation is by the use of bearing plates on top of the insulation. When using bearing plates, the rigid roof insulation is installed over the deck with an underlayment on top of the insulation. The metal clips and panels are then installed over this assembly. At each clip location, a metal bearing plate is placed over the insulation and underlayment. The clip can be either attached through the bearing plate and into the deck below, or the clip can be attached to the bearing plate if the bearing plate is attached separately to the deck and is of adequate strength and thickness to meet building code requirements. Fasteners must also provide adequate pull-out resistance for overall roof system uplift requirements. An example of bearing plate construction is shown in Figure 5.7.

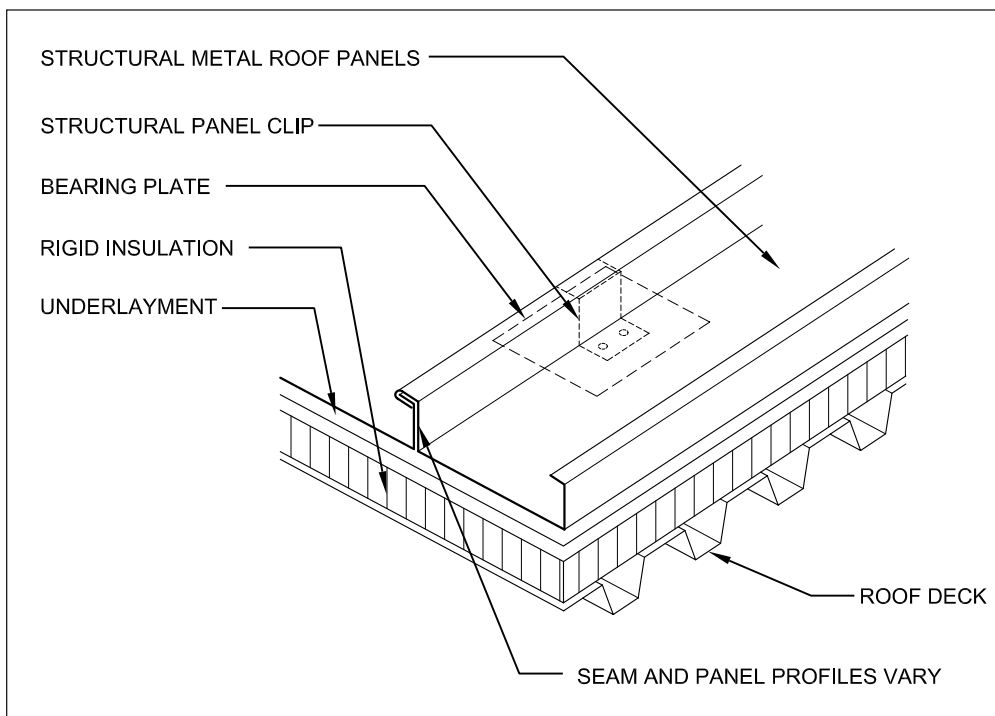


Figure 5.7: Bearing plate and panel clip over rigid insulation

For additional information, refer to the following sources:

- “Moisture Control for Low-slope Roof Assemblies” in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.
- “Moisture Control and Ventilation for Steep-slope Roof Assemblies” in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.

Because every building is in some way unique, building owners and designers may need to consult with appropriate design professionals who are familiar with the complexities of vapor retarder, insulation and ventilation issues.

## **5.6 Ventilation**

Ventilation is the movement of air for the purpose of reducing heat and/or moisture accumulation between the interior and exterior of buildings. If the anticipated vapor drive is from the building's interior to the exterior and is of a magnitude significant enough to warrant concern about moisture accumulation in the roof assembly, the designer must address the situation by improving the vapor retarder effectiveness or reducing the interior relative humidity (dehumidification). However, increasing ventilation of the interior air space also can have the negative effect of removing air that has purposely been conditioned (e.g., heated) to maintain comfortable interior temperatures.

A ventilation cavity has not traditionally been considered necessary for structural metal panel roof systems installed over spaced supports with or without insulation. Regardless of the effectiveness of a vapor retarder and the amount of insulation used, condensation can develop on the undersides of metal panels. Accordingly, the clips and fasteners should be corrosion-resistant. The desired degree of corrosion-resistance required should be based on the climate; for example, a more corrosion resistant clip and fastener will be needed in coastal or environmentally aggressive climates (e.g., industrial areas). The type of ventilation and the design of the ventilation system is the responsibility of the designer and should be determined during the initial design of the building and metal panel roof system. When a finished ceiling is located below the metal roof and structural supports, the resulting cavity will need to be ventilated to control condensation and heat buildup in this enclosed space. Mechanical ventilation of this type of cavity allows for more air exchanges than static ventilation.

Depending on climatic and interior conditions, condensation in metal roof systems can be problematic because the panels themselves are an excellent thermal conductor and surface temperatures often fall below the dew point. Ventilation between the underside of metal panels and a solid substrate is required to be provided because of the potential for condensation on the underside of the metal roof panels. An air space between a panel and the substrate will help minimize the effects of condensation. The depth of this ventilation space is determined by climate, interior relative humidity, effectiveness of the vapor/air retarder, roof slope, distance from eave to ridge, and airflow efficiency of the perimeter details or other means of providing air ingress and egress from the roof cavity.

If insulation is used between purlins over a solid substrate and conditions for condensation development are great, the use of an underlayment over the insulation should be considered. The underlayment can protect the insulation from condensate water, thereby limiting the chance of R-value reduction of the insulation. Also, if a small quantity of ice develops on the undersides of the panels and rapidly melts, the underlayment can effectively shed the water.

Metal roof panels installed over purlins (e.g., hats, Cs, Zs) installed to a concrete or wood substrate may create a ventilation challenge. For a re-cover application where no additional slope is created, the metal roof panels may be placed over the rigid insulation that rests directly on the substrate. An appropriately located vapor retarder may be desirable. If additional roof slope is created by variable height purlins or framing, an air cavity requiring ventilation may be created. It may be necessary to introduce a means to provide lateral ventilation at ridges and peaks.

For additional information, refer to the following sources:

- “Moisture Control for Low-slope Roof Assemblies” in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.
- “Moisture Control and Ventilation for Steep-slope Roof Assemblies” in the Moisture Control section of *The NRCA Roofing and Waterproofing Manual*.

Because every building is in some way unique, building owners and designers may need to consult with appropriate design professionals who are familiar with the complexities of vapor retarder, insulation and ventilation issues.

## **5.7 Panel Profiles**

Panel profiles vary from manufacturer to manufacturer depending on the different methods used for forming the panels. The panels have different physical characteristics and aesthetic appearances. The choice of the profile is often based on performance, as well as aesthetics. Seam height not only affects aesthetics, it also affects performance. Generally, taller seams can accommodate larger amounts (i.e., greater depths) of water runoff. The seam type

(e.g., double lock) also will affect the ability of a metal panel roof system to accommodate water runoff. Seam height and type should be appropriate for the job specifics (e.g., slope) and according to manufacturer's recommendations.

Many structural metal roof panels incorporate striations or longitudinal stiffening ribs in the field of the panel to minimize the effects of oil-canning. See Section 5.9 for additional information about oil-canning. Although many panel profiles are available pre-manufactured, many profiles can be shop-fabricated by roofing contractors (with some length limitation based on equipment) or can be roll-formed on site (with length limitations based on hoisting/lifting requirements).

There are three general panel profiles common to structural metal panels:

- Trapezoidal

The trapezoidal profile shown in Figure 5.8 is a common profile used for structural metal roof panels and is often used for low-slope applications. The rib usually has a triangular or trapezoidal shape, from which its name is derived. This type of profile provides rib height and structural strength.

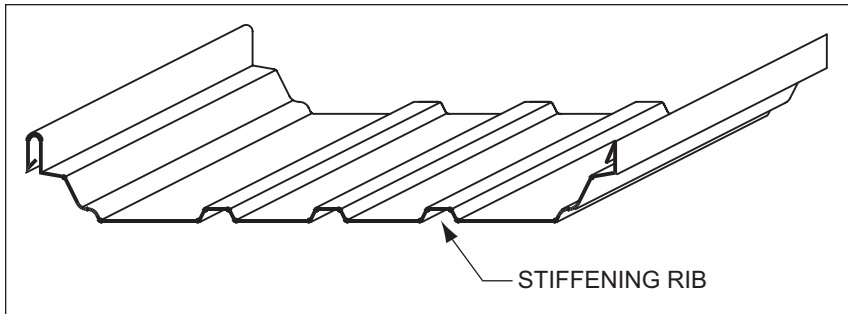


Figure 5.8: Example of a trapezoidal profile

- Intermediate Rib

The intermediate rib profile shown in Figure 5.9 incorporates a center rib, typically of the same profile as that of the end ribs. A panel using this type of profile has a multiple-panel look but is in fact a single panel. This profile type allows for the use of larger panel widths because of the increased structural capacity provided by the intermediate rib.

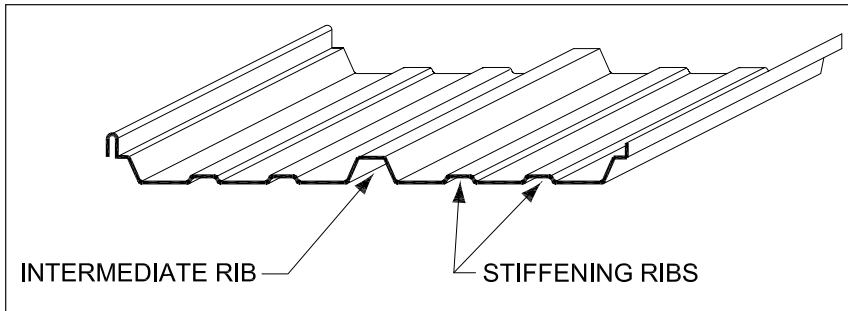


Figure 5.9: Example of an intermediate rib profile

- Vertical Leg

The vertical leg profile shown in Figure 5.10 uses a standing seam design, resembling the typical profile of an architectural metal roof panel.

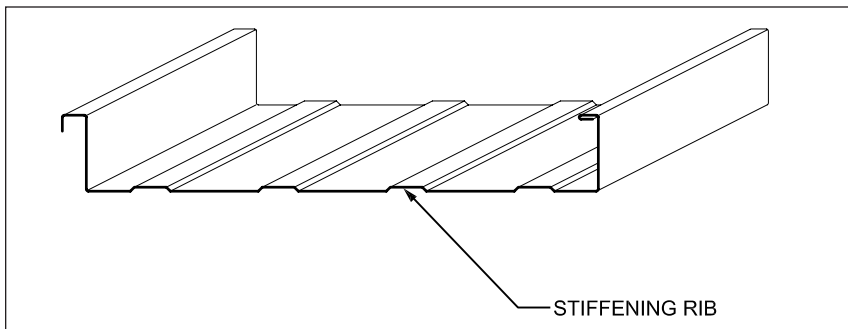


Figure 5.10: Example of a vertical leg profile

Multiple profile variations are available in the marketplace. All seams for structural metal panel roof systems, regardless of profile or type, should be interlocked, that is, no snap-on caps are used. NRCA recommends the use of single- or double-lock mechanical seams for structural metal panel roof systems.

## **5.8 Panel Installation**

Before beginning panel layout and installation, NRCA recommends the roof deck or substrate be checked for levelness and squareness. Corrections to the deck can only be made before panel installation. Deficiencies should be brought to the attention of the appropriate parties, such as the owner or general contractor, and corrections should be made prior to panel layout and installation.

When installing metal roof panel systems on highly visible roof areas, it is generally preferred to closely match the width of the panels at each end of a roof section. For low-slope roof applications or roof areas where, for example, a rake or wall detail exists at one end and a hip or valley condition exists at the other end, there is generally little need to match the width of the end panels. At hips and valleys, it is generally preferable to align the seams at the point of intersection. This is only possible when the intersecting roof areas have the same roof slope.

When a balanced panel layout is not a visual concern, the contractor typically start laying panels at a rake edge beginning with a full-width panel. Panel installation generally has to proceed in one direction (i.e., from left to right or right to left across the roof area) based upon the seam type unless a special starter panel is used. It is sometimes feasible to adjust panel layout to gain a fraction of an inch per panel if the width of the total roof is not an exact multiple of the width of each panel. However, most panel systems have a small tolerances for how tightly the panels may be laid together. Manufacturers' instructions for panel width adjustment tolerance should be consulted and closely followed to avoid potential seam deficiencies and excessive oil-canning.

When the roof is laid out for equally-sized end panels, the center point of the roof is typically determined first. Depending on the relationship of the roof width and the panel module width, either a seam or the midpoint of the center pan can be located on the center point line while still keeping the end panels equal in width. This will help maximize or minimize the end panel width as desired. Manufacturers' installation instructions, seam types, job conditions and other considerations may dictate panel start points and/or layouts as most panel configurations require installation in a single direction.

A layout plan can help to verify the correct panel size and number of panels that will be required for the job. Planning the layout before installation can also help the designer aesthetically blend the roof with building lines, shapes and symmetry.

The roof may be laid out using story poles, tape measures or chalk lines. Making marks on the substrate helps to ensure the panel widths balance at each end of the roof and the panels will be installed perpendicular to the eave. Consistent installation of panels, perpendicular with the eave, will prevent side camber or bowing along the edges of the panels. See Figure 5.11

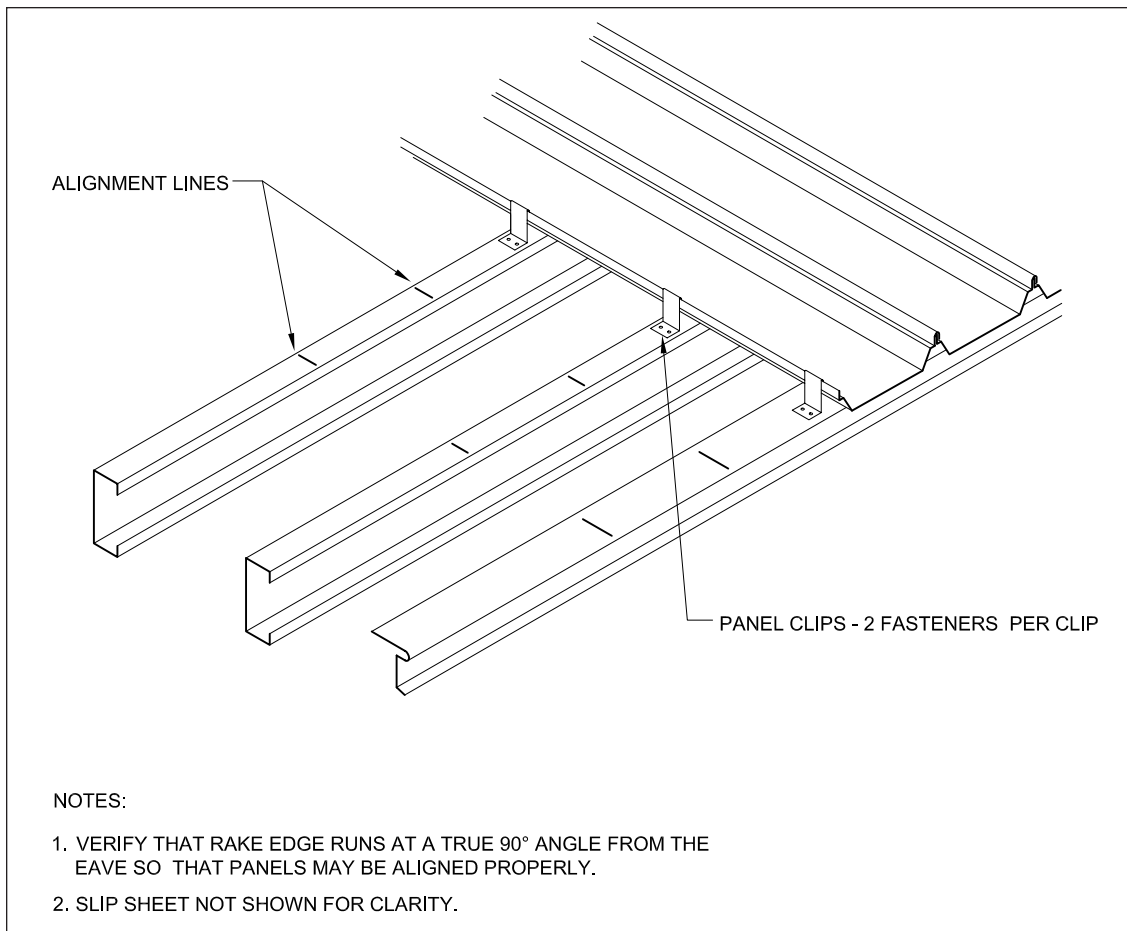


Figure 5.11: Structural panels over purlins

The application of the metal panels begins after all the underlying components, such as vapor retarder, underlayment, insulation and spacer blocks, have been installed. The downslope panel ends should either be designed to hook onto the metal edge flashing or mechanically fastened to resist wind-uplift and water infiltration. However, thermal movement should be taken into account. Locations where the metal panels are mechanically fastened to the substrate become fixed points in the roof system. See Section 5.10.1, “Fixed Points,” for additional information.

Where structural metal panels are used as architectural metal panels over a continuous or closely spaced substrate, refer to Section 4.6, “Panel Installation,” for installation recommendations.

When structural metal panels are installed over spaced structural supports, such as purlins, they are attached to the supports with individual clips. These clips are sometimes one-piece and can allow for some panel movement along the clips’ engaged edges. Expansion clips are available and can allow for more thermal movement. When using expansion clips, structural metal panels can be formed in full-length, eave-to-ridge panels. Depending on the system, the clips are installed on every structural support, and the panels are allowed to move under thermal loads without loosening or damaging the clips.

Expansion clips often are needed to accommodate movement in long panels. During installation, correct positioning of clips is important. During warm-weather application, clips should be installed with the sliding position near the maximum point of panel movement. When a panel contracts from cooler temperatures, it will have adequate space to move so that stress will not be transferred to the clip. During cold-weather applications, clips should be installed near the minimum point of panel movement. When a panel expands from warmer temperatures, it will have adequate space to move so that stress will not be transferred to the clip. See Figure 5.12. Manufacturer specifications should be referred to for proper settings for expansion clips.

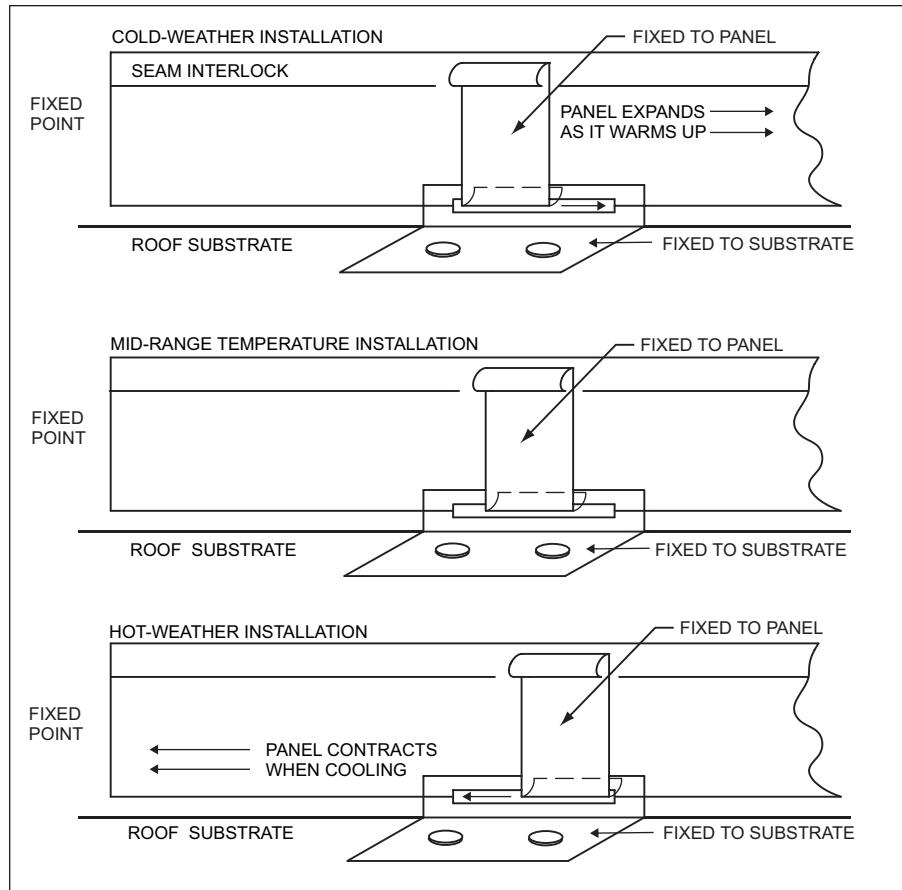


Figure 5.12: Clip installation position with respect to temperature

Low-slope structural metal panel applications require either sealant in the seam or an anticapillary hem. An anticapillary hem includes a turn-back on the top of the male leg of the panel that prevents moisture from being drawn into the seam. See Figure 5.13. In the absence of an anticapillary hem, sealant should be installed in the seam and is best applied at the time of the metal panel fabrication. When sealant is installed in the field, it is typically applied on the male leg of the panel. The choice of sealant composition and grade depends on location or portion of roof system being sealed and manufacturers' specifications. Manufacturers' sealant recommendations should be consulted.

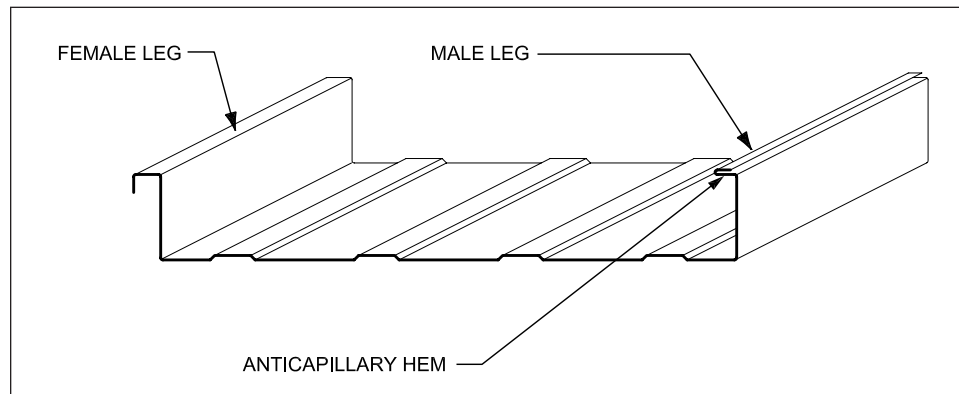


Figure 5.13. An anticapillary hem

Once two or more panels are secured, the seaming process can begin. If the panels are of a mechanical interlock design, it is good practice to crimp the panels together with hand seamers before using a mechanical seamer. This should be done close to the location of the clips so that there will be less likelihood of panels disengaging from the clips and adjacent panels before being seamed. It will also keep the panels firmly nested together for seaming, which may prevent the seamer from disengaging from or damaging the seam.

## 5.9 Oil-canning

Oil-canning is an inherent phenomena prevalent in light-gauge, cold-formed metal products. Oil-canning refers to physical distortions in the flatness of the metal; however, this condition is only aesthetic in nature and it does not

have any adverse effect on the structural integrity or the weatherproofing capability of the panel. Because some paint finishes, clear coats and metals are highly reflective and bright, distortions can be quite apparent. The visual effects of oil-canning can be exacerbated by changing or varying light conditions. Many metal roof panel manufacturers issue disclaimers regarding oil-canning, yet it can nevertheless become a customer-acceptance issue. If a specifier intends to reduce the severity of oil-canning, careful design consideration should be given to the width, gauge and profile of the specific product. NRCA does not consider oil-canning alone to be a cause for rejection.

There are a number of potential causes of oil-canning; however, all are attributable to residual stresses, either induced or redistributed, for different reasons.

- Residual stress during coil production can contribute to camber, the deviation of a side edge from a straight line. This longitudinal curving will place additional stress on the metal as it is pulled through the roll-forming machine, which attempts to form a straight edge on the panel.
- Slitting a master coil can release and redistribute stresses, especially if the slitter blades are out of adjustment or dull.
- The roll-forming equipment itself can cause oil-canning. As metal is run through the rolling stations, it is placed under stress and can stretch, particularly if the equipment is out of adjustment or operated beyond its limitations.

Despite having a properly adjusted, well-maintained roll-forming machine and good quality metal, oil-canning can still occur when panels are installed. It can result from temperature fluctuations and cycles, an uneven substrate or irregular bearing on the structural framing, structural movement or over-torquing of the mechanical fasteners.

The following precautions and considerations should assist in the reduction of oil-canning and its visual effects.

- Specify that coil stock be tension-leveled to ensure flatness of material.
- Use a heavier-gauge metal that is more rigid and less likely to oil-can than lighter-gauge material.
- Limit individual panel pan widths.
- Limit face dimensions on the fascia metal.
- Use stiffening ribs or striations in the field of the metal panel.
- Use stiffening ribs in the fascia metal, or use two-piece fascia metal when the face dimension is greater than 8 inches (200 mm).

Following are considerations to reduce the visual effects of oil-canning:

- Use low-gloss finishes or special surface textures such as embossing or striations
- Consider using metals that weather naturally, as these metals typically dull or fade over time with the development of a layer of oxidation.

## **5.10 Fastening/Attachment Requirements**

During design of a metal panel roof system, consideration must be given to the fastening requirements. If the metal system is being installed as a Factory Mutual Approvals- (FM-) or Underwriters Laboratories (UL)-approved roof assembly, the prescribed fastening schedule and substrates should provide adequate anchorage to resist wind-uplift pressures. Wind-uplift requirements will vary depending on local building codes, which mandate the design wind speed for the area, topography, roof slope, fastener type and pattern, roof deck or substrate type, height and geometry of the building, panel width and metal thickness and type.

With metal roof systems, it is critical that fasteners and clips and their frequencies be designed to meet the wind-uplift requirements for the project. It is important to select the correct fasteners for the substrate. This should include: fastener size, point or tip type, thread type, shank type, length, compatibility and corrosion resistance. Fasteners can be installed into wood substrates by hand or with the use of construction-grade electric tools; into steel, concrete or masonry with construction-grade electric tools; or into bar joists with pneumatic fastening equipment or powder-actuated fastening equipment.

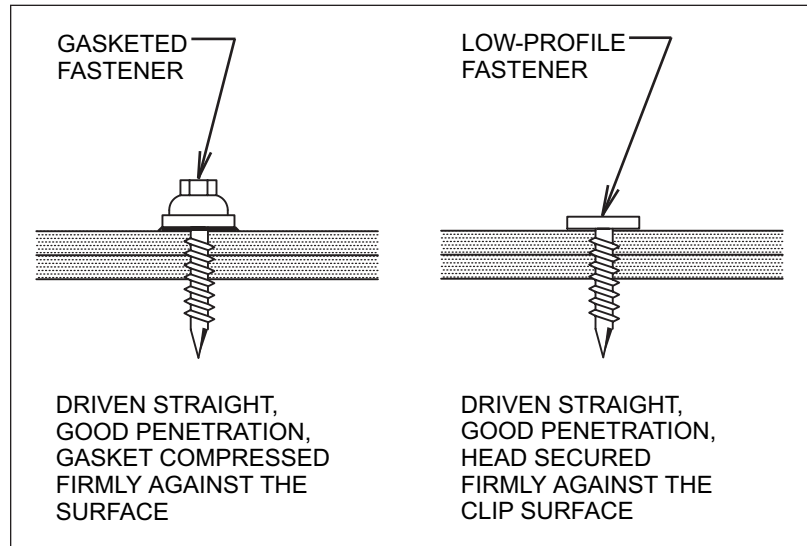
See Section 2 or the Appendix for the “Sheet Metal Fastener Chart” for information about sheet metal fasteners.

If panels are being roll-formed with portable or mobile equipment, fastening requirements may be available from equipment manufacturers, together with the results of wind-uplift tests that may have been conducted on specific metal panel roof assemblies. It is important to adhere to the fastening requirements and/or specifications so that the integrity of the metal roof system attachment is not compromised. NRCA recommends that a minimum of two fasteners per clip are installed.

Care must be taken to drive the fasteners straight and not under-drive or over-drive them. Misalignment of fasteners

can create a wear point on the underside of the overlying panel, which invites degradation—with some panels, corrosion—and can eventually lead to perforation of the panel. Low-profile (i.e., “pancake”) fastener-head design is recommended for clip attachment unless otherwise recommended by manufacturers to minimize wear points and potential damage or perforation of the panel. See Figure 5.14.

Figure 5.14: Properly installed fasteners



Metal panel roof system attachment design should consider increased fastening at the perimeters and corners as it will be necessary to accommodate increased wind-uplift loads at these locations. This may require the installation of additional structural members.

Where metal roof systems are installed directly over rigid board insulation, it is recommended to use bearing plates under the clips. Bearing plates hold down insulation and provide a more suitable substrate for the clip. Bearing plates spread the load of the clip and can prevent localized crushing of the insulation at clip locations. Bearing plates assist with securement of insulation and provide a substrate that prevents rotation of the clip. NRCA recommends bearing plates be a minimum 6 inches by 6 inches (150 mm by 150 mm) and 22 gauge (0.031 inches [0.79 mm]) or thicker. The bearing plate metal should be compatible with the clip. Bearing plate size should be designed to appropriately handle the transfer of loads, using a factor of safety of 4.0. No additional fasteners are required to secure the bearing plate. The clip fasteners will hold the clip and bearing plate in place and are fastened directly to the deck.

### 5.10.1 Fixed Points

Metal panel roof system design must accommodate thermal movement of the metal panels and must resist sliding forces, typically called “drag loads.” Thermal movement is caused by changes in temperature. Drag loads are caused by gravity and snow loads that force the metal panels to move downslope. Typical metal roof systems need to be fixed to resist drag loads but must allow for movement because to panel expansion and contraction. Panel movement is typically allowed to occur in one of two directions: upslope or downslope. This is accomplished by providing a fixed point of attachment either at the hip and ridge or eave and valleys. See Figure 5.15. For long panels, it may be desirable to fix the panels at the midpoint so movement occurs at each end of the panel; each end of the panel will move one-half of the total panel movement. It is easier to accommodate 2 inches (50 mm) of movement at each panel end than 4 inches (100 mm) of movement at one end.

When a metal panel is fixed at the ridge, the fasteners can be concealed under ridge or hip caps. Concealed fasteners at the ridge can be more aesthetically acceptable to building owners in lieu of having exposed fasteners at the eaves. When panels are fixed at the ridge, panels should not be fixed at the valleys. When a metal panel is fixed at the eaves and valleys, fasteners at the ridge cannot be attached to the structure to create a fixed point. Care must be taken at penetrations, roof curbs and vent stacks so that panels are not fixed to the substrate at these locations. Providing more than one fixed point in a metal panel system restricts panel movement and can result in oil-canning or panel damage.

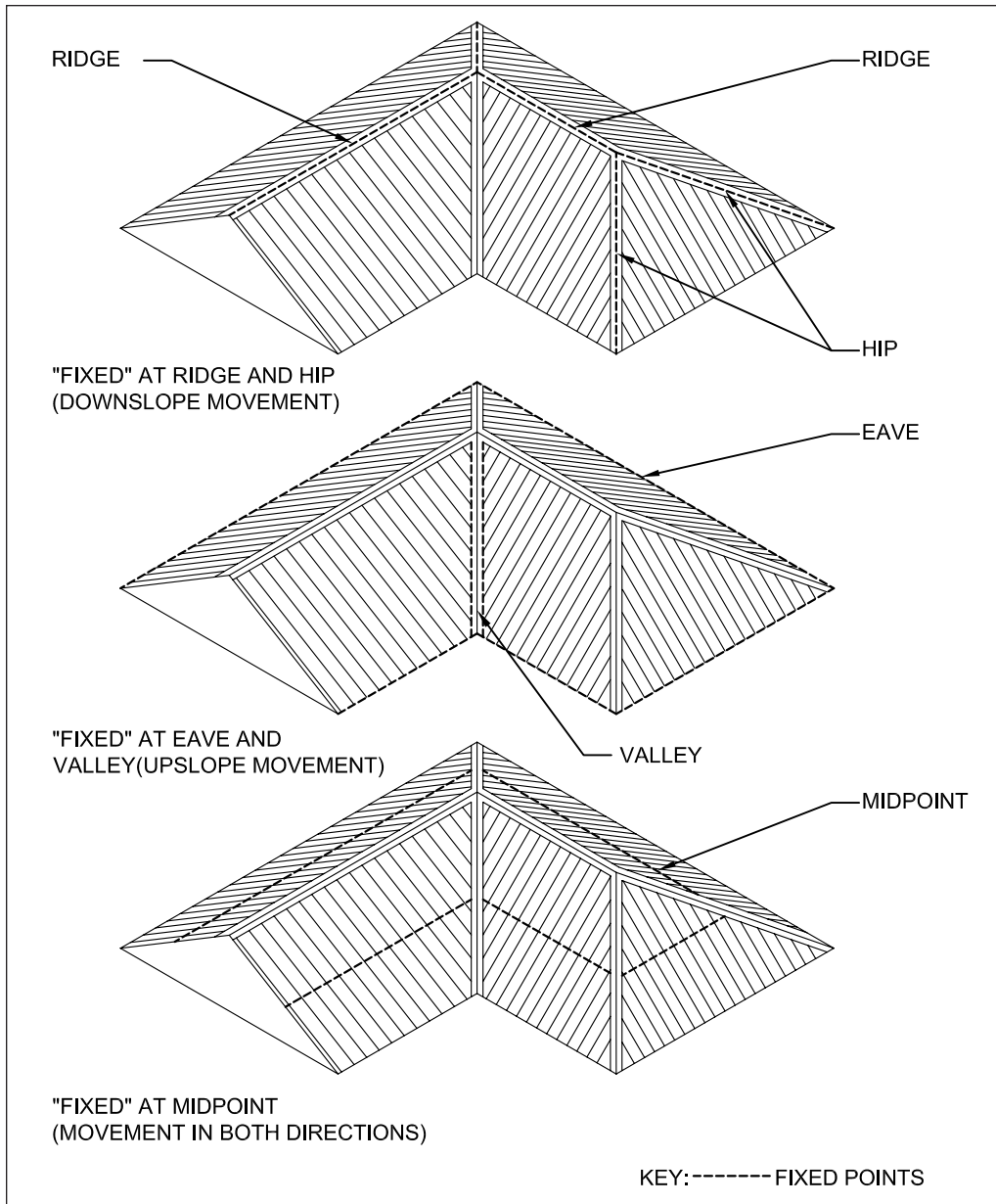


Figure 5.15: Possible fixed-point locations

### 5.10.2 End Laps

End laps in metal panel systems occur where a metal panel overlaps and rests on top of a panel that is downslope. End laps are necessary in structural metal roof panel designs when the length of the roof slope from eave to ridge is longer than the length that factory panels can be feasibly shipped or when a manufacturer does not offer on-site roll forming.

End laps can be designed as a fixed or nonfixed point of the roof system depending on the roof assembly design. End laps can be shop-notched or field-formed. End laps of adjoining panels should be offset. This prevents a buildup of material and provides continuity for sealant details. Back-up plates may be necessary to support panel end lap conditions. These plates support the panel connection and provide the attachment for the fasteners.

For end lap construction, the lower panel is notched on the vertical ribs to receive the upper panel or the upper panel is factory- or field-wedged to fit into the lower panel. When necessary, a backup plate will be installed under the lower panel. The upper panel is set in sealant and nests over the lower panel for a secure fit. Fasteners of specific quantity, size and type are installed across the end lap to mechanically seal the panels and provide compression of the sealants in this location.

End-lap components and detailing may vary with each manufacturer and material type, but certain criteria must normally be met to complete a weatherproof end-lap condition. Panel manufacturers should be consulted for their design criteria.

All end laps should occur within the manufacturer's recommended maximum dimension from the existing support system. This allows for maximum panel strength and reduces panel deflection or possible end lap failure. See S-MTL-4 for additional information.

## **5.11 Drainage**

NRCA recommends structural metal panel roof systems be installed at or above a ½:12 (2.4 degrees) slope. In addition, a structural metal panel roof system must provide positive drainage. Positive drainage is the drainage condition in which consideration has been made during the design for all loading deflections and additional roof slope is provided to ensure drainage within 48 hours following rainfall under conditions conducive to drying. The ½:12 (2.4 degrees) recommendation attempts to account for those factors that affect drainage and slope such as deflection and supporting members' allowable erection tolerances.

Localized positive drainage can be designed and achieved by including crickets and/or diverters at curbs and penetrations. NRCA recommends crickets be installed at roof penetrations that are more than one-half the width of the roof panel.

It is recommended to use external drainage systems in metal roof systems. External drainage systems include, for example, exterior gutters and open eaves. Internal drainage systems include built-in gutters with drains and scuppers and should be avoided where possible. See Section 2, "Architectural Sheet Metal," for more information about internal gutters.

## **5.12 Sheet Metal Flashing**

Because metal roofs are frequently interrupted by the intersection of adjoining roof sections, adjacent walls or penetrations such as curbs and plumbing soil-pipe stacks— all of which create potential locations for leakage—special provisions for weather protection must be made at these locations. Flashings are used to prevent water entry at these locations. Careful attention to flashing details is essential to successful long-term roof performance regardless of the type of metal panel roof construction. The number of roof penetrations should be kept to a minimum. Refer to the Construction Details section for flashing conditions commonly encountered with structural metal panel roof systems. Manufacturers' details may vary and should be considered when installing a structural metal panel roof system.

Designers should consider the following factors for proper detailing of a metal roof system and related sheet metal flashings.

- type of substrate
- roof slope
- roof insulation
- flashing securement in relation to the location of fixed panel points (amount of panel movement)
- panel profile
- panel radius
- vented vs. nonvented
- valley end points
- dormers

### **5.12.1 Eaves**

Flashings at the eaves used as attachment for panels should be made of equal- or heavier-gauge metal than the roof panels to achieve proper panel securement. When a T-type drip edge metal is used at the eave, it can serve as a securement point for the roof panel. See Figure 5.16. If this type of detail is used, the fixed point location will be at the ridge/hip or panel midpoint. In this detail, the panel is hooked to the T-type drip edge to allow movement and secure the panel edge. This type of eave flashing may be used with a vertical leg structural panel but is not typically used with a trapezoidal rib structural panel.

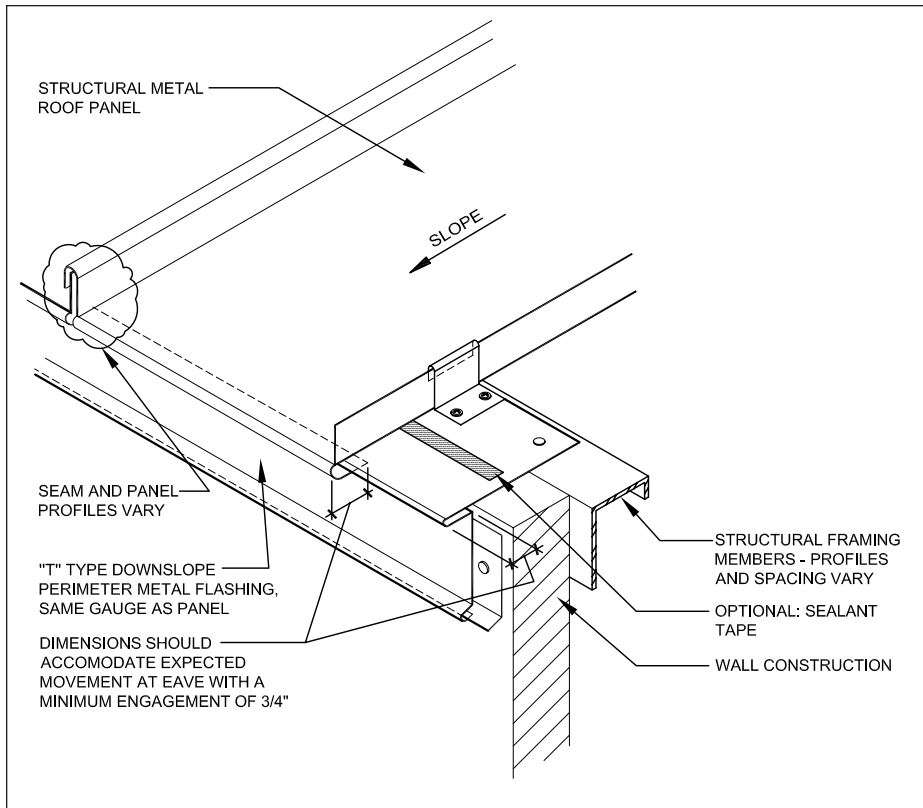


Figure 5.16 T-type drip edge metal at eave.

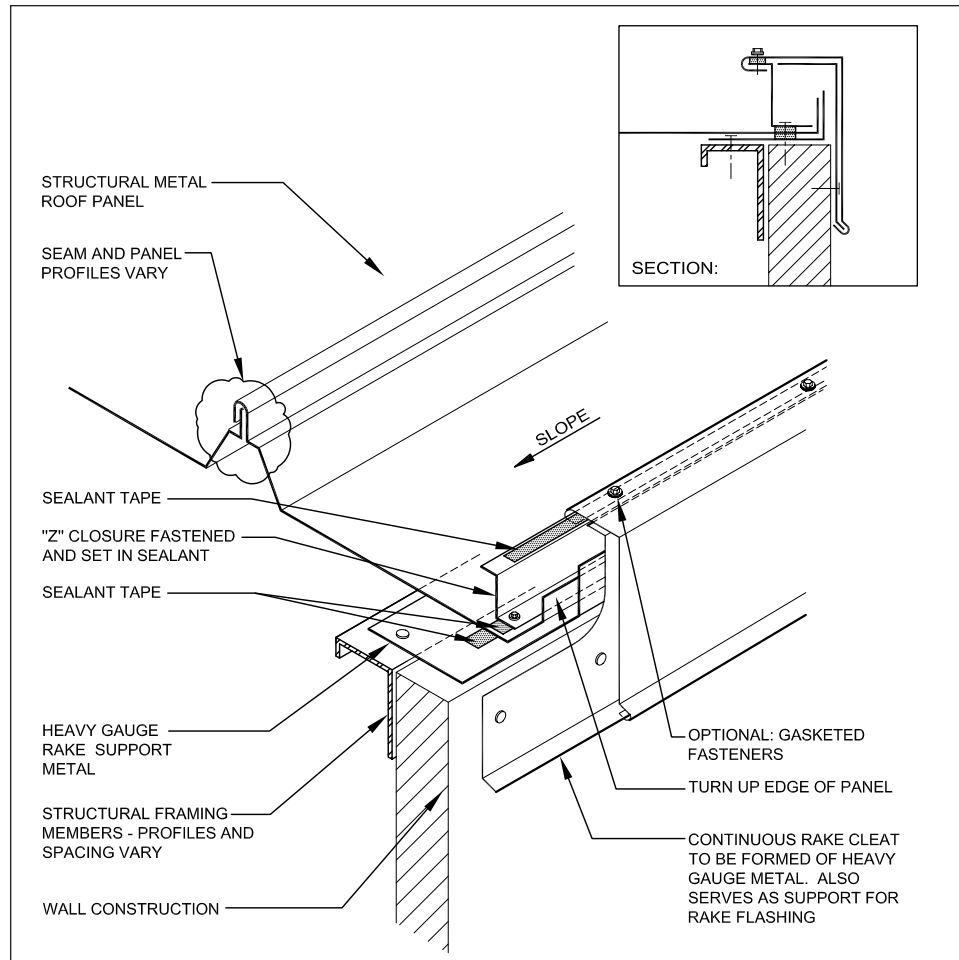
Eave flashings installed over an L-type metal edge require a continuous bead of sealant between the drip edge and panel. At the seam ends, metal and/or foam closures, set in continuous sealant, are required to seal the open ends of the seams. Structural metal roof panels can be attached at the eaves with clips in the seams or with exposed, gasketed fasteners through the panel and drip edge. Use of through-panel fasteners will fix the panels at the fastener location.

### 5.12.2 Rakes

Flashings at the rakes used as attachment for panels are made of equal- or heavier-gauge metal than the roof panels to achieve proper panel securement. When a Z-closure is used at the rake, it often serves as a securement point for the roof panel, as well. The rake is hooked to the top of the Z-closure to allow movement. This type of rake flashing may be used with a vertical leg structural panel, as well as a trapezoidal structural panel.

Rake flashings for structural metal roof systems are typically installed over the metal panels and extend down the face of the wall or structure. The lower edge of the rake flashing is secured with continuous cleats or exposed, gasketed fasteners. The Z-closure is installed on top of the metal panels must be set in a continuous bead of sealant and should only be attached to the metal panel, not to the framing system or substrate. Attachment to the framing or substrate will fix the panel and rake flashing. See Figure 5.17.

Figure 5.17: Example of a rake-edge flashing



### 5.12.3 Gutters and Downspouts

Drainage of structural metal panel roof systems may be controlled by the use of gutters and downspouts. The size, style, attachment, location, climatic conditions and construction should be considered by designers when using gutters and downspouts. Information regarding sizing of drainage can be found in the International Plumbing Code. Gutters and downspouts used in conjunction with structural metal panel roof systems are typically fabricated from the same metal type as the metal panels.

There are two types of gutters: built-in and externally attached (i.e., hanging). Gutter assemblies must be able to support the weight of debris, water and ice. Gutters must also remain leak free while enduring the stress of expansion and contraction.

Built-in gutters at valleys and parapet walls should be avoided by designers and building owners; considering alternative roof drainage designs is strongly recommended by NRCA. When these built-in gutter types are used, overflow protection, or secondary devices, is critical, and consideration should also be given to using a secondary waterproofing membrane.

For more information, see Section 2.3, "Gutters and Downspouts."

### 5.12.4 Valleys

When designing a metal panel roof system valley, the designer should consider several factors, including:

- angle of adjoining roof slopes and resultant slope of the valley
- severity of the topography and climate, such as possibilities for debris and snow buildup, ice damming and strong wind-driven rain
- the need for a valley liner based on whether the metal roof system is hydrokinetic—a watershedding roof system, often referred to as architectural—or hydrostatic—a water-barrier roof system, often referred to as structural

- type and profile of the adjacent metal roof panels that will overlap the valley metal
- proximity of hips, dormers, chimneys, skylights, penetrations or other valleys
- size of the roof areas that will contribute runoff into the valley
- number and type of surrounding trees that will deposit debris onto the roof, which can eventually create a buildup or blockage, hampering drainage through the valley
- total length of the valley
- type of metal used, expected amount of thermal movement and required dimensions of hem to account for thermal movement

Depending on these criteria, some metal roof system manufacturers' "standard" valley details may need to be enhanced for projects in severe climates, in areas of high intensity rainfall or where valleys are relatively low-sloped.

The metal valley design in a structural standing-seam metal panel roof system will vary depending on the panel profile, substrate and slope of the adjoining roofs. For all valley designs, the flow of water must be in a positive direction and the panel-to-valley metal junction sealed in a weatherproof manner. Contraction and expansion also needs to be considered and accounted for.

When the structural metal roof system has a vertical seam that is not trapezoidal and the roof system is being installed over a solid substrate, the metal valley figures, with accompanying text, shown in Section 4, "Architectural Metal Panel Roof Systems," can be referenced. Additional information is available in the Construction Details section of *The NRCA Roofing and Waterproofing Manual*.

When the panel profile of the structural-standing seam metal panel roof system is not vertical but is either trapezoidal or an intermediate rib design, the metal panel cannot be notched, turned under and sealed to the valley-to-panel junction without seam closures. This is a critical area to seal to prevent water entry into the roof system or building.

A structural standing seam metal roof system over open purlins does not have any solid support in the valley areas. Because this location is a critical area in the roof system, some type of solid support is required in this area. This can be accomplished by installing a heavier gauge metal liner, such as 14 gauge, 16 gauge or 18 gauge (0.078-inches, 0.063-inches or 0.050-inches [1.98 mm, 1.60 mm or 1.27 mm] thick) underneath the metal valley flashing. The thickness of the metal liner used should increase as the width of the valley increases. This metal liner becomes an attachment point for the roof panels. The metal liner should extend further than the metal valley flashing to provide support for the roof panel ends. The metal liner also provides support for the contractor during the installation of the roof system, for maintenance personnel and to support potential heavy snow loads.

Once the metal liner is installed, the metal valley flashing can be laid on top. An underlayment, such as EPDM, heavy- vinyl liner or a self-adhering modified bitumen membrane, is strongly recommended between the metal liner and metal valley flashing to help prevent any condensation between the two metals. The profile of the metal valley flashing is similar to the architectural style metal valley flashing. The flange of the metal valley is either clipped to the metal liner or directly attached to the metal liner.

Depending on the valley flashing profile, the metal panels should be attached by hemming to the metal valley flashing. The valley metal flashing is attached with clips to the heavy gauge valley liner. See Figure 5.18.

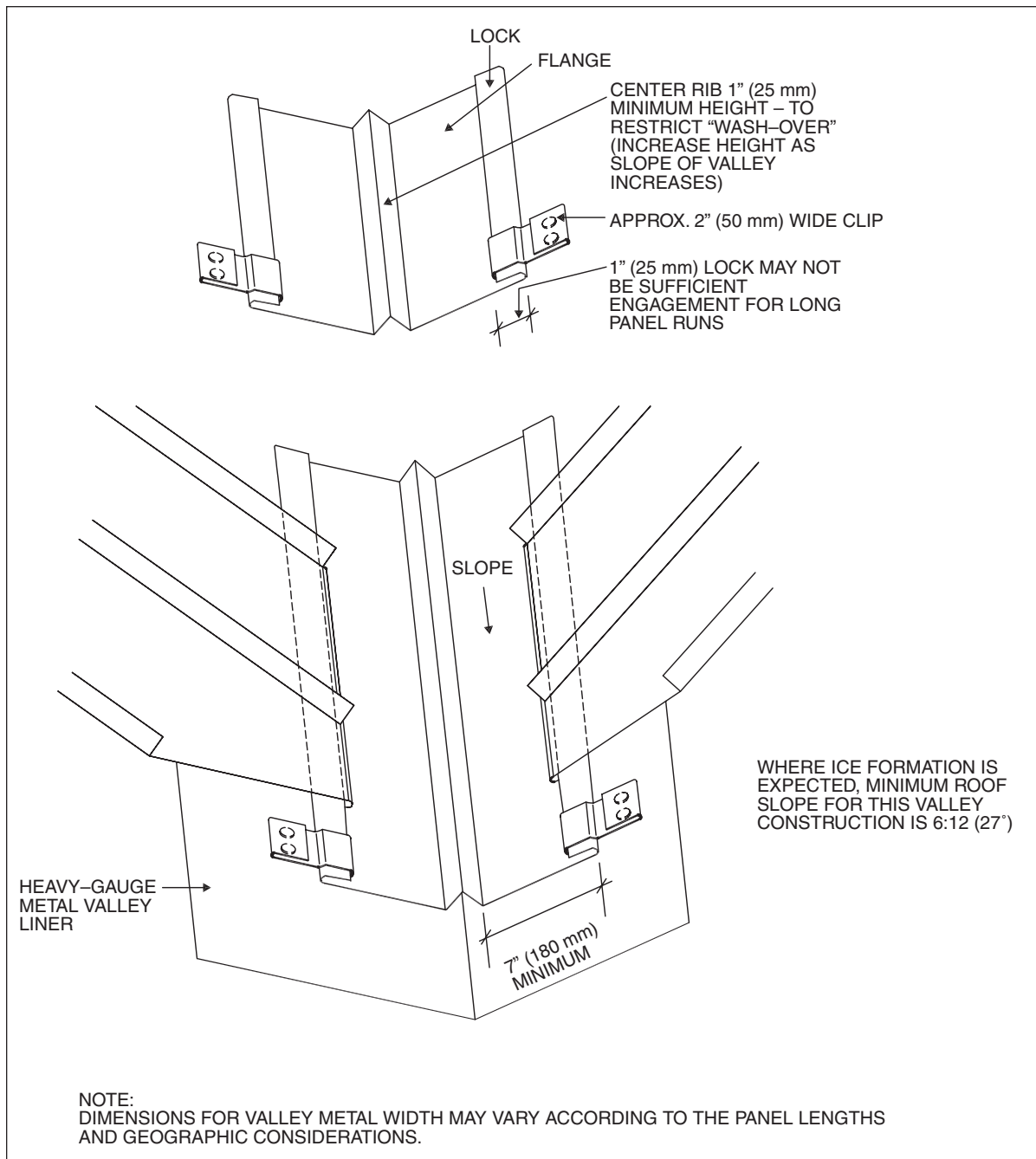


Figure 5.18. Valley with fixed point at top of panel

For all valley flashings, the metal roof panels must be sealed at the junction to the valley flashing. This can be accomplished with sealants, tape sealants and panel seam closures or the combination of these components.

A valley termination is a sensitive and critical termination within a structural metal panel roof system. By design, a valley carries water from the contributory roof areas toward the roof perimeter or to an alternate drainage system. Water exiting a valley may be directed to a perimeter gutter, an internal gutter, a conductor head, another roof area or to the ground below.

At valley terminations, there are typically multiple pieces of metal being joined that can be difficult to make and maintain weatherproof. For T-shaped edge-metal flashing, the lower end of the valley is generally folded under and hooked to the T-shaped edge metal. For L-shaped edge metal flashing, the valley metal is folded down over the face of the L-shaped edge metal, set in sealant and mechanically attached. The lower ends of the metal panels are generally folded under or clipped and sealed to the valley metal. Therefore, at the outer edges of the end of a valley termination there are at least three pieces of metal: the edge metal, the valley metal and the panel. Keeping these locations weatherproof can be difficult. Proper underlayment is necessary. Snow and ice-dam protection should be

installed below the valley in cold climates.

Water, snow or ice falling from a valley to a lower roof area may cause excessive noise and accelerated surface deterioration and excessive splashing; can damage metal panels, adjacent walls and windows; and possibly contribute to leakage problems. Water, snow or ice falling from a valley to the ground below may cause erosion of landscaping and concrete surfaces and cause the diversion of pedestrian traffic during rainfall.

It should be noted that the volume and speed of water exiting the valley is proportional to the slope and length of the valley and the size of the contributory roof area. The valley should gradually widen accordingly down to the point of termination.

## 5.12.5 Penetrations

Flashing of any penetration can best be facilitated when the penetration is less than the width of the panel. Large penetrations are more complex and require additional considerations during design and installation. There are two typical types of roof panel penetrations, which are based on size. Small penetrations are less than one-half the width of the metal panel; large penetrations are greater than one-half the width of the metal panel. Regardless of the penetration size, weatherproof characteristics and independent movement must be accounted for.

Penetrations may require the use of insulation to provide thermal resistance and reduce condensation. Penetration details can vary greatly from system to system. NRCA recommendations are provided in the following text, however, the designer should consult the manufacturer for specific information about the metal roof system, penetration type, panel configuration, attachment, and wind-uplift and code requirements.

### 5.12.5.1 Small penetrations

Small penetrations, such as pipes and vents, that can be installed within the width of the individual roof panel use a shop-fabricated or premanufactured flashing component such as a premanufactured flexible pipe collar. Small pipe penetrations should not penetrate seams and should be centered within the panel to allow for drainage. At a minimum, penetrations should have adequate space to allow for proper installation of flashing components.

For flashings that include full-panel-width sized shop-fabricated or prefabricated flashings, it is recommended that the upslope flange of the flashing piece be installed under the roof panels and the downslope flange of the flashing piece be installed over the roof panels. Proper installation of the flashing will allow for both panel movement and vertical movement of the penetration. Care should be taken not to allow the flashing fasteners to restrict panel movement. Shop-fabricated flashings typically consist of metal shapes formed to fit the item to be flashed and may require a metal rain collar. See Figure 5.19.

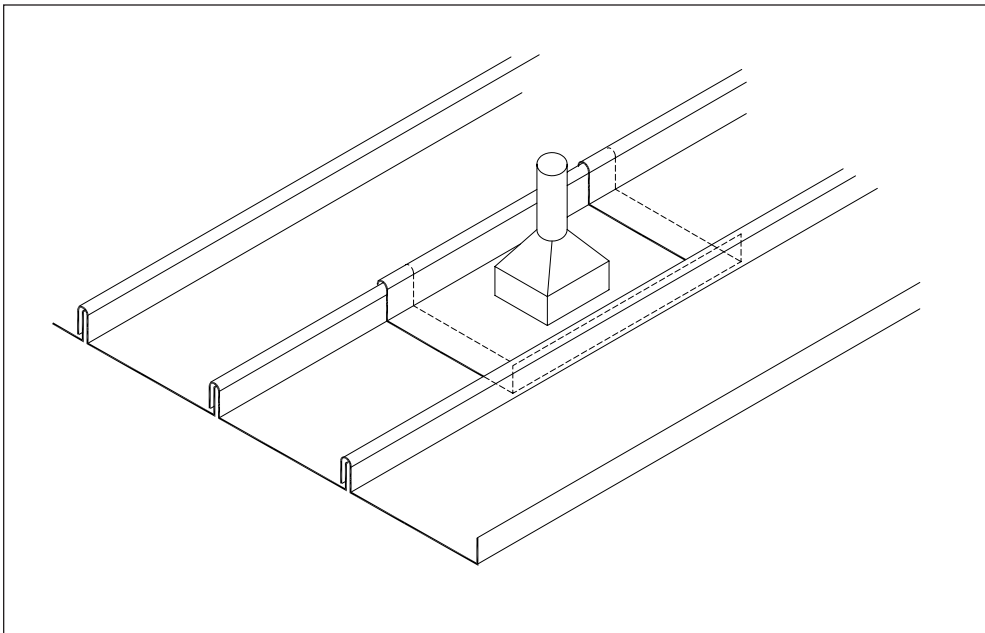


Figure 5.19 A shop-fabricated flashing for a small penetration

A flexible pipe collar includes a rubber-type bellows with a metal flashing flange at the base and is set in a bed of sealant and fastened to the roof panel. An adjustable metal clamping collar is required to be installed at the top of the boot in sealant to terminate the flashing. A metal rain collar may also be installed above the flexible pipe collar. See Figure 5.20.

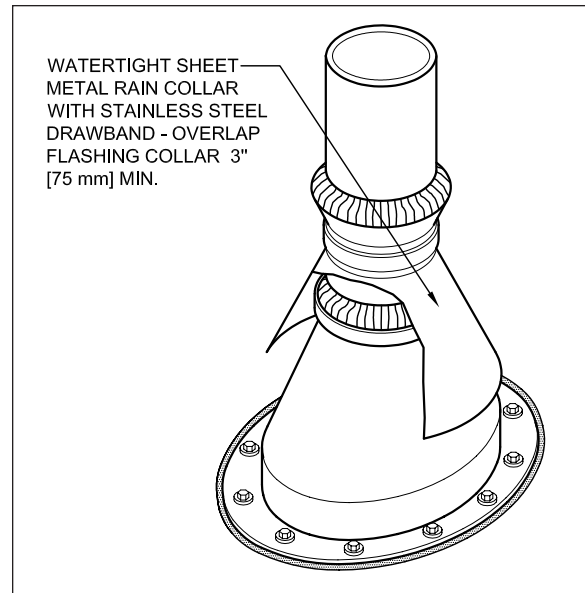


Figure 5.20: A premanufactured flexible pipe collar for a small penetration.

The designer is responsible for coordinating the penetration location to avoid an installation that would interrupt the panel seams. Consideration should be given to using only round penetrations and should include only single units. Aesthetic requirements may involve the painting of the flashing and penetrations or the addition of a skirt to hide the flexible boot. Panel manufacturers should be consulted for their specific requirements for small and large penetrations.

There are also devices available that clamp onto the seams of metal panel roof systems in lieu of penetrating the panel for support of equipment such as walkways and HVAC equipment.

#### 5.12.5.2 Large Penetrations

Large penetrations can be installed in a single panel width as long as they do not prevent adequate drainage. Large penetrations, such as mechanical vents and HVAC units, that require flashing through the panel ribs involve the use of curbs, a sleeve, or a flat sheet that eliminates the seam and allows for drainage. These curbs may be pre-manufactured, shop-fabricated or field-fabricated. The size, weight, type and other requirements determine how the curb and equipment is to be supported. Subframing may be required for support.

Panel supported flashings are used for light loads and move with the roof panels when thermal movement occurs. They are attached to the roof panels and sealed in a weatherproof manner. Smaller units can be centered in one or two panels so that water can flow past the sides of the curb. See Figure 5.21.

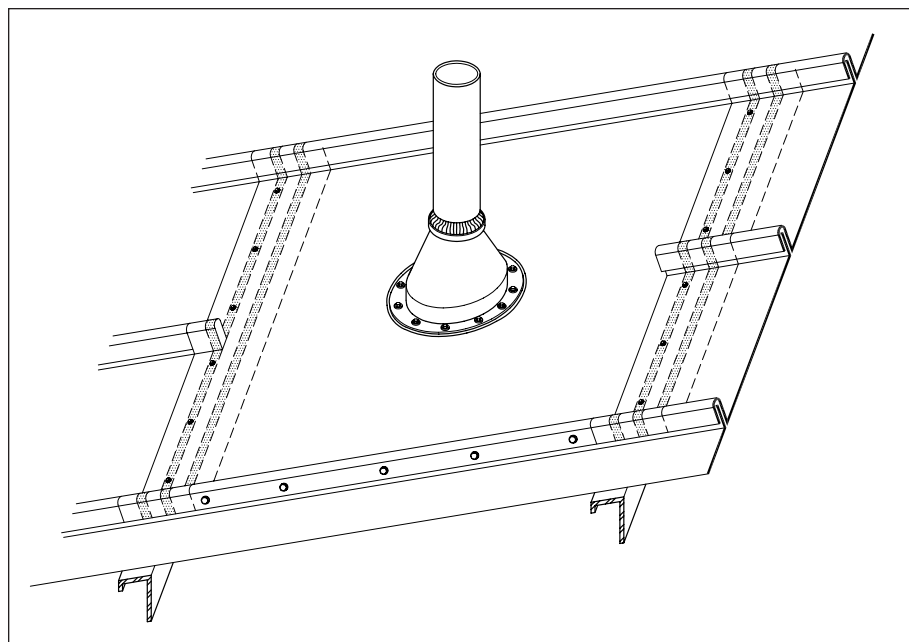


Figure 5.21: Smaller unit in two panels

When larger curbs are used, the panel ribs must be stopped short of the upslope face of the curb so that water can flow past the ends of the ribs and will not be trapped against the curb. If a raised curb is wider than 24 inches (610 mm), it is recommended the designer detail a metal cricket on the upslope side of the curb to help divert water flow to either side of the curb. See Figure 5.22. The cricket should be made of the same or a compatible metal type and gauge as the metal panel. Depending on the metal type, the cricket should be welded, soldered or fastened and set in sealant. Curb heights should be a minimum of 8 inches (200 mm) on the upslope side.

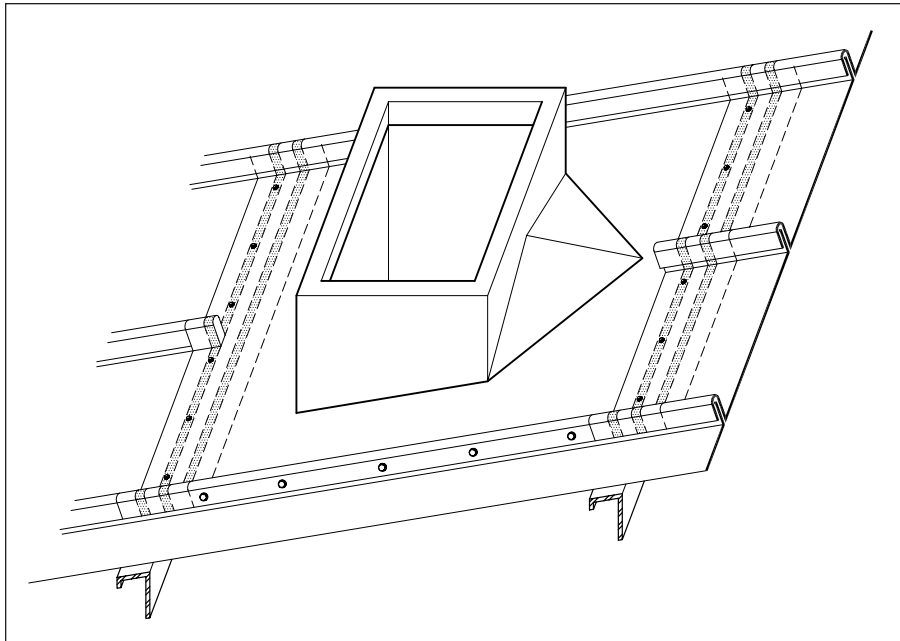


Figure 5.22: Curb with cricket in two panels

### 5.12.5.3 Column Penetrations

A column penetration may be considered a small or large penetration and should be flashed appropriately. When heavy equipment must be supported by a building's structure, differential movement between the support elements and roof panels must be accommodated. If the equipment includes the use of a separate frame supported by vertical supporting elements attached to the building structure, the vertical supporting elements are flashed as small penetrations. The clearance height measured from the metal panel to the bottom of the equipment support member should increase as the equipment width increases. The following chart is also provided in the Construction Details section of The NRCA Roofing and Waterproofing Manual. See Detail S-MTL-17.

Width of Equipment	Clearance Height of Legs
Up to 24 inches (610 mm)	14 inches (350 mm)
25 inches (635 mm) to 36 inches (915 mm)	18 inches (450 mm)
37 inches (940 mm) to 48 inches (1.2 m)	24 inches (610 mm)
49 inches (1.25 m) to 60 inches (1.5 m)	30 inches (750 mm)
61 inches (1.5 m) and wider	48 inches (1.2 m)

Table 1: Clearance height of support legs based on width of equipment.

### 5.12.6 Slope Transitions

There are two types of slope transitions: gambrel-style transitions, where the upper roof area has less slope than the adjacent lower roof area, and the opposite, where the upper roof area has more slope than the adjacent lower roof area. Transition-metal flashings therefore need to incorporate the attributes of eaves and ridges to provide closures at the ends of the upslope panel runs and the beginnings of the downslope panel runs.

When designing a metal roof transition, a designer should consider several factors including:

- angle of adjoining roof slopes
- severity of the topography and climate, such as possibilities of snow buildup, ice damming or strong wind-driven rains
- type and profile of the adjacent metal roof panels that will overlap the transition components

- proximity of hips, dormers, chimneys, skylights, penetrations and valleys
- size of the roof areas that will contribute runoff over the transition
- number and type of surrounding trees that will deposit debris onto the roof, which can eventually create a buildup or blockage, hampering drainage above or below the transition
- type of metal used and anticipated thermal movement
- support members/subframing for slope change

Depending on their lengths, metal transitions are not usually made from one continuous section of metal – typically they are made from two or more sections and several components. As a result, the designer should consider how individual sections of transition metal are to be joined and how transition metal will interface with the metal roof panels and other adjacent components, such as dormers and penetrations, making up the roof assembly. The designer should carefully consider how laps are joined for the transition to remain in place; that is, not block water flow or deform, and still shed water and how the edges of the transition metal should be configured to perform in the assigned location.

Depending on the slopes of the two roof surfaces and type of metal roof system flashing, the transition may be accomplished by using a metal cover, for example “knee joints” or “knuckles,” metal closures, or up-turned panel ends and sealants. Foam closures should be used only in conjunction with metal closures and up-turned panel ends. For a lesser-sloped metal roof below a steeper-sloped roof, all these components may be used to flash transitions. The practice of cutting panel seams and bending the panel pan into or over the transition and only caulking the seam is not recommended.

Transition covers and closures are made of equal or heavier gauge metal to achieve proper panel securement along the transition. Transition metal often serves as a securement point for the eave flashings of the upslope panel run. Therefore, it typically is not directly attached to the panel because of differential expansion and contraction of the materials. Instead, the panel is hemmed around the transition closure to allow movement. Transition metal may also serve as a securement point for the lower panel run. Therefore, design decisions about where and how securement points will function in relation to transitions are important.

Some metal roof system manufacturers’ “standard” transition details may need to be modified for projects in severe climates or areas of high-intensity rainfall. For a transition to perform successfully, it has to shed water at all locations along its length.

At a location where a basic transition may not readily shed water during certain situations such as wind-driven rain or ice-damming conditions, NRCA suggests the transition design be modified to accommodate the expected condition.

For example, if, because of the relatively low slope of a roof and severity of climatic conditions, a particular transition is expected to dam regularly with ice during freeze-thaw cycles, the transition flashing components should be specified with enough overlap to accommodate this expected condition.

The following are additional examples of modifications for transition details:

- Flange Dimension and Roof-panel Overlap

The distance that adjacent metal roof panels must overlap the flanges on either side of the transition should be considered. One of the most important reasons for extending the flanges on either side of the transition is that it allows for a greater overlap under the upper metal roof panel and over the lower metal roof panel.

For metal panel roof systems that will be used as watershedding systems in moderate to severe climates, NRCA suggests that transition metal overlap the lower roof panels a minimum of 6 inches (150 mm) and be overlapped by the upper metal roof panels a minimum of 4 inches (100 mm).

- Underlayment and Liner Material

For structural metal panel roof systems incorporating solid decking, the transition metal is typically laid over an appropriate underlayment sheet that is continuous across the change in slope. However, if the slope is not adequate and climatic conditions will expose the transition to severe wind-driven rain or extended freeze-thaw cycles, enhancing the transition underlayment is necessary.

Instead of using an asphalt-saturated felt underlayment, it may be beneficial to first line the change in slope with an ice dam protection underlayment. Self-adhering polymer modified bitumen membranes can work well for this purpose. These membranes should extend past the edges of the transition metal on both sides.

- Stripping in Transition Metal Flanges

Stripping in the transition metal flanges along the upslope side of the metal transition can help to ensure a

successful transition detail. The membrane transition liner material should be extended beneath and beyond the edges of the transition metal to facilitate stripping in the upslope metal transition flange.

- Slope Transition Support

In snow and ice regions, transition metals may need support. The use of decay-resistant, treated wood blocking, installed above the lower metal panel closures, between the panel seams and at the same height as the seam, will provide support to the transition metal cap/cover. Also, the use of nontreated construction-grade wood is suitable for use in roof assemblies as blocking or nailers, provided reasonable measures are taken to ensure the nontreated wood remains reasonably dry when in service.

When decay-resistant, treated wood is used, the following recommendations are suggested.

- Carbon steel, aluminum and electroplated galvanized steel fasteners and connectors should not be used in contact with treated wood. Hot-dipped galvanized fasteners complying with ASTM A153 and connectors complying with ASTM A653, Class G185, generally are acceptable. Type 304 or Type 316 stainless-steel fasteners and connectors are recommended for maximum corrosion resistance.
- Fasteners with proprietary anticorrosion coatings may be acceptable for use with treated wood. When considering the use of such proprietary coated fasteners and connectors, consult fastener manufacturers for specific information regarding the performances of their products in treated wood and any precautions or special instructions that may be applicable.
- Aluminum fasteners, flashings and accessory products should not be used in direct contact with any treated wood. ACQ-treated wood is not compatible with aluminum.
- Uncoated metal and painted metal flashings and accessories, except for 300-series stainless steel, should not be used in direct contact with treated wood. Metal products, except stainless steel, may be used if separated from treated wood by a spacer or barrier, such as single-ply membrane or self-adhered polymer-modified bitumen membrane material.

Additionally, a separator sheet, such as vinyl or self-adhering underlayment, is needed between the treated wood blocking and the bottom of the metal panel to prevent corrosion of the bottom side of the metal panels.

### 5.12.7 Ridges and Hips

Ridges and hips occur along the intersection of two adjacent roof slopes. Ridge and hip assemblies use similar detailing techniques. Flashing at the ridges and hips is needed to provide a closure for the tops of the metal panels. Proper flashing and securement of the metal cap and panel assembly at these intersections are essential for a long-term, weather-tight detail. Depending on the slope of the roof and type of metal panel roof system, flashing of the ridge or hip is typically accomplished by using metal closures, up-turned panel ends and sealant. See Figure 5.23.

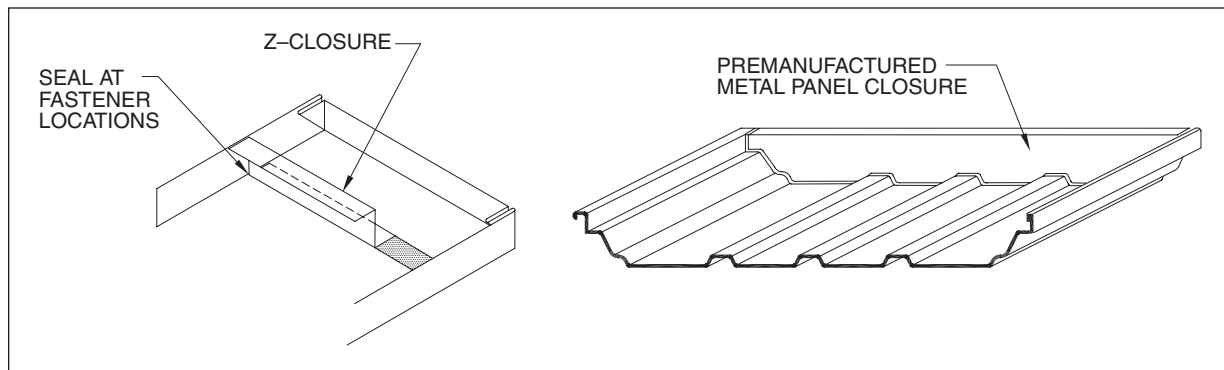


Figure 5.23:  
Examples  
of panel  
closures

NRCA suggests that along each side of the ridge and hip, the ends of the roof panels be turned up to form a pan. This pan acts as a secondary barrier against water intrusion. Some metal panel profiles may not allow panel ends to be turned up to form a pan. To terminate these panel ends, it is recommended that a panel closure be installed at the upper end of the panel and sealed to prevent moisture intrusion.

Metal Z-closures are placed between each panel rib and sealant is installed at fastener locations. The metal cap is then mechanically attached or hooked to the top of the Z-closure. NRCA recommends the Z-closure and cap be the same metal gauge or heavier and the same type of metal as the metal panel. Foam closure strips should not be used as primary closures but only in conjunction with the metal closures and upturned panel ends.

With some vertical seam panels, techniques have been developed where it is possible to turn up panel ends at ridges

and hips without cutting the panel end. A Z-closure is then attached in the field of the panel downslope from the panel end and is aligned with the outer edge of the hip or ridge cap to provide the primary closure for wind-driven rain and snow. This procedure is unique to vertical leg panels and is not necessarily applicable to other panel configurations.

Lap joints for metal ridge and hip caps should be overlapped a minimum of 4 inches (100 mm) and set in two beads of sealant. For long ridge and hip lengths, a designer should detail the ridge or hip cap to allow for thermal movement. Laps for hip caps should be lapped in watershedding fashion.

Where venting is required, ridge assemblies must be detailed to provide airflow but not allow water migration into the building. In most cases, the vented ridge cap includes the same components as a nonvented cap but additionally incorporates the use of an air space and/or perforated material to provide airflow. For proper venting, the deck, underlayment, insulation and metal panel should have a properly sized continuous opening for airflow along the ridge line, as well as a distinct airspace under the panels to allow air to move from eave to ridge. Eave and ridge vent design requires use of net free ventilation amounts for perforated metal. This can be accomplished by installing longer clips. Hips are typically not vented because of the potential for leakage.

Panel manufacturers' vented ridge cap details should be consulted for specific requirements.

Where the metal panel roof system is installed over spaced structural support systems such as purlins or joists, the metal panel clip attachment points are determined by the placement and spacing of the structural framing members. A subpan should be fastened to the structural framing at the hip line to act as a substrate to support and terminate the panels between the angled framing members.

For additional information refer, to the following sources:

- "Moisture Control for Low-slope Roof Assemblies" in the Moisture Control section of The NRCA Roofing and Waterproofing Manual.
- "Moisture Control and Ventilation for Steep-slope Roof Assemblies" in the Moisture Control section of The NRCA Roofing and Waterproofing Manual.

The designer and owner are encouraged to discuss these details with professional roofing contractors experienced with metal panel roof systems for specific recommendations based on roof slope, climatic conditions and regional practice.

## **5.13 Accessories**

### **5.13.1 Snow Guards**

In locations where ice and snow occur frequently, snow guards may be desirable particularly where a metal roof's eave is positioned over pedestrian or vehicular traffic areas. Because of the smooth surface of metal panels and how quickly metal panels transfer heat, snow and ice tend to loosen suddenly from panels. If snow guards are used, it is strongly recommended not to penetrate the metal panels with exposed fasteners, thus avoiding potential leakage. Snow guards should be attached with manufacturer-recommended sealants at flat-pan areas or nonpenetrating attachment at vertical ribs that are typically accomplished through clamping methods. Nonpenetrating attachment is preferable to penetrating the metal panels. The installation of snow guards creates a location for the buildup of snow, debris and ice, and water dams can occur, which may result in leakage. The installation of an ice-dam protection membrane is recommended under and upslope of the areas with snow guards.

There may be a need for additional clips where snow guards are installed because of the expected weight of ice and snow. Snow guard manufacturers should be consulted for specific requirements. Where snow guards are used, the building designer must be aware that the buildup of snow on a roof will add additional weight to the roof system and structure.

### **5.13.2 Skylights**

Skylights incorporated in structural metal panel roof systems should be installed on curbs so they are out of the drainage plane, that is, above the plane of the roof panels. Skylight frames should overlap the curb a minimum of 3 inches (75 mm) to act as counterflashing or separate counterflashing should be installed.

There are manufacturers that provide skylights that are made of translucent materials that have the same profile as the structural metal panel. There are not installed on curbs, but are installed in the plane of the roof instead of a metal panel. NRCA does not recommend the use of these types of skylights.

### **5.13.3 Counterflashing**

See Section 2.6, "Counterflashing" for general information about counterflashing at walls, penetrations and through-wall flashings.

### **5.13.4 Walkways**

Walkways may be used as part of a low-slope metal panel roof system where heavy rooftop traffic is anticipated. Inclusion of walkways reduces or eliminates damage to panels from rooftop traffic. Walkway attachment should not penetrate the roof panels but should be attached to the standing seam with nonpenetrating clamping attachments. Walkways should be skid-resistant, should not inhibit drainage and should allow water to easily drain through horizontal surfaces (e.g., perforated platforms). It is recommended to use pre-engineered walkway systems. Check with the roof system manufacturer for warranty exclusions regarding walkway attachment. In lieu of walkways, installation of a solid deck under panels in traffic areas can be used to prevent deflection and damage.

### **5.13.5 Lightning Protection**

Lightning protection is not typically the responsibility of roofing contractor even though there are watertightness and abrasion issues when installing lightning protection. Coordination between the roofing contractor and lightning protection contractor is critical for a successful installation. Unauthorized installation of a lightning protection system will likely void warranty claims related to problems with or created by the lightning protection.

### **5.14 Wall Panels**

Metal wall panels can be used where a parapet wall intersects the roof line or extends from one roof elevation to another. Metal wall panels can have a standing seam profile, interlocking flat seam profile or sealed lap-seam profile. Metal wall panels can be installed over a continuous or closely spaced substrate or over a framing system. Insulation and underlayment may be installed behind the panels.

The upper edge of the metal wall panels is typically made weatherproof by using metal flashings or closures. All inside and outside corners require metal flashings to seal this junction of the metal wall panels. All penetrations through the wall panels must be flashed in a weatherproof manner. Ventilation of any air space should be considered when installing metal wall panels.

The bottom of metal wall panels should be installed over a positively sloped through-wall flashing that provides drainage from the wall panels onto a lower roof section or other appropriate location. All laps in metal wall panels should be sealed. When exposed fasteners are used to attach the flashing, corrosion-resistant materials should be used.


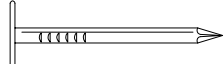
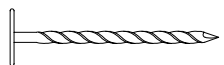
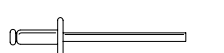
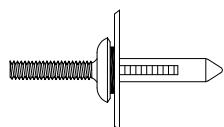



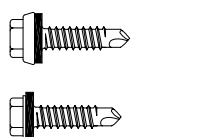


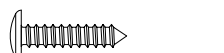
## 6. Appendix

### Metal Gauges, Thicknesses and Weights

Metal	Gauge	Nominal Thickness (inches)	Approximate Pound per Square Foot	Nominal Thickness (mm)	Approximate Kilogram per Square Meter
Aluminum		0.024	0.35	0.64	1.72
		0.032	0.45	0.81	2.20
		0.040	0.57	1.02	2.75
		0.050	0.70	1.27	3.50
		0.063	0.89	1.63	4.40
Copper					
	16 oz.	0.022	1.00	0.56	4.87
	20 oz.	0.027	1.25	0.69	6.10
	24 oz.	0.032	1.50	0.81	7.31
32 oz.	0.043	2.00	1.09	9.77	
Lead Sheets					
	4 lb.	0.062	4.00	1.57	19.53
	3 lb.	0.047	3.00	1.20	14.65
	2½ lb.	0.039	2.50	0.99	12.21
2 lb.	0.031	2.00	0.79	9.77	
Lead-coated Copper Sheets					
	16 oz.	0.026	1.07	0.66	5.21
	20 oz.	0.031	1.31	0.79	6.39
	24 oz.	0.036	1.54	0.91	7.51
32 oz.	0.047	2.03	1.19	9.95	
Stainless Steel	28	0.015	0.66	0.38	3.19
	26	0.018	0.79	0.46	3.84
	24	0.024	1.05	0.61	5.12
Steel*: Galvanized Steel Galvalume® Aluminized Steel	28	0.015	0.63	0.38	3.06
	26	0.019	0.91	0.48	4.42
	24	0.025	1.16	0.64	5.64
	22	0.031	1.41	0.79	6.85
	20	0.038	1.66	0.97	8.08
	18	0.050	2.16	1.27	10.51
16	0.063	2.64	1.60	12.83	
Terne	26	0.018	0.80**	0.46	3.91***
	28	0.015	0.67**	0.38	3.27***
	30	0.012	0.54**	0.30	2.63***
Terne-coated Stainless Steel (TCS)	28	0.015	0.66	0.38	3.19
	26	0.018	0.79	0.46	3.84
	24	0.024	1.05	0.61	5.12
Zinc	24	0.020	0.75	0.51	3.66
	21	0.027	1.00	0.69	4.87

\* U.S. Standard Gauge  
 \*\* 40-lb. coating weight  
 \*\*\* 88.2-kg coating weight

Common Sheet-metal Fasteners

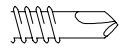
Fastener Illustration	Fastener type	Fastener usage	Fastener material recommendations <sup>4</sup>	Substrate				
				Sheet Metal 18 gauge or lighter	Sheet Metal heavier than 18 gauge	Wood <sup>6</sup>	Concrete	Masonry
	Ring or Annular Shank Nail	sheet metal to wood	hot-dipped galvanized, stainless steel, copper			X		
	Barbed Shank Nail (smooth)	sheet metal to wood	hot-dipped galvanized, stainless steel, copper			X		
	Screw Shank Nail	sheet metal to wood	hot-dipped galvanized, stainless steel, copper			X		
	Pop Rivet	sheet metal to sheet metal	carbon steel <sup>5</sup> , stainless steel, aluminum, copper	X <sup>1</sup>				
	Shear Rivet	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel, aluminum	X <sup>1</sup>	X <sup>1</sup>			
	Nail-in Expansion Fastener	sheet metal to concrete or masonry	lead, nylon, carbon steel <sup>5</sup> , or zinc alloy body with carbon steel <sup>5</sup> or stainless steel pin				X <sup>1</sup>	X <sup>1</sup>
	Concrete Screw	sheet metal to concrete	carbon steel <sup>5</sup>				X <sup>1</sup>	X <sup>1</sup>
	Self-piercing Screw	sheet metal to sheet metal, wood or purlin	carbon steel <sup>5</sup> , stainless steel	X <sup>2</sup>	X <sup>2</sup>	X		
	Self-drilling Screw	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel with neoprene washer	X	X <sup>2</sup>			
	Self-tapping Screw	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel with neoprene washer	X <sup>1</sup>	X <sup>1</sup>			
	Self-drilling Screw	sheet metal or clip to sheet metal, purlin or wood	carbon steel <sup>5</sup> , stainless steel	X	X	X		
	Self-drilling Screw	sheet metal to sheet metal or purlin	carbon steel <sup>5</sup> , stainless steel	X <sup>2</sup>	X <sup>2</sup>			

**Common Sheet-metal Fasteners (cont.)**

**Points<sup>3</sup>**



Self-piercing



Self-drilling

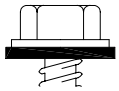


Self-cutting

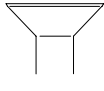


Self-tapping

**Heads<sup>3</sup>**



Hex washer head



Flat head



Wafer head



Oval head



Pancake head



Pan head



Bugle head



Trumpet head

**Drives<sup>3</sup>**



Slotted



Phillips



Phillips/slotted



Square



Hex socket



Phillips hex



Hex



Hex washer

**Notes:**

1. Requires a pre-drilled hole.
2. May require a pre-drilled hole.
3. Screw points, heads and drives may be combined with the fastener types shown. Check with the manufacturer for specific combinations.
4. Check with fastener and substrate manufacturers for corrosion resistance requirements and information.
5. Carbon steel fasteners have some type of coating (e.g., zinc, proprietary) applied to the fastener.
6. When treated wood is the substrate, the following recommendations are suggested:
  - Carbon steel, aluminum and electroplated galvanized steel fasteners and connectors should not be used in contact with treated wood. Hot-dipped galvanized fasteners complying with ASTM A153 and connectors complying with ASTM A653, Class G185, generally are acceptable. Type 304 or Type 316 stainless-steel fasteners and connectors are recommended for maximum corrosion resistance.
  - Fasteners with proprietary anti-corrosion coatings may be acceptable for use with treated wood. When considering the use of such proprietary coated fasteners and connectors, consult fastener manufacturers for specific information regarding the performances of their products in treated wood and any precautions or special instructions that may be applicable.
  - Aluminum fasteners, flashings and accessory products should not be used in direct contact with any treated wood. ACQ-treated wood is not compatible with aluminum.
  - Uncoated metal and painted metal flashings and accessories, except for 300-series stainless steel, should not be used in direct contact with treated wood. Metal products, except stainless steel, may be used if separated from treated wood by a spacer or barrier, such as single-ply membrane or self-adhered polymer-modified bitumen membrane material.

- Ultraviolet (UV) resistance
- Fire resistance
- Weatherability
- Color retention
- High permeance
- Application:
  - Applied as base and/or top coat
  - Applied in multiple coats
  - Each coat applied to achieve a DFT of 10 to 20 mils (0.3 to 0.5 mm) to build up to the final desired coating thickness
- Generally, curing time ranges from 4 to 8 hours
  - Curing is dependent on ambient weather conditions during the curing cycle
  - Temperature and humidity affect curing time
- Temperature should be above 50° F (10° C) during application.

#### Butyl Rubber:

Butyl rubber coatings are based on polymers of butadiene and exhibit the following characteristics:

- Two component, requires mixing
- Low permeance
- Application:
  - Applied as base coat (other coating materials that are more UV-resistant are used as the top coat)
  - Applied in multiple coats
  - Each coat applied to achieve a DFT between 10 to 15 mils (0.3 to 0.4 mm) to build up to the final desired coating thickness
- Generally, curing time ranges from 45 minutes to 6 hours
  - Curing is influenced by ambient weather conditions during the curing cycle
  - Temperature and humidity affect curing time
- Temperature for application is required to be 40° F (4° C) and above

#### Hypalon™:

Hypalon coatings used as part of elastomeric-coated SPF-based roof systems should comply with ASTM D 3468, “Specification of Liquid-Applied Neoprene and Chlorosulfated Polyethylene Used in Roofing and Waterproofing.”

Hypalon,™ a registered trademark of E.I. DuPont de Nemours Co., is based on chlorosulfonated polyethylene rubber and exhibits the following characteristics:

- Single component
- UV resistance
- Fire resistance
- Weatherability
- Color retention
- High permeance
- Application:
  - The coating typically is used as a top coat over compatible coating materials
  - Each coat is applied to achieve a DFT of 8 mils (0.2 mm) or less to build up to the final desired coating thickness

- Generally, curing time ranges from 2 to 6 hours
  - Curing is dependent on ambient weather conditions during the curing cycle
  - Temperature and humidity affect curing time
- Temperature for application is required to be 40° F (4° C) and above.

Silicone:

Silicone coatings used as part of elastomeric-coated SPF-based roof systems should comply with ASTM D 6694, “Specification for Liquid-Applied Silicone Coating Used in Spray Polyurethane Foam Roofing.”

Silicone coatings are based on silicone polymers and exhibit the following characteristics:

- Single component or two component
- UV resistance
- Fire resistance
- Weatherability
- Color retention
- High permeance
- Application:
  - Applied as a base and/or top coat
  - Applied in multiple coats
  - Each coat applied to achieve a DFT up to 15 mils (0.4 mm) but generally should not exceed a total film thickness of 30 mils (0.8 mm)
- Generally, curing time ranges from 1 to 2 hours
  - Curing is dependent on ambient weather conditions during the curing cycle for single-component formulations
  - Curing is influenced by ambient weather conditions during the curing cycle for two-component formulations
  - Temperature and humidity affect curing time
- Applied in temperature ranges that can approach freezing

Aromatic Polyurethane Elastomers:

Aromatic polyurethane coatings are polymers based on unsaturated aromatic backbones, such as benzene rings. This unsaturated state accounts for the slight to moderate darkening and chalking characteristics that occur during exterior exposure. The degree to which discoloration and chalking occur depends on the particular formulation. Aromatic polyurethanes frequently are used as base coats for aliphatic polyurethanes; however, some may be used as finish coat with only mild chalking and discoloration. Aromatic polyurethanes exhibit the following characteristics:

- Single component or two component
- For aromatic polyurethanes designed for use as top coats:
  - UV resistance
  - Fire resistance
- Permeance ratings for these products vary based on formulation
- Application:
  - Applied as a base coat (with other coating materials that are more UV-resistant being used as the top coat) or applied as a top coat when designed for use as a top coat
  - Applied in multiple coats
  - Each coat applied to achieve a DFT up to 15 mils (0.4 mm) to build up to the final desired coating thickness

# Waterproofing

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# General Waterproofing Project Considerations

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## **1. Introduction**

The General Project Considerations section of *The NRCA Waterproofing Manual* provides an overview of general information concerning the design and installation of quality waterproofing assemblies.

The information in this manual represents a consensus opinion of knowledgeable, practicing waterproofing contractors throughout the United States. Some design criteria and application techniques may vary according to climatic conditions, and each geographical area may employ specific “area practices” that are sound and time-proven for that area. NRCA does not intend to imply by any statement or exclusion that proven area practices are unsatisfactory or inappropriate.

NRCA recommends a waterproofing assembly be designed only after a number of criteria have been carefully considered, including:

- Climate and geographic location
- A building’s intended use and design life expectancy
- Exterior and interior temperature, humidity and use conditions
- Code requirements
- Type and condition of substrate, including soil
- Structural system
- Slope and drainage
- Waterproofing system type including overburden
- Accessibility and building configuration
- Building movement
- Type and amount of insulation/protection/drainage needed
- Need for ventilation during installation
- Compatibility with adjacent building and/or system components
- Construction sequencing
- Worker safety
- Potential building additions
- Odors generated by certain system application methods
- Water table
- Construction traffic
- Penetrations

These criteria play important roles in the ultimate success or failure of a waterproofing assembly and should be considered by a designer to determine the appropriate components of a waterproofing assembly, applicable products and specifications, and construction details to be used.

In addition, a designer should be certain waterproofing material manufacturers’ requirements are taken into account, as well as requirements of applicable insurance, building code enforcement and/or other regulatory agencies. It is recommended to consult material manufacturers’ written specifications during the design of a waterproofing assembly.

## **2. Notes to the Owner and Designer**

Achieving a waterproofing system that will perform its functions satisfactorily for an anticipated service life requires proper design, quality materials and quality workmanship.

### **2.1 Proper Design**

Knowledgeable selection of compatible building materials, quality waterproofing materials and systems that will withstand the conditions (e.g., hydrostatic) of the area where a building is located is vital to a quality waterproofing assembly design. Properly prepared specifications with accurate drawings and details are essential. Specific requirements regarding a new waterproofing system’s components and installation should be carefully detailed by a designer.

A designer is responsible for proper specifications and drawings. Waterproofing contractors and material manufacturers should be consulted for input during the design phase.

## **2.2 Quality Materials**

Material selection should be based on the time-proven quality of a waterproofing assembly and its compatibility and appropriateness to the substrate rather than solely on economic considerations or length and scope of a warranty.

## **2.3 Quality Workmanship**

NRCA suggests designers work with qualified professional waterproofing contractors. Consult them during the design phase and before specifications or contract documents are prepared. The work should be performed by skilled, trained workers familiar with the specified product. Waterproofing products by nature provide only one window of opportunity to be installed correctly. Therefore, building owners and designers should consider using the “Waterproofing Contractor Qualification Statement” as suggested by NRCA. A copy of this document is contained in the Appendix.

## **3. Pre-bid Conference**

For waterproofing projects where drawings and specifications have been prepared and two or more waterproofing contractors are asked to submit sealed bids to perform specified work, NRCA recommends a pre-bid conference be conducted. A pre-bid conference can serve the following purposes:

- Introduce all the parties involved in the project, such as owner’s representative, designer and contractor’s key personnel.
- Provide a forum for a thorough review of the project documents and requirements and the owner’s special needs.
- Establish the conditions under which temporary waterproofing and/or traffic paths will be used and who will pay for them.
- Provide an opportunity to identify and resolve any questions, discrepancies, contradictions or errors in written specifications and drawings.
- Provide an opportunity to discuss best practices, as well as limitations for job-site setup, work hours, staging, storing materials, and removal of materials and debris.
- Identify and resolve any misconceptions in the scope of work.
- Identify the quality-control and inspection process.

Before scheduling a pre-bid conference, a designer or building owner’s representative should prepare an agenda for the meeting and distribute it to all invited parties. If the identity of interested bidders cannot be determined before the pre-bid conference, such as in public bid projects, the agenda should be posted and made available to potential attendees before the conference. A pre-bid conference should be attended by all responsible parties, including the owner’s representative, designer, estimators and key personnel of the bidding contractors and any subcontractors. The pre-bid meeting should be scheduled to allow adequate time for bid preparation between the pre-bid meeting and the date on which sealed bids are to be submitted. Ideally, the project documents, including the drawings and specifications, should be distributed to all the bidders before the date of the pre-bid conference to allow each bidder the opportunity to review the documents. A written record or meeting minutes of the conference should be maintained by a designer along with any changes (addenda) to the contract documents and distributed to all parties in a timely manner following the meeting and well in advance of the bid deadline.

In summary, a pre-bid conference, if conducted properly, can result in more accurate bidding and fewer change orders during construction, as well as a more thorough understanding of the project.

## **4. Pre-job Conference**

Once a project has been awarded, NRCA recommends a pre-job conference be held for waterproofing projects. This conference should be attended by the owner, architect/engineer or designer, general contractor, site contractor, waterproofing contractor, consultant, inspector or quality assurance supervisor, wall/slab/deck contractor, mechanical contractor and any others whose work may interface with or affect the waterproofing project. The conference should be scheduled well in advance of any wall/slab/deck completion and before ordering materials and beginning work. If a manufacturer’s guarantee or warranty is specified, representatives from the primary waterproofing material manufacturer(s) should be present. A written record should be made of the proceedings from this meeting and should become a part of the job record. If a waterproofing contractor or waterproofing materials manufacturer discovers problems during inspection of a wall/slab/deck, a second pre-installation inspection attended by the affected parties

should be held to verify corrective measures have been taken.

A designer's specifications, plans, and all waterproofing and flashing details should be reviewed at the pre-job conference. Any discrepancies between the designer's contract documents and manufacturer's specifications should be discussed and resolved. In the event that certain discrepancies arise, the manufacturer's representative should be consulted to assist in resolving the issue. Any known building code or architectural directives that conflict with these requirements should be resolved.

NRCA recommends the directives listed below be followed to ensure a successful pre-job conference:

- Review approved submittals for the waterproofing system.
- Establish trade-related job schedules and appropriate trade coordination and sequencing including appropriate curing times; timely installation of any penetrations, attachments, equipment, overburden and/or protection to avoid or limit traffic on the waterproofing membrane.
- Establish construction schedules and work methods that will prevent damage to a waterproofing system. These may include provisions for installation of a temporary waterproofing system or temporary waterproofing surface protection devices, such as plywood. Installation of traffic paths or walkways helps protect a finished waterproofing system from foot traffic and mechanized construction equipment. And establish who will be responsible for costs to repair damage to a waterproofing system.
- Coordinate all appropriate walls, curbs, drains and other penetrations before installation of the waterproofing system. Where future penetrations are to be added, it is recommended to install a "link seal" detail or a similar detail to accommodate installation of future penetrations.
- Establish those areas on the job site that will be designated as access, staging, work, storage and disposal areas.
- Establish suitable weather conditions and working temperature parameters to which all parties should agree.
- Establish provisions for on-site surveillance after waterproofing system application is completed to ensure the finished waterproofing system is not damaged by other trades, and if damage does occur, proper repairs are performed in a timely manner.
- Establish provisions for responsibility of costs for repairs to the waterproofing system in the event that damage does occur.
- Establish safety regulations and safety requirements, including considerations for safety of workers.
- Establish quality-assurance requirements and procedures, including the level of authority to be granted to quality-assurance personnel to direct changes in the work.
- Establish water testing requirements and procedures, and designate a party responsible for signing off after successfully water testing the completed waterproofing membrane.
- Establish a time line for proper back filling.
- Establish the need for appropriate waterproofing personnel to be on-site when overburden is placed on waterproofing in case of damage.
- Establish a quality-control and inspection process and establish who is responsible for it.
- Establish guidelines for inspection and repair of the wall/slab/deck, including identifying the parties who are responsible for inspection and repair.
- Establish procedures for the submittal process.

At the conclusion of the pre-job conference, the party requesting any proposed changes to the project conditions or waterproofing system should:

- Give written notice of the desired changes to all parties.
- Secure written agreement to the changes from the project designer, owner and all other parties affected by the change.

A pre-job conference checklist is provided in the Appendix.

## **5. Material Storage and Handling**

NRCA recommends the following for the storage and handling of materials:

- All waterproofing materials that are susceptible to retaining moisture or may be damaged by moisture should be stored in a dry location.

- When moisture-sensitive materials are stored outside, they should be placed on pallets or platforms that are raised off the ground. Materials sensitive to moisture should be covered with water-resistant coverings that have been properly secured. Coverings that are “breathable,” such as water-resistant canvas tarpaulins, are preferred.
- Roll materials should be stored on end to prevent rolls from becoming deformed or damaged. Single-ply sheet materials may be stored as shipped with rolls laying horizontally or as recommended by the manufacturer. When storing waterproofing materials on a deck surface, caution should be taken not to overload the deck or structural assembly.
- Bitumen may be stored unprotected from weather on the ground. However, moisture, dirt, snow and ice should be removed from bitumen before it is heated.
- Lids should be secured on cans of stored material.
- Water-based materials such as asphalt emulsions, acrylic coatings and water-based adhesives should be protected from freezing.
- Solvents, adhesives, foam components and sealants should be stored at proper temperatures.
- Insulation materials should be stored and handled with care. When insulation is required to be dry at the point of installation, it is imperative insulation materials be protected from weather and moisture absorption. Some insulation materials are extremely light and must be weighted in storage to prevent wind damage, and some materials may need to be protected from UV radiation.

## **6. Temporary Waterproofing System**

Frequently, building construction sequencing leads to pressure for the installation of waterproofing materials during unsuitable weather conditions or ahead of the construction schedule. This can be an issue for many types of waterproofing projects but is most likely to be an issue for waterproofing projects above habitable spaces or for those that can be used as work platforms or staging area for other trades, such as plaza deck waterproofing. As an effective means of addressing the problems caused by construction scheduling, a temporary waterproofing system installation may be necessary. A temporary waterproofing system facilitates the application of the specified waterproofing system during more suitable weather but allows other trades to complete their work before the permanent waterproofing system is installed. Thus, other trades may stay on schedule, completing their work under the protection of the temporary waterproofing, and other trade traffic is limited from potentially damaging the finished waterproofing system.

If a temporary waterproofing system is to be employed, NRCA recommends the specifications clearly state a temporary waterproofing system will be required, the type and specification of temporary waterproofing system to be used, and whether the temporary waterproofing is to remain in place as part of the permanent waterproofing assembly. If it is to remain in place, the temporary waterproofing system must be compatible with the permanent waterproofing system.

## **7. Weather Considerations**

The performance of a waterproofing system is dependant upon adhesion of a membrane to a suitable substrate; consequently, weather conditions play an important factor in the successful installation of a waterproofing system. A waterproofing contractor is vitally concerned with the limitations imposed on construction activity by the weather. To satisfy construction schedules and cope with the limitations imposed by weather, a designer, general contractor and waterproofing contractor should consider the following guidelines for the application of waterproofing materials during various weather conditions.

### **7.1 Cold Temperatures**

It is recommended that waterproofing materials that have a temperature sensitivity not be applied unless correct solvent, adhesive, heat-welding or bitumen-application temperatures can be maintained. For bituminous waterproofing work, the heating and application of hot bitumen should conform to the manufacturer's recommendations. If proper application temperatures cannot be maintained, waterproofing system application should cease.

Hot bitumen must not be allowed to cool substantially before placing membrane reinforcing in the bitumen. Depending on the cold-weather flexibility properties of certain modified bitumen materials, prewarming and unrolling them in cold weather should be executed per manufacturer's instructions. Moisture must not be allowed to condense or freeze or frost allowed to form on adhesives and solvents before bonding or welding takes place. Heat welders must be maintained at proper temperatures to provide complete, permanent welds. When installing heat-fused modified bitumen membranes in cold temperatures, equipment temperature and application rate should be adjusted to achieve thorough membrane adhesion. Concrete decks can remain excessively cold, which could have an adverse affect on the placement of the membrane and/or waterproofing system. Care must be taken to minimize material damage from the construction process during cold weather.

## **7.2 Hot Temperatures**

Hot temperatures and/or conditions of high humidity also present challenges to maintaining proper application conditions for bitumens, certain solvents, adhesives and membrane-welding equipment. In hot weather, bitumen will cool more slowly, which can lead to sticking, making the membrane susceptible to physical damage from the construction process, equipment and foot traffic. Hot weather combined with construction activity can also lead to damage of certain materials. Hot weather also cures or evaporates solvents and adhesives more quickly, which can impair solvent welding, bonding and long-term adhesion. Humidity levels may also impair the welding, bonding and/or adhesion of various products. Heat welders must be properly adjusted and monitored so as not to scorch, burn or overheat materials. Concrete decks can retain an excessive amount of heat, which could have an adverse affect on the placement of the membrane and/or waterproofing system.

## **7.3 Wind**

Wind can affect the application of waterproofing materials in many ways. Hot materials may be blown about, creating safety issues. Spray-applied liquid materials, such as adhesives and coatings, can become airborne in the wind and cause damage to surrounding property or affect the quality of the application—masking or overspray protection may be required. During even low winds, handling membrane sheet materials may become difficult and dangerous. Wind may affect proper application temperatures and curing of materials. Insulation boards, sheathing and other relatively large, bulky materials may become difficult and hazardous to handle. Debris may become airborne and can contaminate laps, seams and fluid-applied membranes.

## **7.4 Precipitation**

Waterproofing materials should not be installed if water, frost, snow or ice is present on an area under construction. Materials that can be adversely affected by these elements include various wall/slab/deck materials, membranes, flashings, sealants and coatings. NRCA recommends most materials for waterproofing systems should not be installed if precipitation of any kind is occurring or is imminent unless the area is adequately protected. After moisture has been present on the substrate, it is advisable to run an adhesion test to determine whether the membrane will properly adhere to the substrate.

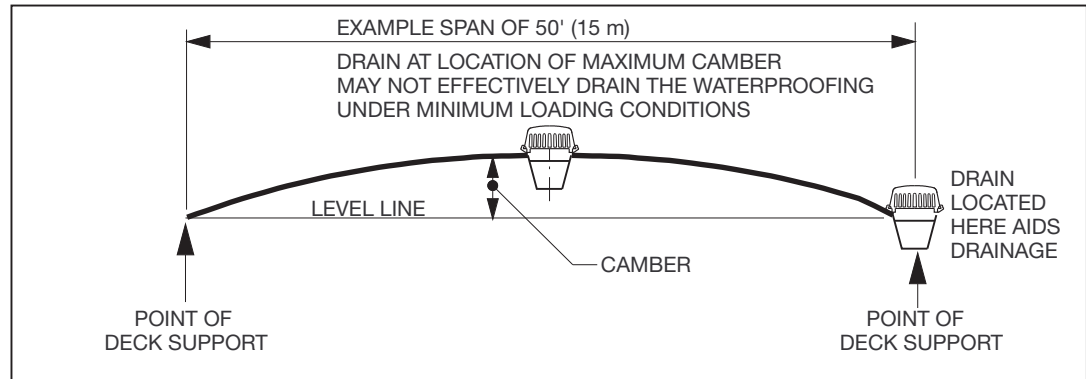
## **8. Wall/Slab/Deck and Structural Design Considerations**

Along with other factors, a successful waterproofing application depends on a structurally sound wall, slab or deck. To ensure the construction of a structurally sound wall, slab or deck, provisions for the following items should be included in a building's structural design and in the design of a wall, slab or deck:

- Live loads, such as snow, ice, and rain
- Construction loads, such as moving installation equipment, workers and materials; some construction loads, such as roller dollies used to transport single-ply materials, can exceed 600 pounds (272 kg) in quite small areas
- Dead loads, such as mechanical equipment, duct work, piping, or conduit such as fire sprinkler and electrical lines
- Dead loads, such as a waterproofing system, soil overburden, concrete toppings, pavers and water that is retained
- Deck strength (gauge, density, type and thickness)
- Expected deflection
- Drainage
- Placement of expansion joints
- Placement and structural support of curb and penetration members and details
- Attachment or securement provisions for a deck
- Suitability for adhesion/attachment of waterproofing membrane
- Suitability for water test loads

A structurally sound wall, slab or deck should remain rigid so as not to deflect excessively under live loads. It should be understood that a waterproofing contractor can only inspect the surface of a wall, slab or deck to receive the waterproofing materials and cannot assume responsibility for the wall, slab or deck's slope, structural integrity, method of attachment, or any other conditions beyond his control or professional expertise.

Figure 1: Example of deck camber where a drain located at midspan may not provide drainage.



## 9. Surface Inspection

Before applying waterproofing materials, it is recommended that a waterproofing contractor, with the appropriate parties, make a visual inspection of a substrate surface to verify it is clean, dry, smooth and ready for waterproofing system application. A wall, slab or deck should be brush- or broom-clean, reasonably smooth, free of voids or depressions, and adequately attached. This inspection should be attended by the waterproofing contractor, material manufacturer and all the appropriate parties, such as the general contractor, wall/slab/deck contractor, architect/engineer or designer, and owner's representative. All visible defects in the wall/slab/deck should be noted, and corrections should be made before beginning waterproofing work. It is recommended that the contractor who is responsible for defects or damage to the wall/slab/deck be responsible for the repairs. NRCA recommends project specifications clearly define this responsibility.

## 10. Slope and Drainage

NRCA recommends all horizontal waterproofing systems over habitable spaces be designed and built to provide positive drainage. For horizontal waterproofing systems over habitable spaces, NRCA recommends that a drainage layer be installed to facilitate the movement of water. For vertical waterproofing systems, NRCA recommends the use of a drainage layer tied to a drainage system (installed by others) at the base of the waterproofing system to relieve hydrostatic pressure.

Because every waterproofing project has its own set of drainage criteria, the designer is responsible for including proper drainage provisions in the waterproofing system design.

For horizontal waterproofing systems over habitable spaces, a designer should specify a minimum 1/8:12 (0.6-degree) slope or greater and should make provisions in the design for complete positive drainage. To achieve the necessary slope throughout the entire surface area, a designer should consider the following:

- Structural framing for the deck
- Deck type and its characteristics
- Overburden/topping material
- Type of membrane specified
- Penetration locations
- Varying deck deflections
- Building and deck layout
- Flashing termination heights

Certain decks, such as precast concrete decks or long-span prestressed concrete decks, may incorporate camber in anticipation of future loading conditions. The camber must be considered in the design of the slope and drainage system. Depending on the structural design of a deck or slab system and placement of drains, the camber may assist or restrict drainage. See Figure 1.

This example illustrates that the computations for slope should be determined by the deflections expected in each particular slab/deck.

NRCA recommends that a designer consult the local building code of jurisdiction regarding the required slope, primary drainage and secondary (overflow) drainage for each project. Building codes dictate the number of drains, size of drain pipes and plumbing accessories, and the need for secondary drainage systems. Design information for drainage is found in the plumbing section of the applicable building code.

Primary drains and overflows are typically installed at the same level as the waterproofing membrane's surface. For all waterproofing systems, it is recommended that a protection course be installed between the waterproofing membrane and any overburden. The drainage course may also act as a protection course. For horizontal waterproofing systems, the drainage course is suggested to promote the movement of water under topping slabs, wearing course, etc. to promote the movement of water to relieve hydrostatic pressure.

See the Waterproofing Construction Details section of this manual for specific waterproofing details.

## **11. Expansion Joints and Control Joints**

Expansion joints and control joints are used to minimize the effects of stresses and movements of a building's components and prevent these stresses from splitting, buckling/ridging or damaging a waterproofing system. Expansion joints in a waterproofing assembly, which includes a waterproofing membrane and wall/slab/deck, should be placed in the same location as the building's structural expansion joints. Each of a building's components has varying coefficients of expansion, and each is subjected to varying temperature changes and resultant thermal movement. In the design and placement of waterproofing expansion and control joints, it is recommended a designer consider:

- Thermal movement characteristics of a building
- Structural supports and wall/slab/deck
- Waterproofing system
- Climatic conditions
- Proper detailing

## **12. Curbs and Penetrations**

NRCA recommends curbs and penetrations be flashed into the waterproofing membrane. The designer should properly detail penetrations for drains, piping, conduit, equipment supports, and other projections or penetrations. Where future penetrations are to be added, it is recommended to install a "link seal" detail or a similar detail to accommodate installation of future penetrations.

The maximum amount of space (for horizontal and vertical applications) should be provided between pipes, walls and curbs to facilitate proper installation of waterproofing materials. NRCA recommends a minimum 12 inches (300 mm) of clearance between pipes, a minimum 12 inches (300 mm) of clearance between pipes and curbs or walls, and a minimum 12 inches (300 mm) of clearance between curbs and curbs or walls. Waterproofing systems have different installation methods that may require different spacings, and certain project conditions may not allow these recommended clearances. However, adequate space (i.e., clearance) is required for a mechanic to properly install the required flashings at penetrations.

NRCA recommends penetrations through a waterproofing system not be located so they restrict the flow of water. Pipe clusters are not recommended because of the difficulty to properly flash them to a waterproofing membrane.

All curbs, wood blocking, penetrations, drains and drain leaders should be firmly anchored and in place before installation of a waterproofing system. All openings for penetrations should be cut through the deck and the opening filled with compatible material before installation of a waterproofing membrane.

Vibrations from surface-mounted mechanical equipment should be isolated from a waterproofing membrane and flashings. It is recommended that condensate water from mechanical equipment not be discharged onto an elastomeric traffic coating's surface. The installation of drainage piping is encouraged to direct equipment discharge water directly to drains.

Heavy loads, such as large mechanical units, should not be wheeled or rolled over a completed waterproofing membrane because they may cause damage to the waterproofing assembly. Protection boards should be installed if work is required over a completed waterproofing membrane before installation of a topping slab. After the work is completed, the temporary protection should be removed and any damage repaired and water tested. Where topping slabs or other paver systems are not used, use of a traffic bearing waterproofing membrane is recommended. See the Waterproofing Construction Details section of this manual for specific waterproofing details.

## **13. Waterstops**

Waterstops are devices installed at the intersection of cold joints in concrete walls and slabs, walls and footings, or at vertical joints in concrete work. Waterstops are a secondary means of protection against water infiltration. Waterstops are typically fabricated from a variety of materials such as bentonite and treated rubber and are installed before placement of concrete. There are waterstops available that use tubes and injectable foam and are used as secondary systems. These are used where leaks would be critical and are anticipated.

The surface on which a waterstop is installed should be relatively smooth and free from sharp edges. The designer should indicate the location of the waterstops within the cold joint and which party is responsible for installation of waterstops. Placement is critical—waterstops should not be placed too closely to the edge of concrete walls. Waterstops require a minimum 2 inches (50 mm) of concrete cover. The swelling of a waterstop can damage the concrete. See the Waterproofing Construction Details section of this manual for installation details.

## **14. Flashings**

The most vulnerable part of a waterproofing system for water entry is the point at which horizontal and vertical surfaces intersect, including penetrations. Designers should carefully design all flashing details.

Flashings and membranes are subject to differential horizontal-to-vertical movement and can separate from their substrate, tear, and can become a source for water entry into the waterproofing system and/or building interior. This can cause wrinkling and buckling, delamination and loss of adhesion.

NRCA recommends designers develop flashing details that can accommodate movement at horizontal-to-vertical conditions at walls, slabs and decks. This condition may occur where walls, slabs and decks are not attached to each other or fixed-in-place.

There are two types of flashings for waterproofing: membrane base flashings and sheet-metal counterflashings.

### **14.1 Membrane Base Flashings**

Membrane base flashings are generally composed of strips of compatible membrane materials used to flash horizontal-to-vertical intersections and/or transitions. NRCA recommends the height of a base flashing be a minimum of 4 inches (100 mm) above the surface of the topping material. Where no topping materials are used (e.g., surface-applied traffic-bearing waterproofing systems), NRCA recommends the height of the base flashing be a minimum of 4 inches (100 mm).

Membrane base flashings should be adhered to the substrate to prevent displacement and/or slippage. Depending on the type of waterproofing system, termination of the system may vary. Some systems require securing or fastening by termination bars or other appropriate mechanical fastening devices approved by the membrane manufacturer. When phasing is required, other parties, such as the general contractor, should be responsible for protection of the exposed waterproofing system or leading edge before completion of the flashing system.

The installation of fillets at membrane base flashings to accommodate horizontal-to-vertical plane change is consistent with good waterproofing practice when using bituminous waterproofing membranes. Most thermoset and thermoplastic waterproofing systems are capable of accommodating 90-degree angle changes and do not require the use of fillets.

### **14.2 Sheet-metal Counterflashings and Terminations**

When the waterproofing base flashings are subject to UV exposure, sheet-metal counterflashings should be installed to cover the top edge and overlap the upper portion of membrane base flashings. In lieu of sheet-metal counterflashings, some other means of protecting the membrane flashing from UV exposure and physical damage is needed. However, some waterproofing systems do not require counterflashing to protect them from UV exposure.

Sheet-metal counterflashings also provide a means of mechanical termination for waterproofing flashings. However, some waterproofing systems are self flashing and do not require mechanical terminations or counterflashings.

Sheet-metal counterflashings should be installed into or on the wall above the base flashing. NRCA suggests the design of counterflashings consist of separate reglet and counterflashing pieces, allowing installation of the sheet-metal counterflashing after the membrane base flashing is complete. Projects where single-piece counterflashings have been installed will require removal and replacement of the metal flashing during future maintenance operations.

When precast walls are used, a designer should carefully consider the flashing provisions required to properly interface the waterproofing to the precast wall units. Cast-in raggles or reglets frequently used for this purpose are difficult to align. When they are not horizontally aligned, they hinder the proper installation of sheet-metal reglets and counterflashing components. For this reason, the use of cast-in raggles or reglets is not recommended. Also, where counterflashings span vertical panel-to-panel joints, the interfaces of counterflashings and panels with sealants are difficult to waterproof. In these situations, consideration should be given to camber, and the independent thermal movement of the walls, waterproofing membrane and flashings. Because metals have thermal expansion and contraction characteristics that differ from most waterproofing membranes, it is advisable to isolate metal flashings from the waterproofing membrane and flashing when possible.

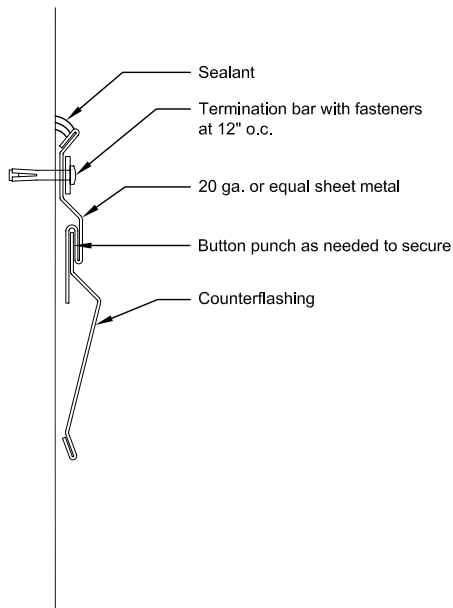


Figure 2: Surface-mounted reglet with removable counterflashing

## 15. Overburden

Consideration should be given to the selection of the overburden and the components above a waterproofing membrane. Protection board, insulation, drainage layers and overburden are installed on top of a waterproofing membrane. The selection of the overburden is a significant part of an overall waterproofing system. For concrete overburden, steel rebar, wire mesh, etc. should not come in direct contact with a waterproofing membrane as damage to the membrane can occur during placement and screeding operations. The overburden should not be above the top edge of waterproofing flashing terminations unless it is a soil topping. The components above a waterproofing membrane should all be compatible and be compatible with the waterproofing membrane.

Accessory items, such as electrical conduits, irrigation lines, piping, etc. should not be attached to a waterproofing system.

## 16. Quality Assurance and Water Tests

Continuous visual inspection during waterproofing system application provides a complete and meaningful means of examining workmanship practices. If part-time inspections are performed, the inspections should occur at the beginning and end of significant phases and when other construction trade's work may affect the performance of the waterproofing system. The quality-assurance representative's responsibilities should be clearly defined to ensure complete understanding of expectations of materials to be installed, installation methods and definition of deficiencies with appropriately defined corrective actions. The representative should, in a timely manner, provide a contractor with copies of all reports prepared for an owner and should orally inform the contractor's field personnel of locations of items requiring corrective action.

Quality assurance by the owner should continue after completion of the waterproofing installation until all overburden work is completed.

Before installation of overburden, a water test is conducted to evaluate whether a waterproofing system (but not a dampproofing system) is leak-free under hydrostatic (e.g., standing water) and/or non-hydrostatic conditions (e.g., flowing water). A water test is conducted in one of two ways.

- A water test is conducted by temporarily plugging or otherwise closing any deck drains and erecting temporary dams where required to retain water on the surface of the waterproofing material, then flooding the surface to a maximum depth of 2 inches (50 mm) at the high point and retaining the water for a minimum of 24 hours or as required by the manufacturer.
- A water test is conducted by applying continuously flowing water over the waterproofing membrane's surface for a minimum of 24 hours or as required by the manufacturer without closing drains or erecting dams.

Selecting the correct water test depends on the structural capacity of the deck/substrate and the slope of the deck/waterproofing system. However, job-site conditions may dictate the methodology of each project's water test. Decks without significant slope (e.g., a plaza deck) can be water tested using a flood test or a flowing water test.

Decks with significant slope (e.g., a parking garage ramp) can be water tested using a flowing water test. Determining the structural capacity of the deck is the responsibility of the designer.

Care must be taken so the weight of water retained does not exceed the load-carrying capacity of the structural deck, and the height of the water does not exceed the height of the lowest flashing. The water should be allowed to remain on the waterproofing membrane for a minimum 24 hours for the flood test or for the flowing water test or as required by the manufacturer, after which the areas beneath the membrane should be inspected for leaks. If leaks are detected, the test should be stopped, repairs made to the membrane and the area retested. The protection course should be installed over the tested area after successfully completing the water test unless a protection course is an integral part of the waterproofing system. The water test documents the performance of the waterproofing membrane before placement of overburden or topping material.

This information and a sample water test verification form are located in the Appendix.

## **17. Post-installation Considerations**

After a waterproofing system has been installed, the waterproofing contractor and the general contractor should advise the appropriate parties of their need to provide surveillance and protection of the waterproofing system until the protection course, overburden and topping slab are installed; or until the backfill is installed and compacted; or during the remainder of the construction period if a topping slab is not used or if a traffic-bearing membrane is used. Accessory items, such as electrical conduits, irrigation lines, piping, etc. should not be attached to a waterproofing system. Damage to a waterproofing system caused by other trades is a major source of subsequent waterproofing problems. Construction traffic, staging, other trades' work, debris and contaminants should be kept off a finished waterproofing system. Damage can be difficult to discover, and leaks or points of water entry into the waterproofing system can remain undetected for an extended period of time, which can lead to further problems, such as structural degradation. Where construction damage is anticipated, the use of a temporary waterproofing system should be considered before a project begins.

## **18. Warranties**

The length of a waterproofing system warranty should not be primary in the selection of a waterproofing product or waterproofing system because the warranty does not necessarily provide assurance of satisfactory waterproofing system performance. The selection of a waterproofing system for a particular project should be based upon the product's qualities and suitability for the prospective construction project. A long-term warranty may be of little value to a consumer if the waterproofing system does not perform satisfactorily and the owner is plagued by leaks. Conversely, if a waterproofing system is well-designed, well-constructed and well-manufactured, the expense of purchasing a warranty may not be necessary.

Warranty documents often contain restrictive provisions that significantly limit the warrantor's liability and consumer's remedies in the event that problems develop. The warranty document may also contain other restrictions and limitations, such as a preclusion against assignment or transfer of the warranty, exclusion of damages resulting from a defective waterproofing system and inclusion of monetary limitations. It is NRCA's position that the removal of overburden, protective toppings, equipment, etc., that are not strictly part of the waterproofing system are the responsibility of others. A waterproofing contractor and waterproofing material supplier are not responsible for removing any overburden of any kind installed by others placed over the waterproofing membrane, including slabs, pavers, equipment, machinery, etc. It is recommended to consult the respective manufacturers for warranty clarification.

## **19. Building Owner Recommendations**

Building owners should file all job records, drawings, specifications and the water test verification form for future reference. They should record maintenance procedures as they occur.

The following statements should be included in an owner's maintenance program:

- Bag and remove debris from the waterproofed area because debris left in areas around drains may be swept toward drains and may clog drains.
- Notify the waterproofing contractor immediately upon discovery of a waterproofing leak.
- Note conditions resulting in leakage.
- Note whether the leak starts immediately after rain begins, stops shortly after rain stops or continues to leak until the waterproofing is dry. All associated facts enable the diagnosis and repair of waterproofing problems to proceed more rapidly.

- Do not allow the installation of new penetrations through a completed waterproofing system without consulting with the waterproofing contractor and membrane manufacturer (if the waterproofing system is under a manufacturer's warranty) about the methods and details for these installations.
- When future penetrations are added, penetrations should be installed in the previously installed "link seal" detail or similar detail.

## **20. Appendix**

### **20.1 Waterproofing Contractor Qualification Form**

#### **20.2 Pre-job Conference Checklist**

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## WATERPROOFING CONTRACTOR QUALIFICATION STATEMENT

(Note: This document is presented in the format of AIA Document A-305)

The undersigned certifies under oath the truth and correctness of all statements and of all answers to questions made hereinafter.

**Submitted To:** \_\_\_\_\_

**Company:** \_\_\_\_\_

**Address:** \_\_\_\_\_

**Submitted By:** \_\_\_\_\_

**Company:** \_\_\_\_\_

**Address:** \_\_\_\_\_

**Telephone:** ( ) \_\_\_\_\_ **Fax:** ( ) \_\_\_\_\_

**Principal Office:** \_\_\_\_\_

### I. ABOUT YOUR COMPANY

1.0 What is your form of business organization?

\_\_\_ C-Corporation \_\_\_ S-Corporation \_\_\_ LLC \_\_\_ Partnership \_\_\_ Sole Proprietorship

1.1 Please answer the following depending on your company's business organization:

#### Corporation

Date of incorporation: \_\_\_\_\_

State of incorporation: \_\_\_\_\_

President's name and years of waterproofing industry experience: \_\_\_\_\_

Vice president's name and years of waterproofing experience: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Secretary's name and years of waterproofing industry experience:

\_\_\_\_\_

\_\_\_\_\_

Treasurer's name and years of waterproofing industry experience:

\_\_\_\_\_

\_\_\_\_\_

1.2 If other than a corporation, sole proprietorship or partnership, describe the type of company and name the principals.

\_\_\_\_\_

1.3 How many years has your company been in business as a waterproofing contractor? \_\_\_\_\_

1.4 How many years has your company been in business under its present name? \_\_\_\_\_

1.5 Under what other or former names has your company operated? \_\_\_\_\_

1.6 Please list any trade association membership(s) that your company holds, along with the number of years the membership(s) has been held. \_\_\_\_\_

\_\_\_\_\_

1.7 List states and categories in which your company is legally qualified to do business. Indicate registration or license numbers, if applicable. List states in which partnership or tradename is filed.

State	Category	Registration/license #	State of partnership/ trade name
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

## II. ABOUT YOUR WORK

2.1 What kind of waterproofing work does your company perform? Check all that apply.

Below Grade     Plaza Deck     Green Roofs     Traffic Coatings     Injection Repair

2.2 Does your company perform all waterproofing work in house?    \_\_\_\_yes    \_\_\_\_no

If no, please explain. \_\_\_\_\_  
\_\_\_\_\_

2.3 What is your company policy concerning on-site supervision of work and internal quality control procedures?

\_\_\_\_\_  
\_\_\_\_\_

2.4 Has your company ever failed to complete work awarded to it?    \_\_\_\_yes    \_\_\_\_no

If yes, please explain. \_\_\_\_\_

2.4.1 Within the past five years, has any officer or partner of your company ever been an officer or partner of any other company when it failed to complete a waterproofing contract?    \_\_\_\_yes    \_\_\_\_no

If yes, explain when, where and why. \_\_\_\_\_  
\_\_\_\_\_

2.5 Have you or your company ever filed for bankruptcy?    \_\_\_\_yes    \_\_\_\_no

If yes, please explain. \_\_\_\_\_  
\_\_\_\_\_

2.6 What is your company's experience modification rate (EMR) for worker's compensation insurance during the past three years?

EMR—last year: \_\_\_\_\_ State: \_\_\_\_\_

EMR—previous year: \_\_\_\_\_ State: \_\_\_\_\_

EMR—previous year: \_\_\_\_\_ State: \_\_\_\_\_

2.7 Does your company handle projects involving the removal of asbestos-containing waterproofing materials?

\_\_\_\_yes \_\_\_\_no Installation? \_\_\_\_yes \_\_\_\_no

2.8 Is your company currently involved in litigation? \_\_\_\_yes \_\_\_\_no

If yes, please explain. \_\_\_\_\_

Do you subcontract any work listed above? \_\_\_\_yes \_\_\_\_no

If yes, please explain. \_\_\_\_\_

### III. ABOUT YOUR REFERENCES

3.0 Please list trade references. \_\_\_\_\_

\_\_\_\_\_

3.1 Please list bank references. \_\_\_\_\_

\_\_\_\_\_

3.2 Please provide the names of your bonding company along with the name and address of your agent.

\_\_\_\_\_

3.3 Please list manufacturers with which your firm has licensed applicator agreements.

\_\_\_\_\_

4.0 Dated in \_\_\_\_\_ this \_\_\_\_\_ day of \_\_\_\_\_ 20\_\_\_\_\_

\_\_\_\_\_  
(Name of organization)

\_\_\_\_\_  
(by) (Title)

5.0 \_\_\_\_\_ being duly sworn deposes and says that he/she is the \_\_\_\_\_ of \_\_\_\_\_ and that answers to the foregoing questions and all statements therein contained are true and correct.

5.1 Subscribed and sworn before me this \_\_\_\_\_ day of \_\_\_\_\_ 20\_\_\_\_\_

NOTARY PUBLIC: \_\_\_\_\_ My commission expires: \_\_\_\_\_



## Pre-job Conference Checklist

NRCA recommends the directives listed below be followed to ensure a successful pre-job conference:

- Review approved submittals for the waterproofing system.
- Establish trade-related job schedules and appropriate trade coordination and sequencing, including appropriate curing times; timely installation of any penetrations, attachments, equipment, overburden and/or protection to avoid or limit traffic on the waterproofing membrane.
- Establish construction schedules and work methods that will prevent damage to a waterproofing system. These may include provisions for installation of a temporary waterproofing system or temporary waterproofing surface protection devices, such as plywood. Installation of traffic paths or walkways helps protect a finished waterproofing system from foot traffic and mechanized construction equipment. And establish who will be responsible for costs to repair damage to a waterproofing system.
- Coordinate all appropriate walls, curbs, drains and other penetrations before installation of the waterproofing system. Where future penetrations are to be added, it is recommended to install a “link seal” detail or a similar detail to accommodate installation of future penetrations.
- Establish those areas on the job site that will be designated as access, staging, work, storage and disposal areas.
- Establish suitable weather conditions and working temperature criteria to which all parties should agree.
- Establish provisions for on-site surveillance after waterproofing system application is completed to ensure the finished waterproofing system is not damaged by other trades, and if damage does occur, proper repairs are performed in a timely manner.
- Establish provisions for responsibility of costs for repairs to the membrane waterproofing system in the event that damage does occur.
- Establish safety regulations and safety requirements, including considerations for safety of workers.
- Establish quality-assurance requirements and procedures, including the level of authority to be granted to quality-assurance personnel to direct changes in the work.
- Establish water testing requirements and procedures, and designate a person responsible for signing off after successfully watertesting the completed waterproofing membrane.
- Establish a time line for proper back filling.
- Establish the need for appropriate waterproofing personnel to be on-site when overburden is placed on waterproofing in case of damage.
- Establish a quality-control and inspection process and establish who is responsible for it.
- For waterproofing projects, establish guidelines for inspection and repair of the wall/slab/deck, including identifying the parties who are responsible for inspection and repair.
- Establish procedures for the submittal process.

At the conclusion of the pre-job conference, the party requesting any proposed changes to the project conditions or waterproofing system should:

- Give written notice of the desired changes to all parties.
- Secure written agreement to the changes from the project designer, owner and all other parties affected by the change.

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## **1. INTRODUCTION**

The Waterproofing and Dampproofing Guidelines section of *The NRCA Roofing and Waterproofing Manual* is written to provide in-depth technical information concerning the design and installation of quality waterproofing and below-grade dampproofing systems.

Waterproofing and dampproofing practices vary considerably in different parts of North America because of the variety of conditions that exist and the various materials that are available for use. Many times, waterproofing and dampproofing systems are essentially customized, meaning they are designed for specific structures and applied on job sites. Adherence to the practices outlined in this manual is an option of each contracting firm. Area practices and the time-proven methods employed by individual firms are frequently given priority over these recommended general procedures.

*The NRCA Waterproofing Manual* defines waterproofing and dampproofing as follows:

- Waterproofing: treatment of a surface or structure to prevent the passage of water under hydrostatic conditions
- Dampproofing: treatment of a surface to resist the passage of moisture in the absence of hydrostatic conditions

A waterproofing assembly consists of a substrate and a membrane and may incorporate a protection/drainage/insulation layer. Horizontal waterproofing assemblies often incorporate a topping or wearing surface for additional protection and/or aesthetic reasons.

Waterproofing systems can be divided into two primary categories: positive side and negative side, which are defined as follows:

- Positive (exterior) side waterproofing systems: a category of waterproofing systems where the waterproofing membrane/layer is installed between its substrate and the source or supply of water.
- Negative (interior) side waterproofing systems: a category of waterproofing systems where the substrate is between the waterproofing system and the source of water.

The types of waterproofing systems discussed in *The NRCA Roofing and Waterproofing Manual* are:

- Asphalt Built-up Membrane
- Coal-tar Built-up Membrane
- Hot-fluid-applied Polymer-modified Asphalt Membrane
- APP and SBS Polymer-modified Bitumen Sheet Membrane
- Self-adhering Polymer-modified Bitumen Sheet Membrane
- Butyl Rubber Membrane
- EPDM Membrane
- Polyvinyl Chloride (PVC) Membrane
- One- and Two-component, Fluid-applied Elastomeric Materials
- Bentonite Waterproofing
- Crystalline Waterproofing
- Cementitious Waterproofing
- Elastomeric Traffic Coatings

The information contained in this manual is intended to deal primarily with new construction. However, there is a section that discusses repair-type waterproofing products and replacement waterproofing situations.

Because of the wide variety of waterproofing and dampproofing products, this manual cannot address all the different methods and practices for designing and installing all the products available to designers, contractors and building owners.

In this manual, the National Roofing Contractors Association (NRCA) presents a consensus of opinions from knowledgeable, practicing waterproofing contractors throughout the United States as to the practices and procedures for good waterproofing. Where this manual provides specific suggestions or recommendations, it should be noted these may be a more conservative approach than may be commonly provided by individual product manufacturers, designers or contractors. The waterproofing design and application procedures included in this manual generally are recognized to be sound and time-proven and apply throughout the United States.

The recommendations contained in the Waterproofing and Dampproofing section of *The NRCA Waterproofing Manual* should not be construed as the only methods for designing and installing waterproofing systems. Some design criteria and application techniques vary according to climatic conditions, and some geographic areas employ “area practices” that are sound and time-proven. NRCA does not mean to imply by any statement or exclusion that time-tested and proven area practices are unsatisfactory or inappropriate. Users of this manual are encouraged to contact NRCA or NRCA members in their geographical areas for specific advice concerning area practices and current technical information.

The Waterproofing and Dampproofing section of *The NRCA Roofing and Waterproofing Manual* is composed of the following sections:

- “Introduction.” This is the introductory section to the Waterproofing section of *The NRCA Waterproofing Manual* and contains general information applicable to all waterproofing systems.
- “Waterproofing.” This section contains information regarding waterproofing design guidelines, substrates, products, accessory materials and repair materials.
- “Dampproofing.” This section contains information regarding dampproofing design guidelines and products as they relate to below-grade foundation walls.
- “Appendix.” This section contains the water test verification form.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Roofing and Waterproofing Manual*.

NRCA suggests the Waterproofing and Dampproofing section of *The NRCA Roofing and Waterproofing Manual* be used in the design of waterproofing systems only after a number of criteria have been carefully considered, including:

- Climate and geographic location
- A building’s intended use and design life expectancy
- Exterior and interior temperature, humidity and use conditions
- Code requirements
- Type and condition of substrate, including soil
- Structural system
- Slope and drainage
- Waterproofing system type including overburden
- Accessibility and building configuration
- Building movement
- Type and amount of insulation/protection/drainage needed
- Need for ventilation during installation
- Compatibility with adjacent building and/or system components
- Construction sequencing
- Worker safety
- Potential building additions
- Odors generated by certain system application methods
- Water table
- Construction traffic
- Penetrations

These criteria play important roles in the ultimate success or failure of every waterproofing assembly and must be considered by a designer to determine the appropriate components of a waterproofing assembly, applicable products and specifications, and construction details to be used.

In addition, the designer should be certain waterproofing product manufacturers’ requirements are taken into account, as well as requirements of applicable insurance, building code enforcement and/or other regulatory agencies. It is recommended to consult material manufacturers’ written specifications during the design of a waterproofing assembly.

## 2. WATERPROOFING

### 2.1 Waterproofing

Waterproofing is defined as the treatment of a surface or structure to prevent the passage of water under hydrostatic pressure. Water exerts a pressure of 62.4 pounds per square foot per foot (1,000 kg per square meter per meter) of depth because water weighs 62.4 pounds per cubic foot (lb/ft<sup>3</sup>) (1,000 kg per square meter per meter). See Table 1: Weights of Different Heights of Water. Therefore, water lying against a barrier exerts a steadily increasing pressure as the depth of the water increases. The waterproofing treatment must keep the water from penetrating into the building interior.

Water	
Depth, inches (mm)	Weight, pounds/foot <sup>2</sup> (kg/meter <sup>2</sup> )
1 (25.4)	5.2 (83.3)
2 (50.8)	10.4 (166.7)
3 (76.2)	15.6 (250.0)
4 (101.6)	20.8 (333.3)
5 (127.0)	26.0 (416.7)
6 (152.4)	31.2 (500.0)
7 (177.8)	36.4 (583.3)
8 (203.2)	41.6 (666.7)
9 (228.6)	46.8 (750.0)
10 (254.0)	52.0 (833.3)
11 (279.4)	57.2 (916.7)
12 (304.8)	62.4 (1000)

Table 1: Weights of different heights of water

Waterproofing is used to:

- Waterproof floors and walls below grade of buildings, tunnels and similar structures from the passage of ground water
- Waterproof horizontal decks over habitable spaces
- Waterproof wet spaces, such as kitchens, showers and mechanical equipment rooms from other areas of buildings
- Protect bridge decks against deterioration from deicing salts and help minimize the negative effects of moisture intrusion into the structural elements and topping materials
- Contain water or other fluids within items such as pools, planters, fountains, lagoons, irrigation trenches and dams

An understanding of the different loads and stresses placed upon the waterproofing material is important to the proper design of a structure. The following are some of the performance attributes required of waterproofing systems:

- A waterproofing membrane should perform completely trouble- and maintenance-free for an extended period of time. It is usually quite difficult, if not impossible, to excavate around the foundation walls or remove a reinforced concrete floor slab to repair or replace the waterproofing material.
- A waterproofing membrane should perform successfully in a wet environment.
- A waterproofing membrane should resist environmental contaminants, such as acids or alkalis, and other contaminants. For example, soil chemistry varies from location to location and sometimes from foot to foot of excavated depth. The material must be compatible with the soil and substrate to which it is applied. Some waterproofing materials are intolerant of certain soil salts, and others are affected by oils or other materials that could be spilled onto floors in mechanical equipment rooms.
- A waterproofing membrane must remain in place and intact until the protective wearing course can be applied or backfill installed. However, the greatest threat to waterproofing often comes from other construction trades such as backfill placement where rocks and construction debris and other sharp objects may be dumped against the waterproofing material. Even though horizontal surfaces are usually covered with a protection course, other trades often

use the waterproofed surface as a staging area or for access to adjacent work areas. This is critical for waterproofing because the waterproofing membrane is not readily accessible for repair.

- A waterproofing membrane should accommodate anticipated structural movement in the substrate to which it has been applied. Below-grade concrete and masonry structures may experience settlement and/or shrinkage as the substrate materials cure. Horizontal plaza decks experience thermal movement and load deflection. These characteristics make it necessary for the waterproofing material to be able to bridge small cracks and expand and contract to some degree without rupture or failure.

Waterproofing materials are generally concealed and often placed into a protected environment. Therefore, materials used for waterproofing may not perform successfully if used for roofing applications. The following are conditions favorable to waterproofing membranes (compared to roof membranes):

- Waterproofing membranes are subjected to limited thermal stress. Below-grade waterproofing materials are usually kept at near constant temperatures because of their contact with earth back-fill on the exterior and proximity to relatively constant interior temperatures.
- Waterproofing membranes are not exposed to direct ultraviolet radiation because they are buried in the ground, covered with a plaza deck surface or used inside a building. Sunlight and other environmental exposures cannot affect them once the building is completed.
- Waterproofing membranes are directly adhered to structural substrates. Structural decks and walls are typically dimensionally stable. When the materials are fully adhered to the substrates, water penetrating the waterproofing system cannot freely move laterally. Therefore, leaks tend to appear close to the point of moisture penetration. However, loose-laid membranes are acceptable for below-grade matt-slab conditions over compacted fill where there is upward hydrostatic pressure.
- Waterproofing membranes are protected from physical abuse. After installation, waterproofing materials are usually covered with a protection course and/or drainage course and backfill or with a permanent protection slab.

## **2.2 Drainage**

A drainage system is a system of perimeter and/or underslab drains used to relieve the hydrostatic pressure in the earth surrounding a below-grade structure.

Clearly, the most effective way to waterproof walls and floors is to remove the water from the soil before it reaches the wall or floor. Each of the waterproofing materials described in this manual is designed to resist hydrostatic pressure to varying degrees. However, the waterproof integrity of any building can be greatly improved if the hydrostatic pressure against the waterproofing material can be reduced or eliminated entirely.

In below-grade structures, the determination of whether a drainage system can be used depends upon the quantity of water that must be handled and how it is to be handled or resisted. When gravity can be used to direct water from around the building foundation into a storm sewer, greater amounts of water can be handled than when pumping must be used to lower the water table. Operating the pumps can be costly if there is a great amount of water to handle, and there is always the threat of problems if the pumps fail.

If it is determined a drainage system cannot be economically employed, the foundation floor slab must be designed with sufficient concrete mass and reinforcement to resist the uplift pressures of the anticipated water table, and the construction has to be carefully waterproofed, which can be an expensive construction process. If a drainage system can be employed, the slab on grade can be designed with only surface load considerations, thereby greatly reducing construction costs.

The decision to use a drainage system depends on a careful analysis of soil borings and water-table level readings and should be made with the input of an experienced soils or geotechnical engineer. A site with coarse, permeable soil that freely permits water percolation combined with a water-table level that is above the top of the foundation floor slab is probably an unlikely candidate for a drainage system, particularly if the water table must be lowered by pumping for construction to begin. Conversely, a site with a dense clay soil resistant to water percolation could be an excellent candidate for a drainage system even if the water-table level is considerably higher than the foundation floor slab.

### **2.2.1 Geocomposites (Drainage mat)**

Hydrostatic pressure can be relieved from perimeter walls below grade by using a coarse aggregate backfill or a pre-fabricated drainage product known as a “geocomposite.” This system channels ground water traveling toward the building down to a perimeter drainage system located below the bottom of the foundation floor slab. The drain system may be installed either at the exterior or interior perimeter of the foundation walls or both, depending on the specific type of drainage system being used. When aggregate is used to relieve hydrostatic pressure against wall

surfaces, a separate protection course must be placed against the waterproofing membrane to protect the membrane from damage during aggregate placement. Loose aggregate should not be placed directly against the waterproofing membrane. Alternatively, geocomposites relieve hydrostatic pressure and some also serve as protection for the waterproofing membrane during backfill operations.

### **2.2.2 Drains**

Consideration should also be given to relieving water pressure from the surface of horizontal suspended structural slabs, such as a plaza deck slab. When water that permeates its way through upper layers down to the membrane surface can drain freely to deck drains, the horizontal waterproofing membrane will perform better. This horizontal movement of water can be achieved by placing a suitable insulation board specially designed with drainage channels or grooves on its underside, a protection course, and a layer of aggregate or a geocomposite directly above the waterproofing membrane surface.

Deck drains that have the ability to receive water at the top surface of the overburden (e.g., concrete slab, pavers) and at the membrane level are called bi-level drains or multi-level drains. NRCA recommends the use of bi-level drains where drainage occurs at two levels. Bi-level drains typically consist of a drain bowl and clamping ring with weep holes at the membrane level and a flat-topped strainer with perforated vertical sides. The clamping ring and vertical portion of the strainer may be one piece with a removable top. The weep holes and/or perforations allow for drainage of moisture that permeates the overburden and reaches the membrane level.

## **2.3 Design Guidelines and Performance Requirements**

This section identifies certain conditions that can be expected on various building surfaces and locations that should be considered when reviewing the physical properties of various waterproofing materials. Section 2.4, Suggested List of Waterproofing Materials, identifies those materials that could be considered for use at each location. However, this information is only provided as a guide. The final decision rests with the waterproofing system designer, taking into account the various performance requirements for the particular surface and location and the materials that might meet those requirements.

When considering material selection, a designer needs to consider how the horizontal and vertical waterproofing tie together. This is a critical location to the success of the overall waterproofing system for the building and/or project.

Various building surfaces requiring waterproofing exert different loads and stresses on waterproofing materials depending on their locations in the structure. As an example, the physical properties of a waterproofing material for an exposed parking deck subject to thermal stresses, dynamic loads, and deflection, would be considerably different from those for a concrete slab on grade, where the temperature and other loads are constant. It is, therefore, necessary to anticipate loads and stresses that can occur on the building's surface and then select a material that is best suited for the project. Some waterproofing materials may function well in certain building areas and perform poorly in others.

As a general rule, waterproofing materials should be fully adhered or bonded directly to the substrate. Adhered materials are more desirable than those that are loose-laid over the substrate because they reduce the possibility of lateral water migration between the waterproofing material and substrate. If a problem occurs in the waterproofing material, it is essential the problem be confined to a localized area to expedite repairs and reduce repair costs. Although there may be relatively dry periods depending on where the material is employed and the level of ground water, waterproofing is usually in continuous contact with ground water or is retaining water, such as in a planter or pool. Water infiltrating through a breach in a loose-laid waterproofing membrane can easily migrate away from the point of penetration and leak into the structure a considerable distance from the breach. This makes locating and repairing the leak extremely difficult, time-consuming and costly. Because waterproofing materials are usually covered by subsequent construction or are buried underground, the ability to identify problem locations is important. Because of this, loose-laid waterproofing membrane materials are often too risky for a typical construction project. However, loose-laid materials may be an appropriate choice when the waterproofing is installed against the earth as would be the case in the construction of work slabs, pools, ponds, lagoons and reservoirs.

The maximum amount of space (for horizontal and vertical applications) should be provided between pipes, walls and curbs to facilitate proper installation of waterproofing materials. NRCA recommends a minimum 12 inches (300 mm) of clearance between pipes, a minimum 12 inches (300 mm) of clearance between pipes and curbs or walls, and a minimum 12 inches (300 mm) of clearance between curbs and curbs or walls. Waterproofing systems have different installation methods that may require different spacings, and certain project conditions may not allow these recommended clearances. However, adequate space (i.e., clearance) is required for a mechanic to properly install the required flashings these locations.

NRCA recommends waterproofing flashings terminate 4 inches (100 mm) minimum above a waterproofing membrane if there is no topping material and 4 inches (100 mm) above the top of the finished wearing surface or elevation and be protected by counterflashing.

### **2.3.1 Slabs in a Hydrostatic Condition**

Slabs below grade and slabs on grade are typically constructed of reinforced, cast-in-place concrete. These slabs must be structurally designed to resist the loads imposed from above (e.g., live loads) and from below (e.g., upward hydrostatic pressure). NRCA recommends all interior building slabs below grade in a hydrostatic condition receive some form of waterproofing treatment. However, slabs on grade where there is little hydrostatic pressure or little ground water may not require an extensive waterproofing treatment but may only require dampproofing or a vapor retarder. The designer should make a thorough analysis of ground-water levels and soil percolation rates surrounding the site before deciding on the use of dampproofing in lieu of waterproofing. Waterproofing generally can be applied to either side of slabs below grade or slabs on grade.

Waterproofing materials used in this location usually do not need to possess the same crack-bridging or elongation capabilities as would materials used to waterproof suspended slabs that are subject to thermal and load deflection.

The following is a list of characteristics that waterproofing materials for slabs in a hydrostatic condition should possess. The material should:

- Be compatible with adjoining waterproofing systems (e.g., at the interface of horizontal and vertical waterproofing systems)
- Function in a constantly wet environment
- Resist the contaminants (e.g., chemicals and minerals) found in the soil surrounding the site
- Be compatible with the surface to which it is installed; this may include work slabs, compacted soil and compacted gravel/drainage rock
- Resist abuse from other trades working over the material after it is installed and properly protected—protection courses generally will be required to isolate the waterproofing membrane from this traffic; even when a separate protection course is installed, a material possessing different physical strength properties will withstand construction abuse differently
- Withstand hydrostatic pressure

### **2.3.2 Walls Below Grade/Vertical Surfaces**

Walls below grade can be constructed of reinforced cast-in-place concrete, shotcrete, prestressed concrete panels, masonry or preservative-treated wood.

Foundation walls, whether of concrete or masonry (e.g., block), must be structurally designed to resist the lateral loads imposed upon them by earthen backfill and hydrostatic pressure. A geocomposite may be employed to reduce lateral earth and hydrostatic pressures. NRCA recommends building foundation walls below grade surrounding habitable spaces receive some form of waterproofing and drainage treatment. Foundations that are under high hydrostatic pressure should also have a drainage system, such as a perforated drain pipe set in an aggregate bed. A thorough analysis of ground-water levels and soil percolation rates surrounding a site should be made before selecting the waterproofing system.

Waterproofing can be applied to either the positive (exterior) or negative (interior) side of below-grade cast-in-place concrete foundation walls. At times, however, these foundations may not be accessible from the earth side because of the placement of the wall against sheeting or shoring. Waterproofing should only be applied to the exterior (earth side) of precast concrete or masonry (e.g., block) foundations.

#### **2.3.2.1 Positive (Exterior) Side Waterproofing**

For proper waterproofing installation, an adequate working space not less than that allowed by local governing or regulatory bodies is needed between the exterior face of the foundation wall and the surrounding earth. The excavation must be kept free of water. For best results, the waterproofing should be installed in lifts, typically 6 feet to 8 feet (1.8 m to 2.4 m) high, as backfill is placed and compacted. Refer to local Occupational Safety and Health Administration (OSHA) requirements for specifics regarding work practices for excavation.

The following is a list of properties that waterproofing materials should possess when applied to the exterior side of foundation walls. The material should:

- Achieve adhesion to the wall; this is essential to achieve a watertight structure
- Function in an environment that can range from damp to wet
- Resist the contaminants (e.g., chemicals and minerals) found in the surrounding soil

- Accommodate minor shrinkage and movement (e.g., expansion/contraction and/or deflection) anticipated in the design of the foundation wall
- Hold its position on the wall surface and resist exposure to environmental elements until the protection/drainage course and backfill has been placed—the backfilling operation should take place as soon as possible after the waterproofing system installation is complete; the waterproofing materials must therefore resist short-term exposure to high and low temperatures, sunlight and precipitation
- Withstand backfill and compaction operations

### **2.3.2.2 Concrete Walls Inaccessible From the Exterior (Blind-side Application)**

Where there is an inadequate workspace between a foundation wall and the surrounding earth, the best method of installing waterproofing is as follows:

- Waterproofing is installed against the sheeting or shoring before the placement of the concrete foundation walls. This waterproofing material needs the same properties as if it had been applied from the exterior side, and it must remain in place during installation of steel reinforcement, concrete forms and the concrete itself.

A less preferred method of waterproofing a wall is as follows:

- A crystalline/cementitious waterproofing system is applied to the interior side of the foundation wall after it is placed. However, if floors intersect the foundation wall, exterior side waterproofing is recommended or grouts will need to be applied at the floor lines on the interior.

Crystalline waterproofing is appropriate for rehabilitation of existing structures. However, NRCA recommends waterproofing systems should be installed on the positive (exterior) side. Positive (exterior) side waterproofing systems are best suited to prevent moisture intrusion. Crystalline waterproofing is typically a negative (interior) side waterproofing system. It typically is not used as a primary waterproofing system but can be under certain job conditions, such as a water treatment facility. It can be used as a secondary waterproofing system. In addition, crystalline waterproofing is typically appropriate as a maintenance effort to control leakage.

The following is a list of properties that waterproofing materials should possess when applied to the interior side of reinforced concrete foundation walls. The material should:

- Function in a wet to damp environment
- Be compatible with the substrate (i.e., concrete)
- Withstand hydrostatic pressure forces at the negative (interior) side
- Provide an aesthetic finish if it is exposed to view

### **2.3.3 Slabs At or Above Grade**

Suspended structural decks may be constructed of reinforced cast-in-place concrete, prestressed concrete panels or wood. These deck types are generally designed to accommodate pedestrian or vehicle traffic and often contain planters, fountains and other types of construction. The sandwich-style construction created usually consists of a structural deck, waterproofing membrane layer, insulation or protection course, drainage course (optional) and traffic-bearing finish course.

The suspended structural deck should be sloped to drain with an adequate number and type of dual-level drains. The number, sizing, type (i.e., dual level with weep holes) and placement of drains should be in accordance with the governing plumbing or building code.

The following is a list of properties waterproofing materials for slabs at or above grade should possess. The material should:

- Achieve full adhesion to the deck; this is an attribute essential for achieving a watertight structure. Adhesion prevents lateral migration of water between the underside of the waterproofing membrane and top of the deck if the membrane is damaged. If the membrane is not adhered, water from a leak can migrate to other areas of the deck.
- Function in a wet environment. Even with slope provided for drainage, water flow will be restricted by a protection course or insulation, and some localized ponding will occur at deck irregularities.
- Accommodate minor shrinkage and movement (e.g., expansion/contraction and/or deflection) anticipated in the design of the slab.

#### **2.3.3.1 Between-slab Membranes**

With these assemblies, a separate traffic-bearing finish course of some type (e.g., pedestals and pavers, concrete

slab) is installed over the completed waterproofing membrane. This same type of assembly would be employed in planters and under landscaped areas (other than green roof systems). Because the waterproofing membrane will be inaccessible, NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

The following is a list of properties waterproofing materials should possess when used with a between-slab membrane:

- The material should achieve full adhesion to the deck; this is an attribute essential for achieving a watertight structure. Adhesion prevents lateral migration of water between the underside of the waterproofing membrane and top of the deck, if the membrane is damaged. If the membrane is not adhered, water from a leak can migrate to other areas of the deck.
- The material should function in a wet environment. Even with slope provided for drainage, water flow will be restricted by a protection course or insulation, and some localized ponding will occur at deck irregularities.
- The material should accommodate minor shrinkage and movement (e.g., expansion/contraction and/or deflection) anticipated in the design of the slab.
- The protection/drainage course must resist damage before and during application of the final traffic-bearing course/landscaping.

### **2.3.3.2 Traffic-bearing Waterproofing Membranes (Surface-applied)**

With these assemblies, traffic-bearing waterproofing membranes are usually applied in liquid form directly to reinforced, cast-in-place concrete, prestressed concrete panels or plywood deck surfaces. Because these membranes provide an aesthetic, traffic-resistant finish, there is no need for a separate traffic-bearing course. This reduces the dead load on the structural deck. Being exposed to traffic, these materials do require maintenance to restore worn and weathered areas.

The following is a list of properties that traffic-bearing waterproofing membranes should possess. The membrane should:

- Achieve adhesion to the deck; loose, peeling or blistering areas compromise the skid-resistance and appearance of the membrane, as well as its waterproofing performance.
- Resist abrasion from traffic over the surface.
- Resist the contaminants (e.g., chemicals and materials) it will be exposed to in service; for example, in a parking garage, the traffic-bearing waterproofing membrane must resist items such as grease, oil, gasoline, road salt and automotive chemicals.
- Be skid-resistant, even when it is wet; these membranes are usually installed in pedestrian or vehicle-traffic areas.
- Accommodate minor shrinkage cracking, expansion and contraction, deflection and other movement anticipated in the substrate design.
- Be repairable and maintainable to preserve its waterproofing and skid-resistant functions.

### **2.3.4 Planters**

Planters are structures made from masonry, concrete or wood. Waterproofing for planters is usually applied between the masonry, concrete or wood structure and the planting material and liquid being contained. Waterproofing of planters should include sloping the base of the planter and incorporating a drainage layer to promote drainage, and it is recommended to substantially adhere the membrane to the substrate.

The following characteristics should be considered when selecting waterproofing materials for these structures. The materials must be:

- Safe for use in direct contact with planting materials (e.g., soil, fertilizer) intended to support plant life
- Be able to resist root penetration
- Resistant to and unaffected by the solid materials and liquid water it is containing and function under constant submersion and potentially high levels of hydrostatic pressure
- Able to resist the combined effects of exposure to sunlight, weather and intermittent wetting when exposed above the planting material's surface
- Compatible with and able to conform to the surfaces to which it is installed, including rough concrete walls,

masonry and work slabs

In addition, NRCA recommends the installation of planter drains with drainage ports so they can be properly maintained. Drains should include strainers and/or drainage fabric to prevent planting materials from clogging the drain and/or drain lines.

### **2.3.5 Fountains, Pools, Tanks and Water Features**

There are many kinds of structures built to contain liquids. These include structures for storing potable water and structures for holding sewage or chemicals. Some of these structures are earthen and others are made from concrete and other materials. Waterproofing for these structures is usually applied between the earthwork or surface of the structure and the liquid being contained. The following characteristics should be considered when selecting waterproofing materials for these structures. The materials must be:

- Safe for use in direct contact with liquids intended for human or animal consumption if intended for potable water containment.
- Resistant to and unaffected by the liquid it is containing and function under constant submersion and high levels of hydrostatic pressure
- Able to resist the combined effects of exposure to sunlight, weather and intermittent wetting when exposed above the contained liquid's surface
- Compatible with and able to conform to the surfaces to which it is installed, including rough concrete walls, work slabs and compacted earth

## **2.4 Suggested List of Waterproofing Materials**

### **2.4.1 Slabs Below Grade**

The following waterproofing materials are appropriate for use beneath slabs below grade where an appropriate substrate (e.g., a 4-inch- [100-mm-] thick, reinforced concrete slab) is in place before installation of the waterproofing membrane:

- Asphalt or coal-tar built-up membranes
- Hot-fluid-applied polymer-modified asphalt membrane
- APP and SBS polymer-modified bitumen sheet membrane
- Self-adhering polymer-modified bitumen sheet membrane
- Butyl or EPDM (thermoset) membranes
- PVC (thermoplastic) membrane
- Fluid-applied elastomeric materials
- Bentonite (confinement of the material is critical)
- Pre-applied (before installation of the wearing slab) sheet membrane

The following waterproofing materials are appropriate for use beneath slabs below grade where an appropriate substrate (e.g., compacted earth, nonreinforced concrete slab) is in place before installation of the waterproofing membrane:

- Bentonite (confinement of the material is critical)
- Pre-applied (before installation of the wearing slab) sheet membrane

The following waterproofing materials are appropriate for use on the interior side of slabs below grade:

- Cementitious waterproofing
- Crystalline waterproofing

### **2.4.2 Walls Below Grade**

#### **2.4.2.1 Positive (Exterior) Side Waterproofing**

The following waterproofing materials are appropriate for use as positive (exterior) side waterproofing for walls below grade:

- Asphalt or coal-tar built-up membranes
- Hot-fluid-applied polymer-modified asphalt membrane
- APP and SBS polymer-modified bitumen sheet membrane
- Self-adhering polymer-modified bitumen sheet membrane
- Butyl or EPDM (thermoset) membranes
- PVC (thermoplastic) membrane
- Fluid-applied elastomeric materials
- Cementitious waterproofing
- Crystalline waterproofing
- Bentonite (confinement of the material is critical)
- Pre-applied (before installation of the wall) sheet membrane

#### **2.4.2.2 Negative (Interior) Side Waterproofing**

The following waterproofing materials are appropriate for use as negative (interior) side waterproofing for walls below grade:

- Cementitious waterproofing
- Crystalline waterproofing

#### **2.4.3 Slabs At or Above Grade**

##### **2.4.3.1 Between-slab Membranes**

The following waterproofing materials are appropriate for use as between-slab membrane waterproofing for slabs at or above grade:

- Asphalt or coal-tar built-up membranes
- Hot-fluid-applied polymer-modified asphalt membrane
- APP and SBS polymer-modified bitumen sheet membrane
- Self-adhered polymer-modified bitumen sheet membrane
- Butyl or EPDM (thermoset) membranes
- PVC (thermoplastic) membrane
- Fluid-applied elastomeric materials

##### **2.4.3.2 Traffic-bearing Waterproofing Membranes (Surface-applied)**

The following waterproofing materials are appropriate for use as traffic-bearing waterproofing membranes for slabs at or above grade:

- Traffic-bearing, fluid-applied, elastomeric materials

#### **2.4.4 Planters**

The following waterproofing materials are appropriate for use as waterproofing membranes for planters:

- Asphalt built-up membranes
- Hot-fluid-applied polymer-modified asphalt membrane
- APP and SBS polymer-modified bitumen sheet membrane
- Self-adhering, polymer-modified bitumen sheet membrane
- Butyl or EPDM (thermoset) membranes
- PVC (thermoplastic) membrane

- Fluid-applied elastomeric materials
- Cementitious waterproofing
- Crystalline waterproofing

### **2.4.5 Fountains, Pools, Ponds, Lagoons and Reservoirs**

The following waterproofing materials are appropriate for use as waterproofing membranes for fountains, pools, ponds, lagoons and reservoirs with concrete, masonry or wood substrates:

- Hot-fluid-applied polymer-modified asphalt membrane
- APP and SBS polymer-modified bitumen sheet membrane
- Self-adhering polymer-modified bitumen sheet membrane
- Butyl or EPDM (thermoset) membranes
- PVC (thermoplastic) membrane
- Fluid-applied elastomeric materials
- Bentonite
- Cementitious waterproofing
- Crystalline waterproofing
- Pre-applied (before the installation of the structure) sheet membrane

The following waterproofing materials are appropriate for use as waterproofing membranes for fountains, pools, ponds, lagoons and reservoirs with earthen substrates:

- Bentonite
- Butyl or EPDM (thermoset) membranes
- PVC (thermoplastic) membrane

NRCA does not consider polyethylene sheets to be waterproofing membranes. Polyethylene sheets should only be used as vapor retarders.

## **2.5 Substrates**

Most waterproofing materials are bonded or applied to surfaces that are installed by other trades. It is essential to the performance of the waterproofing material these substrates be structurally sound; free from excessive cracks, holes and projections; and relatively smooth without sharp edges. Certain concrete curing compounds and finishes may affect or interfere with the performance of the waterproofing material. The use of oils, waxes and other surface contaminants, including noncompatible form-board release agents, should be avoided or the contaminants must be removed before waterproofing. The use of certain release agents can prohibit the adhesion of waterproofing products. The waterproofing contractor should visually inspect the substrate surfaces before the application of waterproofing materials and report any deficiencies so they may be corrected by the responsible trade.

Waterproofing substrates provide the structural support for the waterproofing materials, as well as dead and live loads, depending on the structural element being waterproofed. Waterproofing substrates should be dimensionally stable, appropriately fire-resistant (to the degree required for a given building type), provide appropriate attachment capability for the waterproofing membrane, appropriately accommodate building movement and deflection, and may provide the proper slope for drainage.

The most common types of waterproofing substrates are:

- Masonry
- Concrete
- Shotcrete
- Plywood
- Others—cementitious boards, gypsum boards, lagging, soil/earth

Masonry waterproofing substrates include brick and block walls. Concrete waterproofing substrates include

poured-in-place concrete, precast concrete and shotcrete. Lightweight insulating concrete is not an acceptable substrate for a waterproofing system. Substrates composed of wood include marine-grade plywood and pressure-preserved treated wood planks; however, the use of OSB as a substrate for waterproofing membranes is not recommended. NRCA is concerned about dimensional stability caused by the effects of moisture.

The following are recommended surface-preparation procedures acceptable for most waterproofing materials. Other procedures may be recommended or required by the waterproofing material manufacturer.

### **2.5.1 Masonry Substrates**

Holes, joints and voids in masonry substrates should be pointed flush with the surface. The masonry surface should be smooth and free from projections. Penetrations through the masonry surface should be grouted tightly. Irregular existing masonry surfaces that will be waterproofed with a membrane should receive an approximate 1/2-inch- (13-mm-) thick parging finished to a smooth steel trowel surface. Block filler may be used in lieu of parging where conditions warrant.

Split-face block is very difficult to waterproof. Spray-applied coatings/sealers are not generally appropriate to fill the voids of split-faced block.

### **2.5.2 Concrete Substrates**

Concrete substrates should be properly cured and the surface should be dry before installing waterproofing materials. The concrete surface should be finished and cured according to the waterproofing manufacturer's recommendations. Hydration must occur in concrete substrates to the degree the surfaces become dry enough to accommodate application of waterproofing systems. If a suitable surface cannot be obtained within a reasonable time period, direct membrane adhesion should be postponed. An adhesion test is recommended to determine appropriate membrane adhesion.

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or must be removed from the concrete surface by the responsible trade. Honeycombs, tie-wire holes and other voids in the concrete substrate must be cut out and filled with a nonshrinking concrete patching compound. Concrete fins or other projections should be removed to provide a smooth surface. Horizontal concrete slabs should be free from gouges, voids, depressions, ridges and concrete droppings and should be sloped to drains.

ASTM D5295, "Standard Guide for Preparation of Concrete Surfaces for Adhered (Bonded) Membrane Waterproofing System," provides additional recommendations regarding the preparation of concrete deck surfaces before the installation of waterproofing.

ASTM D5295 suggests tests are performed to evaluate the surface condition of concrete before installation of waterproofing membranes. NRCA does not recommend the use of the surface dryness test referenced in D5295, which is D4263, "Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method," to determine whether concrete is dry enough for application of a waterproofing membrane. In general terms, the test method consists of taping an 18 inch x 18 inch (460 mm x 460 mm) polyethylene sheet to the concrete surface and observing whether moisture collects on the underside of the polyethylene sheet. NRCA does not feel this is an appropriate test method for determining concrete deck dryness for the installation of waterproofing membranes. NRCA suggests performing a peel test by applying a small test patch of the waterproofing membrane, allowing it to cure and then attempting to peel the membrane from the concrete substrate to determine adhesion. Performing a peel test provides for a determination of how moisture content, dust, oil, laitance and curing compounds affect adhesion. There is no standardized peel test method, so this must be coordinated with the waterproofing contractor, manufacturer and owner. Alternately, the waterproofing manufacturer should provide an appropriate test method to determine dryness of the concrete deck or an appropriate test to determine adhesion.

### **2.5.3. Shotcrete Substrates**

Shotcrete is defined by the American Concrete Institute as mortar or concrete that is pneumatically projected at high velocity onto a surface. Shotcrete can also be projected onto a cage of reinforcing bars in conjunction with pre-applied waterproofing systems. Because of the unique process for the application of shotcrete, NRCA recommends designers consult the specific waterproofing material manufacturer for the specific requirements for its product use in conjunction with shotcrete applications.

### **2.5.4 Plywood Substrates**

The grade of plywood used is critical to the performance of the waterproofing. NRCA suggests the use of marine-grade plywood as a substrate for below-grade waterproofing applications.

Marine-grade plywood is made entirely of Douglas-fir or Western Larch. The grade of all plies of veneer is B or better. B-grade veneer may have knots but no knotholes. A-grade veneer has no knots or knotholes. Both A and B grade may contain wood or synthetic patches. Panels are sanded on both faces or Medium Density Overlay (MDO) or High

Density Overlay (HDO). The maximum core-gap size permitted is 1/8 inch (3 mm). Its exposure durability rating is EXTERIOR and the glue used is a fully waterproof structural adhesive. It is considered a “premium” panel grade for use in situations where these characteristics are required. Marine-grade plywood is not treated with any chemicals to enhance its resistance to decay. If decay is a concern, it should be pressure-preservative treated to an appropriate standard.

The surface of wood substrates must be smooth, and holes, open joints and gaps between boards or panels should be plugged or covered. Knotholes are not acceptable for surface-applied waterproofing purposes. Plywood panel edges should bear on joists or blocking to reduce deflection from traffic. Joints should be spaced according to the plywood manufacturer’s recommendations. The thickness and deflection characteristics of wood substrates are important design considerations. Wood decks should be sloped for drainage.

Fasteners used for attaching wood must be corrosion-resistant-type or resin-coated; ribbed or ring-shanked nails; or screws countersunk to prevent their backing out and puncturing the waterproofing membrane.

### 2.5.5 Soil/Compacted Earth or Drainage Rock

Compacted earth or drainage rock used as a substrate for waterproofing membranes should be smooth; free of sharp projections, voids, contours, ridges, etc., and 85 percent to 90 percent compacted. Where the surface of the substrate is not appropriate for direct installation (e.g., drainage rock), installation of a protection board is recommended to act as a suitable surface for the waterproofing membrane.

## 2.6 Waterproofing Products

### 2.6.1 Asphalt Built-up Membrane

Asphalt built-up waterproofing membranes are composed of alternating layers of asphalt reinforcing ply sheets. The most common type of reinforcing ply sheet is an asphalt-impregnated glass fiber matt.

The number of plies of membrane depends on the hydrostatic pressure head that needs to be resisted. The relationship between hydrostatic pressure and the minimum number of plies recommended is as follows:

Hydrostatic Pressure Head, Feet of Water	1 foot-10 feet (300 mm-3 m)	11 feet-25 feet (3.4 m-7.6 m)	26 feet-50 feet (7.9 m-15.2 m)
Number of Plies	3	4	5

Asphalt built-up waterproofing membranes are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure.

Asphalt built-up waterproofing membranes generally should not be installed when substrate surface temperatures are below 32° F (0° C). If application at lower surface temperatures is necessary because of project conditions, consult the manufacturer for specific cold-temperature application recommendations. Installation should not proceed when moisture is present.

The completed membrane should not be exposed to prolonged periods of sunlight before covering or backfilling to prevent slipping and softening of the bitumen.

Asphalt built-up membrane waterproofing components should conform to the following recognized standards:

Asphalt	ASTM D312, Type I, II or III
Asphalt	ASTM D449, Type I, II or III
Asphalt Primer	ASTM D41
Asphalt-impregnated Glass-fiber Mat	ASTM D2178, Type IV or VI
Bitumen-saturated Cotton Fabric	ASTM D173
Treated Glass-fiber Fabric	ASTM D1668

The asphalt used in waterproofing applications (ASTM D449) differs from asphalt used in roofing (ASTM D312) in that waterproofing asphalt has lower softening-point and flash-point temperatures and therefore somewhat different physical properties. However, ASTM D312 asphalt can be used for waterproofing applications.

### 2.6.1.1 Installation

Form release agents and concrete curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive asphalt built-up membrane waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids and sharp projections. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately; Primer and an additional ply of reinforcing felt or fabric should be applied with hot asphalt before the application of the primary membrane system.

Prime the surface with asphalt primer as recommended by the manufacturer of the waterproofing materials. Reinforce all inside and outside corners with two 12-inch- (300-mm-) wide plies of reinforcing material centered on the corner. Apply the specified number of plies of reinforcing felt using hot asphalt in a continuous, firmly bonding film with sufficient pressure to assure good adhesion. For horizontal applications, consideration should be given to using the phased method of application, which is installing one-half of the total number of plies shingle fashion in one direction then installing the remaining plies shingle fashion in a direction across the underlying plies. For vertical applications, orient the reinforcing felt vertically in workable height lifts, fastening the reinforcing felt at the top of each course.

Flash all penetrations with two additional plies of reinforcing material. Use the base flashing material as recommended by the membrane manufacturer at the intersection of vertical and horizontal surfaces.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

### 2.6.2 Coal-tar Built-up Membrane

Coal-tar built-up waterproofing membranes are composed of alternating layers of coal tar and reinforcing ply sheets. The number of plies of membrane depends on the hydrostatic pressure head that needs to be resisted. The relationship between hydrostatic pressure and the minimum number of plies recommended is as follows:

Hydrostatic Pressure Head, Feet of Water	1 foot-10 feet (300 mm-3 m)	11 feet-25 feet (3.4 m-7.6 m)	26 feet-50 feet (7.9 m-15.2 m)
Number of plies	3	4	5

Coal-tar built-up waterproofing membranes are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure.

Coal-tar built-up waterproofing membranes should generally not be installed when substrate surface temperatures are below 32° F (0° C). If application at lower surface temperatures is necessary because of project conditions, consult the manufacturer for specific cold-temperature application recommendations. Installation should not proceed when moisture is present.

The completed membrane should not be exposed to prolonged periods of sunlight before covering or backfilling to prevent slipping and softening of the bitumen.

Coal-tar built-up membrane waterproofing components should conform to the following recognized standards:

Coal Tar	ASTM D450, Type II	Coal-tar-impregnated Glass-fiber Mat	ASTM D4990
Coal-tar Primer	ASTM D43	Bitumen-saturated Cotton Fabric	ASTM D173
Coal-tar Saturated Organic Felt	ASTM D227	Treated Glass-fiber Fabric	ASTM D1668
Asphalt-impregnated Glass-fiber Mat	ASTM D2178, Type IV		

Coal tar used in waterproofing applications (ASTM D450, Type II) differs from coal tar used in roofing (ASTM D450, Type I) in that waterproofing coal tar has lower softening-point and flash-point temperatures and therefore somewhat

different physical properties.

### 2.6.2.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive coal-tar built-up membrane waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids and sharp projections. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately. Primer and an additional ply of reinforcing felt or fabric should be applied in hot coal tar before the application of the primary membrane system.

Prime the surface with coal-tar primer as recommended by the manufacturer of the waterproofing materials. Reinforce all inside and outside corners with two 12-inch- (300-mm-) wide plies of reinforcing material centered on the corner. Apply the specified number of plies of reinforcing felt using the phased method of application. Apply the coal tar in a continuous, firmly bonding film and with sufficient pressure to assure good adhesion. For horizontal applications, consideration should be given to installing one-half of the total number of plies shingle fashion in one direction then installing the remaining plies shingle fashion in a direction across the underlying plies. For vertical applications, orient the reinforcing material vertically in workable height lifts, fastening the reinforcing at the top of each course.

Flash all penetrations with two additional plies of reinforcing material. Use the base flashing material as recommended by the membrane manufacturer at the intersection of vertical and horizontal surfaces.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

### 2.6.3 Hot-fluid-applied Polymer-modified Asphalt Membrane

Hot-fluid-applied polymer-modified asphalt consists of refined asphalt, synthetic rubbers and extenders. The material is typically supplied in 50-pound (23-kg) cakes wrapped in polyethylene film, shipped in containers that weigh 400 pounds to 600 pounds (181 kg to 272 kg). The cakes are melted in a double jacketed oil bath or hot-air jacketed kettle and applied as a liquid that quickly cools to form a solid membrane material.

Hot-fluid-applied polymer-modified asphalt membrane waterproofing is used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure. These systems may include a fabric reinforcement layer.

Hot-fluid-applied polymer-modified asphalt membrane waterproofing should generally not be installed when substrate surface temperatures are below 32° F (0° C). If application at lower surface temperatures is necessary because of project conditions, consult the manufacturer for specific cold-temperature application recommendations. Installation should not proceed when moisture is present. Hot-fluid-applied polymer-modified asphalt membrane waterproofing cannot be left exposed to prolonged periods of sunlight and must be covered to protect it from ultraviolet light.

There are no current ASTM material standards for hot-fluid-applied polymer-modified asphalt waterproofing materials. Manufacturers generally provide specific physical property data according to ASTM test methods.

#### 2.6.3.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive hot-fluid-applied polymer-modified asphalt membrane waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids, cracks, sharp projections, oil and grease. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately with an additional ply of reinforced membrane before the application of the primary membrane system.

Prime the surface with asphalt primer as recommended by the manufacturer of the waterproofing materials. Rein-

force inside and outside corners, cracks and construction joints with a 6-inch- (150-mm-) wide piece of reinforcing sheet embedded in hot-fluid-applied polymer-modified asphalt. Flash larger cracks, expansion joints and similar details according to the manufacturer's recommendations. Apply the hot polymer-modified asphalt as a continuous coating to the required thickness. Some systems require the use of an embedded reinforcing fabric.

At the intersection of vertical and horizontal surfaces and penetrations, use the base flashing material as recommended by the membrane manufacturer. Exposed vertical surfaces need additional protection when other finish materials are not used.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being performed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

For additional information, refer to ASTM D6622, "Standard Guide for Application of Fully Adhered Hot-Applied Reinforced Waterproofing Systems."

#### 2.6.4 APP and SBS Polymer-modified Bitumen Sheet Membrane

Polymer-modified bitumen sheet membranes are composed of polymer-modified asphalt and one or several layers of reinforcing material. The polymer modifier extends the low-temperature flexibility and improves the high-temperature properties of the membrane sheet. Polymer-modified bitumen sheet waterproofing membranes are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure.

Polymer-modified bitumen sheet membranes may be installed by one of three techniques depending on the composition of the modifier used. APP-modified sheets are either heat-fused or installed in cold adhesive. Heat-fused means to be installed by heating the underside of the sheet with a propane torch or other heating device, melting the polymer-modified bitumen on the bottom side and adhering the sheet in the molten material. SBS-modified sheets are either heat-fused or installed in hot asphalt or cold adhesive.

Most polymer-modified bitumen sheet waterproofing membranes should not be installed when the substrate surface temperature is below 40° F (4° C). If application at lower surface temperatures is necessary because of project conditions, consult the membrane manufacturer for minimum temperature limitations and specific cold-temperature application recommendations. Heat-fused membranes may be applied at lower temperatures. Installation should not proceed when moisture is present.

APP and SBS polymer-modified bitumen sheet membrane waterproofing components should conform to the following recognized standards:

Asphalt Primer	ASTM D41
Asphalt	ASTM D312, Type III or IV
Asphalt-impregnated Glass-fiber Mat	ASTM D2178, Type IV or VI
Asphalt-impregnated and Coated Glass-fiber Base Sheet	ASTM D4601, Type II
Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using a Combination of Polyester and Glass-fiber Reinforcements	ASTM D6162
Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Glass-fiber Reinforcements	ASTM D6163
Styrene Butadiene Styrene (SBS) Modified Bituminous Sheet Materials Using Polyester Reinforcements	ASTM D6164
Reinforced Bituminous Flashing Sheets for Roofing and Waterproofing	ASTM D6221

Atactic Polypropylene (APP) Modified Bituminous Sheet Materials Using Polyester Reinforcements	ASTM D6222
Atactic Polypropylene (APP) Modified Bituminous Sheet Using a Combination of Polyester and Glass-fiber Reinforcements	ASTM D6223

### 2.6.4.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive polymer-modified bitumen waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids, cracks and sharp projections. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately with an additional layer of reinforcement before the application of the primary membrane system.

Prime the surface with primer as recommended by the manufacturer of the waterproofing materials. Reinforce inside and outside corners, cracks and construction joints with a 6-inch- (150-mm-) wide piece of reinforcing sheet. Expansion joints and similar details should be installed according to the manufacturer’s recommendations. Use the base flashing material as recommend by the membrane manufacturer at the intersection of vertical and horizontal surfaces and penetrations.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before to permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being performed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

For additional information, refer to ASTM D6769 “Standard Guide for Application of Fully Adhered, Cold-Applied, Prefabricated Reinforced Modified Bituminous Membrane Waterproofing Systems.”

### 2.6.5 Self-adhering Polymer-modified Bitumen Sheet Membrane

Self-adhering polymer-modified bitumen sheet membranes are composed of polymer-modified asphalt and fillers and have a sticky adhesive layer that is exposed by the removal of a protective sheet. Sheets are normally 60 mils (1.5 mm) thick. The polymer modifier extends the low-temperature flexibility and improves the high-temperature properties of the membrane sheet. Self-adhering polymer-modified bitumen sheet waterproofing membranes are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure.

Self-adhering polymer-modified bitumen sheet membranes are installed by removal of the protective sheet, exposing the adhesive layer and adhering them to a substrate. Polymer-modified bitumen sheets that are self-adhering do not require the use of either heat or a separate adhesive.

Self-adhered-polymer modified sheet waterproofing membranes are not intended for applications in which they will be permanently exposed to sunlight. Most self-adhering polymer-modified bitumen sheet waterproofing membranes should not be installed when the substrate surface temperature is below 40° F (4° C). If application at lower substrate temperatures is necessary because of project conditions, consult the membrane manufacturer for minimum temperature limitations and specific cold-temperature application recommendations. Installation should not proceed when moisture is present.

There are no ASTM material standards currently for self-adhering polymer-modified bitumen waterproofing membranes.

#### 2.6.5.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive self-adhering polymer-modified bitumen waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids, cracks and sharp projections. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately with an additional layer of reinforcement before the application of the primary membrane system. Installation of fillets or cant strips are required by some manufacturers at the base of some vertical flashings.

Prime the surface with primer/conditioner as recommended by the manufacturer of the waterproofing materials. Reinforce inside and outside corners, cracks and construction joints with a 6-inch (150-mm) wide piece of reinforcing sheet. Expansion joints and similar details should be installed according to the manufacturer's recommendations. Use the base flashing material as recommend by the membrane manufacturer at the intersection of vertical and horizontal surfaces and penetrations.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

For additional information, refer to ASTM D6135, "Standard Practice for Application of Self-Adhering Modified Bituminous Waterproofing."

## 2.6.6 Butyl Rubber Membrane

Butyl rubber waterproofing membranes consist of factory-fabricated sheets of reinforced butyl rubber. Sheets are normally 60 mils, 90 mils or 120 mils (1.5 mm, 2.3 mm or 3.0 mm) thick. Butyl rubber waterproofing membranes are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure.

Butyl rubber waterproofing membranes should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation is necessary at lower surface temperatures because of project conditions, consult the manufacturer for specific cold-weather application recommendations. EPDM membrane waterproofing should be adhered to the substrate, not mechanically attached or loose-laid. Butyl rubber membranes should only be used in conjunction with adhesives and tapes recommended by the membrane manufacturer. Butyl rubber sheets cannot be used in contact with certain acids, oils, grease and solvents. Contact the membrane manufacturer for specific details concerning these contaminants. Installation should not proceed when moisture is present.

Vulcanized-rubber (butyl) sheet material should conform to the following recognized standard:

Vulcanized-rubber Sheets (Butyl)	ASTM D6134, Type II
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### 2.6.6.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive butyl rubber waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids, cracks, sharp projections, oil and grease. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately with an additional layer of membrane before the application of the primary membrane system.

Lay the membrane on the substrate or a flat surface and allow it to relax for a minimum of 30 minutes before use. Clean membrane surfaces to be bonded of any loose dust, dirt and release agents as recommended by the manufacturer. Position the membrane on the substrate without stretching in a manner that minimizes voids, wrinkles and entrapped air. Clean overlapping areas between sheets, and join the sheets with recommended adhesives and tapes.

Flash the intersection of vertical and horizontal surfaces and all penetrations with the base flashing material recommended by the membrane manufacturer.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing

surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

For additional information, refer to ASTM D5843, “Standard Guide for Application of Fully Adhered Vulcanized Rubber Sheets Used in Waterproofing.”

## 2.6.7 EPDM Membrane

EPDM waterproofing membranes consist of factory-fabricated sheets of ethylene propylene diene monomer. Sheets are normally 45 mils to 60 mils (1.1 mm to 1.5 mm) thick, with special thicknesses of 90 mils to 120 mils (2.3 mm to 3 mm) available. It is recommended to use a minimum 60-mil- (1.5-mm-) thick membrane for waterproofing. EPDM membrane waterproofing should be adhered to the substrate, not mechanically attached or loose-laid. Vulcanized-rubber sheet membranes, otherwise known as EPDM membranes, are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure.

EPDM waterproofing membranes should not be used in contact with bituminous cements and mastics. EPDM membrane sheets cannot be used in contact with certain acids, oils, grease and solvents. Contact the membrane manufacturer for specific details concerning these contaminants.

EPDM waterproofing membranes should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation is necessary at lower surface temperatures because of project conditions, consult the manufacturer for specific cold-weather application recommendations. EPDM membranes should only be used in conjunction with adhesives and tapes recommended by the membrane manufacturer. EPDM sheets cannot be used in contact with certain acids, oils, grease and solvents. Contact the membrane manufacturer for specific details concerning these contaminants. Installation should not proceed when moisture is present.

Vulcanized-rubber (EPDM) sheet material should conform to the following recognized standard:

Vulcanized-rubber Sheets (EPDM)	ASTM D6134, Type I
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### 2.6.7.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive EPDM membrane waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids, cracks and sharp projections. Cracks 1/16 inch (1.6 mm) or wider should be reinforced separately with an additional layer of membrane 6-inch (150-mm) minimum width before the application of the primary membrane system.

Lay the membrane on the substrate or a flat surface and allow it to relax for a minimum of one-half hour before use. Clean membrane surfaces to be bonded of any dust, dirt and release agents as recommended by the manufacturer.

Expansion joints and similar details should be installed according to the manufacturer’s recommendations. Use the base flashing material as recommend by the membrane manufacturer at the intersection of vertical and horizontal surfaces and penetrations.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

For additional information, refer to ASTM D5843, “Standard Guide for Application of Fully Adhered Vulcanized Rubber Sheets Used in Waterproofing.”

## 2.6.8 Polyvinyl Chloride (PVC) Membrane

PVC waterproofing membranes consist of factory-fabricated sheets of reinforced polyvinyl chloride. Sheets are a

minimum 60 mils (1.5 mm) thick. Polyvinyl chloride (PVC) waterproofing membranes are used to resist water penetration on those areas of structures that are exposed to hydrostatic pressure. PVC membrane waterproofing should be adhered to the substrate, not mechanically attached or loose-laid.

PVC waterproofing membranes should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation at lower surface temperatures is necessary because of project conditions, consult the manufacturer for specific cold-weather application recommendations. Installation should not proceed when moisture is present.

The completed membrane should not be exposed to prolonged periods of sunlight before covering or backfilling to prevent slipping. PVC materials are not compatible with polystyrene insulation products and certain bitumen-based products, such as coal tar. Consult the manufacturer of the PVC membrane to verify compatibility with other substrates.

There are currently no ASTM material standards for PVC sheet waterproofing membranes.

### 2.6.8.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive PVC membrane waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of dust, dirt, voids, cracks and sharp projections.

Lay the membrane on the substrate or a flat surface and allow it to relax for a minimum of 30 minutes before use. Clean membrane surfaces to be bonded of any dust, dirt and release agents as recommended by the manufacturer.

Expansion joints and similar details should be installed according to the manufacturer's recommendations. Use the base flashing material as recommend by the membrane manufacturer at the intersection of vertical and horizontal surfaces and penetrations.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

### 2.6.9 One- and Two-component Fluid-applied Elastomeric Membrane

Fluid-applied elastomeric waterproofing membranes consist of high solids content polyurethane elastomers in liquid form. Some products are made solely of polyurethane, and others are modified with coal tar or asphalt. There are different grades of product for horizontal, vertical and special applications.

One- and two-component fluid-applied elastomeric waterproofing membranes are used to resist water penetration on walls below grade; between slabs on horizontal surfaces, plaza decks, and terraces; and in planter boxes, tunnels and water features. The material cures to form a monolithic waterproof membrane. Single-component elastomers eliminate the need for mixing products at the job site. Two-component materials require job-site mixing but cure faster in cooler weather and under higher humidity conditions than one-component materials.

Fluid-applied elastomeric waterproofing membranes should not be used on exposed surfaces unless the product is UV-resistant or a compatible UV-protective coating is used. These materials cannot be applied to damp or contaminated surfaces. Two-component materials require proper mixing at the job site and have limited pot life after mixing.

Fluid-applied elastomeric waterproofing membranes should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation at lower substrate temperatures is necessary because of project conditions, consult the manufacturer for specific cold-weather application recommendations. Installation should not proceed when moisture is present.

Fluid-applied elastomeric waterproofing membranes should conform to the following recognized standards:

High-solids Elastomeric Membrane	ASTM C836 ASTM C957
Neoprene and Chlorosulfonated Polyethylene	ASTM D3468

### 2.6.9.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive fluid-applied elastomeric waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of holes, voids, cracks and sharp projections. Concrete surfaces should be finished with a light-steel trowel followed by a fine-hair broom. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately as recommended by the material manufacturer before the application of the primary membrane system. Concrete surfaces should be properly cured. The elapsed time between placement of concrete and installation of the waterproofing material will be as recommended by the material manufacturer. Masonry block surfaces should be parged or filled as recommended by the manufacturer. Suspended slabs to be waterproofed must be vented from underneath so moisture can be dissipated. Horizontal surfaces should be sloped for drainage.

When required by the manufacturer, prime the substrate with a primer approved by the manufacturer, and allow it to dry. Apply the product by spray, roller, trowel or squeegee, using a grade of product consistent with the method of application. It is strongly recommended a reinforcement mat be embedded into a separate coat of liquid membrane over shrinkage or stress cracks. Apply the waterproofing system over the entire surface at the specified thickness.

Reinforcement is typically required at the junction of horizontal and vertical surfaces and penetrations. The use of sealant, fabric sheet flashing, metal or additional membrane may be required as these locations. Consult the membrane manufacturer for specific detailing procedures.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

NRCA strongly recommends horizontal waterproofing membranes be water-tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion. The definition and criteria for performing a water test and a suggested form for documenting a water test are included in Section 4, Appendix.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being installed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

### 2.6.10 Bentonite Waterproofing

Bentonite is a naturally occurring high-swelling montmorillonite clay that is mined, processed and packaged in several forms for use as a waterproofing medium.

Bentonite waterproofing is only used for below-grade applications. It is used on the exterior side of the structure being waterproofed and must be contained in place by compacted backfill or concrete fill. It is one of the few products capable of being “blind-side” applied by attaching it to lagging before structural concrete placement.

Bentonite waterproofing should not be used for above-grade applications or in horizontal applications where it can flex or be subject to thermal stress. Bentonite requires initial exposure to moisture to properly hydrate and function properly but cannot be exposed to standing or moving water or precipitation. The material must be able to retain a minimum moisture content, meaning that it must not dry out. Bentonite requires a solid, void-free surface and confinement with 85 percent modified Proctor density compacted backfill, concrete or shotcrete. Shotcrete applications will require additional considerations because of its unique application process. It is recommended application of shotcrete be performed by a certified shotcrete applicator. Consult the waterproofing manufacturer for specific requirements. When not properly confined on both sides, moving water will remove and displace the bentonite. Soils containing acids, alkalis or brines should be checked for compatibility before bentonite use. It is recommended to take soil samples so a compatible and proper type of bentonite is used.

There are currently no ASTM material standards for bentonite waterproofing.

#### 2.6.10.1 Installation

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Foundation walls must be broom clean and free of voids and sharp projections. All voids, cracks and joints must be filled, parged or sealed according to manufacturers' recommendations. Under-slab surfaces should be level, compacted and free from standing water. Lagging should be continuous and even. Voids or irregular surfaces in the lagging should be filled or made smooth with compatible materials before applying the bentonite.

Bentonite installation should occur immediately before placing concrete, compacted backfill or other confinement to minimize premature hydration and damage.

Mechanically fasten the bentonite waterproofing system to foundation walls or to lagging. For under-slab locations, loosely place a bentonite system directly on the compacted ground, either butted or slightly overlapped as per manufacturers' recommendations. Bentonite materials may be fastened to each other to limit their movement before and during concrete placement.

Bentonite products are self-sealing. However, flashing installation at the intersection of vertical and horizontal surfaces and all penetrations should be performed with the flashing material recommended by the manufacturer. At construction joints, penetrations, inside and outside corners, a reinforcing layer of bentonite waterproofing or other specific product recommended by the manufacturer should be installed. Flash or seal working expansion joints with materials specifically designed for the purpose as recommended by the manufacturer.

Cover the bentonite with a polyethylene sheet as a temporary protection from precipitation, if it is anticipated. Remove this film from the bentonite before compacted fill or concrete placement. Cover the bentonite with a protection course as recommended by the manufacturer for backfill protection. Install properly compacted backfill within 48 hours after completion of the waterproofing membrane.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

Bentonite waterproofing systems cannot be water tested.

## **2.6.11 Crystalline Waterproofing**

NRCA recommends waterproofing systems should be installed on the positive (exterior) side. Positive (exterior) side waterproofing systems are best suited to prevent moisture intrusion. Crystalline waterproofing is typically a negative (interior) side waterproofing system. It typically is not used as a primary waterproofing system but can be under certain job conditions. It can be used as a secondary waterproofing system. In addition, crystalline waterproofing is typically appropriate as a maintenance effort to control leakage.

Crystalline waterproofing is a compound of cement, quartz sand or silica sand and other active chemicals that are mixed and packaged for use in a dry powder form. The compound is mixed with water and applied to the concrete surface where it penetrates into the concrete pores. The crystalline compound chemically reacts with the concrete and fills the concrete pores, rendering them more resistant to water penetration.

Crystalline waterproofing is used on concrete surfaces both above and below grade. It may be applied to either the exterior or interior side of the structure being waterproofed. Because moisture is required for activation of the material, it may be applied to damp or uncured concrete.

Crystalline waterproofing should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation is necessary at lower surface temperatures because of project conditions, consult the manufacturer for specific cold-weather application recommendations.

Crystalline waterproofing must be applied to a sound concrete substrate. Honeycombs and large cracks must be routed and patched with mortar before application of the crystalline materials. Crystalline waterproofing should not be applied to suspended structural decks, any deck with expected movement, or any deck subject to expansion and contraction.

There are currently no ASTM material standards for crystalline waterproofing.

### **2.6.11.1 Installation**

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. Concrete must be structurally sound and concrete surfaces must be clean and free of dirt, laitance, oils, curing agents and foreign materials. Structural defects, honeycombs, form ties, cracks, etc. must be routed to sound concrete and grouted according to manufacturers' requirements. The surface should be roughened by etching, sandblasting or mechanical means, therefore exposing open concrete pores to the crystalline application. If the concrete is cured, the surface must be dampened according to manufacturer's recommendations.

Crystalline waterproofing compounds should be mixed with water according to manufacturer's instructions and applied using a stiff masonry brush or broom. The slurry coating should be worked well into the pores and irregularities of the concrete. Follow the manufacturer's recommendations when applying and curing these products.

Crystalline waterproofing is self-flashing. However, additional detailing is typically required at penetrations. Refer to the manufacturer's recommendations for specifics about detailing.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

Crystalline waterproofing does not typically require a protection course. However, temporary protection is recommended to protect crystalline waterproofing from damage, freezing temperatures, rain, and premature drying from wind and sunlight during the curing period.

Negative (interior) side waterproofing systems are generally not suitable for watertesting.

## **2.6.12 Cementitious Waterproofing**

NRCA recommends waterproofing systems should be installed on the positive (exterior) side of the structure. Positive (exterior) side waterproofing systems are best suited to prevent moisture intrusion. Cementitious waterproofing is typically a negative (interior) side waterproofing system. It typically is not used as a primary waterproofing system but can be under certain job conditions. It can be used as a secondary waterproofing system. In addition, cementitious waterproofing is typically appropriate as a maintenance effort to control leakage.

Cementitious waterproofing consists of heavy cement-based compounds and various additives that are mixed and packaged for use in a dry powder form. The compound is mixed with water and liquid bonding agents to a workable concrete-like consistency.

Cementitious waterproofing is used on concrete and masonry surfaces above and below grade. It may be applied to either the exterior or interior side of the structure being waterproofed. Some cementitious waterproofing products are suitable for pools and reservoirs. Cementitious waterproofing is available in a variety of textures and colors, making it useful as an aesthetic concrete finish.

Cementitious waterproofing should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation is necessary at lower surface temperatures because of project conditions, consult the manufacturer for specific cold-weather application recommendations.

Cementitious waterproofing must be applied to a sound concrete or masonry substrate. Cementitious waterproofing should not be applied to suspended structural decks, any deck with expected movement, or any deck subject to expansion or contraction.

There are currently no ASTM material standards for cementitious waterproofing.

### **2.6.12.1 Installation**

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. Concrete must be structurally sound and concrete or masonry surfaces must be clean and free of dirt, laitance, oils, curing agents and foreign materials. Structural defects, unsound concrete, honeycombs, form ties, cracks, etc., must be routed to sound concrete and grouted according to manufacturer's requirements. The surface should be roughened by etching, sandblasting or mechanical means to a medium sandpaper finish for proper adhesion. Active leaks should be plugged with a waterproof plug material recommended by the manufacturer. If the concrete is cured, the surface must be dampened according to the manufacturer's recommendations.

Cementitious waterproofing compounds should be mixed with a water or liquid bonding agent according to manufacturer's instructions to the consistency desired. Apply the cementitious waterproofing compound only to damp and cool concrete or masonry surfaces. Follow the manufacturer's recommendations when applying and curing these products.

Apply cementitious waterproofing material by troweling or brushing the material onto the concrete surface to the desired thickness. Large areas may be covered by using plaster spraying or shotcrete equipment. Pores, fissures and irregularities should be filled with material.

Depending on the product and hydrostatic pressure head being resisted, apply one or two coats of material in thickness ranging from 1/16 inch to 1/8 inch (1.6 mm to 3 mm) per coat. If a second coat is desired, apply it while the first coat is still wet but after it has achieved an initial set.

Protect the cementitious waterproofing from damage, freezing temperatures, rain, and premature drying from wind and sunlight during the curing period.

Seal expansion joints, moving cracks and penetrations before applying the cementitious waterproofing with sealants or elastomeric materials. Create a cove or fillet of cementitious waterproofing compound at inside corners and vertical to horizontal intersections before coating the rest of the surface.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Waterproofing Manual*.

Cementitious waterproofing does not typically require a protection course. However, temporary protection is recommended to protect cementitious waterproofing from damage, freezing temperatures, rain, and premature drying from wind and sunlight during the curing period.

Negative (interior) side waterproofing systems are generally not suitable for watertesting.

### **2.6.13 Elastomeric Traffic Coating**

Elastomeric traffic coatings are applied in multiple coats. In most instances, a primer is required. The base coat, or primary waterproofing coat, is typically a one- or two-part, self-leveling elastomeric product. The top coat is usually a one- or two-part modified elastomer that provides additional chemical and ultraviolet resistance to the coating system. Aggregate (e.g., sand, crushed walnut shells or metal oxide) is typically broadcast into this coat to provide a skid-resistant surface. Finish coatings are available in a variety of colors.

Elastomeric traffic coatings provide a waterproof, skid-resistant surface for parking decks, traffic decks, plazas, balconies, terraces and mechanical equipment rooms, as well as other concrete surfaces. Elastomeric traffic coatings can be applied over concrete, wood or metal substrates.

Elastomeric traffic coatings should generally not be installed when substrate surface temperatures are below 40° F (4° C). If installation is necessary at lower surface temperatures because of project conditions, consult the manufacturer for specific cold-weather application recommendations.

#### **2.6.13.1 Elastomeric Pedestrian Traffic Coatings**

Elastomeric pedestrian traffic coatings are applied in two or more coats. The first coat, or base coat, is usually a one- or two-part material depending on the system selected. The base coat is applied and allowed to cure overnight. The wear coat is usually a one- or two-part material. If it is a two-part material, it is supplied in premeasured containers. The wear coat is available in a variety of colors. If a non-skid surface is desired for a pedestrian traffic coating, the aggregate (e.g., sand, crushed walnut shells or metal oxide) is typically installed in the top coat of the system. It is critical that manufacturer's recommendations for mixing and proportioning of materials are followed.

Elastomeric pedestrian traffic coatings should not be used where subject to vehicle traffic, and should not be installed over spalled or contaminated concrete surfaces. Elastomeric pedestrian traffic coatings should not be used in existing split-slab or slab-on-grade constructions because of the possibility of moisture entrapment that causes blistering of the coating. Because it is a traffic-bearing surface and is subject to wear, it must be periodically recoated.

#### **2.6.13.2 Elastomeric Vehicular Traffic Coatings**

Typical vehicular traffic coating applications use three or more coats: a base coat, an intermediate coat with aggregate and a top coat. Additional protection can be achieved by application of an additional intermediate coat with aggregate.

Elastomeric vehicle traffic coatings should not be installed over spalled or contaminated concrete surfaces and should not be used in existing split slab or slab-on-grade constructions because of the possibility of moisture entrapment that causes blistering of the coating. Because it is a traffic-bearing surface and is subject to wear, it must be periodically recoated, especially at ramps and other high-traffic areas.

Elastomeric traffic coatings should conform to the following recognized standard:

Elastomeric Coating	ASTM C957
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#### **2.6.13.3 Installation**

Form-release agents and concrete-curing compounds must be compatible with the waterproofing materials being used or removed from the concrete surface by the responsible trade. The substrate must be structurally sound. Surfaces to receive fluid-applied elastomeric waterproofing must be broom-clean; adequately cured and dry; reasonably smooth; and free of holes, voids, cracks and sharp projections. Concrete surfaces should be finished with a light-steel trowel followed by a fine-hair broom. Cracks 1/16 inch (1.6 mm) or wider should be addressed separately as recommended by the material manufacturer before the application of the primary membrane system. Concrete surfaces should be properly cured. The elapsed time between placement of concrete and installation of the waterproofing material will be as recommended by the material manufacturer. Resin curing should not be used because it interferes with adhesion. Suspended slabs to be waterproofed must be vented from underneath so moisture can be dissipated. Horizontal surfaces should be sloped for drainage. Concrete substrates should be acid-etched or shot-blasted and primed before the application of the waterproofing material.

Plywood substrates must be structurally sound and type AC with the Type A side on the surface to be waterproofed. Attach plywood to its supports with screws, not nails. The underside of a plywood substrate must be adequately

ventilated. Surfaces to receive fluid-applied elastomeric waterproofing must be broom-clean; adequately dry; reasonably smooth; and free of holes, voids, cracks and sharp projections. Joints and cracks should be filled with elastomeric sealant and/or fabric reinforced before application of elastomeric traffic coating according to manufacturer's recommendations. OSB is not recommended as a substrate for elastomeric traffic coating. Plywood substrates may not be suitable for vehicular traffic.

Apply the base waterproofing coat to the prepared substrate. The amount of material required will vary depending on the product and the texture of the surface. Allow the coating to cure at least 24 hours but retain a tacky surface. If the base coating over-cures, refer to the manufacturer's recommendations.

For vehicular traffic systems, apply the wear-coat material to traffic lanes, ramps and turn areas, and broadcast aggregate into the wet coating and evenly distribute it. If recommended by the manufacturer, backroll the aggregate to ensure even distribution. Allow the coating to cure overnight and clean loose aggregate before the application of the top coat.

Apply the finish and color coat to the entire waterproofed surface. Allow the materials to properly cure before allowing traffic on the materials. The wearing surface should cure a minimum of 72 hours or as recommended by the material manufacturer. Examine the surface before any traffic is allowed onto the deck, as drying times vary with humidity and temperature.

Penetrations, expansion joints and drains can be flashed with sealant, fabric reinforcement or sheet neoprene. Form a cant with sealant at the junction of vertical and horizontal surfaces. Apply the base and wear coats over the joint or cant and up the vertical surface to a clean, straight line. Fabric reinforcement is often used to reinforce critical flashing areas. Cure the wearing surface for at least 24 hours or as recommended by the material manufacturer before traffic is allowed over it.

Construction details applicable to waterproofing systems are provided in the Waterproofing Construction Details section of *The NRCA Roofing and Waterproofing Manual*.

Because of the unique nature of surface-applied elastomeric traffic coatings, they may or may not be water tested.

## **2.7 Waterproofing System Accessory Materials**

The following materials may be required to complement the installation of waterproofing materials.

### **2.7.1 Protection Courses**

Protection courses are used to protect waterproofing membranes from damage during backfill operations and installation of finished surfaces by other trades. Protection courses are generally installed on vertical surfaces immediately following the installation of the waterproofing material and are held in place with adhesive or stick clips. Protection courses on horizontal surfaces over suspended structural decks are placed immediately following successful water testing unless the protection course is an integral part of the waterproofing system. Integrated protection courses/materials are typically sheet products (roll goods). The protection course may be set loose on horizontal surfaces or spot-adhered to prevent displacement. Protection courses should never be mechanically fastened on horizontal surfaces. Adhesives must be compatible with the protection course and waterproofing materials.

Protection courses may include integral filter fabrics, or filter fabrics may be used independently above or below insulation. If a geocomposite drain mat is not used, filter fabric should be installed.

The waterproofing material itself may be an appropriate adhesive on vertical surfaces. Backfill should be placed as soon as possible but no more than 24 hours following placement of the protection course to minimize the chance of it falling away from the substrate.

The following are the more common types of materials used as protection courses:

- Polystyrene protection board
- Extruded polystyrene composite panels
- Premolded asphaltic membrane protection board
- Some types of drainage boards
- Asphaltic-based protection sheet (roll goods)

#### **2.7.1.1 Polystyrene Protection Board**

Polystyrene insulation is available in various densities and thicknesses depending on the amount of protection and insulation performance characteristics desired. There are two types of polystyrene insulation available for use as a protection course:

- Expanded polystyrene insulation is available in densities from 1 pound to 3 pounds per cubic foot (16 kg/m<sup>3</sup> to 48 kg/m<sup>3</sup>) and in thicknesses from 2 inch (13 mm) to 24 inches (600 mm).
- Extruded polystyrene insulation is available in thicknesses from 1/4 inch to 3 inches (6 mm to 75 mm). It is recommended to use extruded polystyrene insulation with 25 psi minimum compressive strength.

### **2.7.1.2 Extruded Polystyrene Composite Panels**

Extruded polystyrene sandwich panels are constructed of polystyrene insulation with plastic cap sheets on both sides. Boards are available 4 feet (1.2 m) wide x 50 feet (15 m) long in various thicknesses, fanfolded into bundles. Because of its low compressive resistance, this product should not be used on horizontal deck surfaces in heavy traffic areas.

### **2.7.1.3 Premolded Asphaltic Membrane Protection Boards**

Premolded membrane protection boards are composed of various reinforcements held together with bituminous products. The boards are available in thicknesses of 1/8 inch to 1/4 inch (3 mm to 6 mm) and are usually 4 feet (1.2 m) x 8 feet (2.4 m) in size.

## **2.7.2 Prefabricated Drainage Products (Geocomposites)**

The following are the most common types of geocomposites:

- Drainage mat
- Insulating drainage panels

Drainage mat consists of waffle-like plastic core material that is factory-laminated with a specific filter fabric. Drainage mats are used on vertical foundation walls to drain groundwater into an exterior or interior drainage system. They are used in horizontal applications to permit water to flow into deck drains or off the edge of the horizontal surface below grade. These products enhance the performance of the waterproofing material by relieving hydrostatic pressure from the material surface. Some drainage mats protect the waterproofing material from damage during backfill operations or may offer additional insulation to the structure being waterproofed. Geotextile filter fabrics are used with these products to prevent soil fines from clogging the drainage mat and restricting drainage.

Designers specifying drainage mat should select material with appropriate compressive strength for the waterproofing system. The flow rate of the drainage mat should be appropriate for the expected quantities of water and the runoff should be collected and removed by some type of drainage system. Typically, the drainage system is not installed by the waterproofing contractor.

Insulating drainage panels consist of high-density, moisture-resistant insulation boards with grooved drainage channels on one face that are covered with a geotextile. Panels provide protection for waterproofing, thermal insulation and drainage for groundwater. Panels are held in place with adhesives or stick clips.

### **2.7.3 Waterstops**

Waterstops are devices installed at the intersection of cold joints in concrete walls and slabs, walls and footings or at vertical joints in concrete work. Waterstops are a secondary means of protection against water infiltration. Waterstops are typically fabricated from a variety of materials such as bentonite and treated rubber and are installed before placement of concrete. There are waterstops available that use tubes and injectable foam. These are used where leaks would be critical and are anticipated.

The surface on which a waterstop is installed should be relatively smooth and free from sharp edges. The designer should indicate the location of the waterstops within the cold joint and the party who is responsible for installation of waterstops. Placement is critical—waterstops should not be placed too closely to the edge of concrete walls. Waterstops require a minimum 2 inches (50 mm) of concrete cover. The swelling of a waterstop can damage the concrete. See the Waterproofing Construction Details section of this manual for installation details.

## **2.8 Waterproofing Repair and Maintenance**

Floor slabs and walls against earth below grade are most often inaccessible from the exterior side to affect waterproofing repairs if they become necessary. In most cases, it is too impractical and disruptive to remove sidewalks and/or streets to excavate along the exterior of a structure to expose the leaking waterproofing system for repair. The same can hold true for leaking plaza decks where sidewalks or planters may have to be removed to expose a leaking membrane for repair. It is, therefore, necessary for procedures to be developed for the correction of leaking exterior walls and floors from the negative side, or interior, of the structure.

Elastomeric vehicle traffic coatings are subject to wear and must be periodically recoated, especially at ramps and

other high-traffic areas.

### **2.8.1 Crystalline Waterproofing Repairs**

Crystalline waterproofing is appropriate for rehabilitation of existing structures. However, NRCA recommends waterproofing systems should be installed on the positive (exterior) side. Crystalline waterproofing is typically a negative (interior) side waterproofing system and is appropriate as a maintenance effort to control leakage.

Crystalline waterproofing is used on concrete surfaces above and below grade. It may be applied to either the exterior or interior side of the structure being repaired.

For additional information regarding crystalline waterproofing systems, refer to Section 2.6.11.

#### **2.8.1.1 Preparation and Installation**

Concrete must be structurally sound and concrete surfaces must be clean and free of dirt, laitance, oils, curing agents and foreign materials. Structural defects, honeycombs, form ties, cracks, etc., must be routed to sound concrete and grouted according to manufacturers' requirements. The surface should be roughened by etching, sand-blasting or mechanical means, therefore exposing open concrete pores to the crystalline repair application. The surface of cured concrete must be dampened according to manufacturer's recommendations. Crystalline waterproofing compound should be mixed with water and applied using a stiff masonry brush or broom. The slurry coating should be worked well into the pores and irregularities of the concrete. Follow the manufacturer's recommendations when applying and curing these products.

### **2.8.2 Polyurethane Chemical Grout Injection**

Polyurethane chemical grout injection employs specialized equipment and materials required to seal leaking cracks and voids in concrete structures with a flexible material capable of accommodating some additional movement. The process involves intersecting cracks or voids in concrete structures halfway through the mass by drilling holes into the defect(s) at an angle. A liquid polyurethane grout is injected under high pressure to force the material into the structure's void. Water leaking through the void serves as a catalyst for the flexible grout, causing it to expand in volume, sealing the void.

This is one of the few processes that can be used to seal leaks through plaza decks from the underside. There are several manufacturers of the material and equipment to accomplish this process. Some manufacturers have different operating instructions and procedures, making it difficult to establish a standard specification for the injection of polyurethane chemical grouts. NRCA recommends the installation specifications of the manufacturer selected be carefully followed and a contractor experienced in the use of the materials, methods and equipment perform necessary repairs.

Installation uses a drilling process. It is recommended to make sure the proper depth for the drilling process is determined and there are no items in the wall that can be damaged (e.g., electrical conduit).

### **2.8.3 Acrylamide Gel Chemical Grout Injection**

Acrylamide gel chemical grout injection employs specialized equipment and materials. Unlike the polyurethane chemical grout injection process, which is designed to seal cracks and voids in the concrete structure, the acrylamide grout gel is designed to create a dense, water-impermeable mass in the earth opposite a leaking crack or void.

Installation generally involves drilling a hole completely through the wall or floor in the proximity of a leak, followed by the pumping of large quantities of the gel into the earth until the leak into the building is stopped. In the absence of moisture, the gel can shrink, allowing water to again penetrate the structure. For this reason, this process works best for walls or floors against earth. It is not as satisfactory in plaza decks where drying is possible or pumping the gel under pressure could lift sidewalks or roadbeds over plaza areas. Several manufacturers produce the material and equipment for the gel-injection process and each has subtle differences that defy a standard specification. NRCA recommends the manufacturer's installation specifications be carefully followed and a contractor experienced in the use of these materials and equipment perform the necessary repairs.

## **3. DAMPPROOFING**

### **3.1 Design Guidelines and Performance Requirements for Dampproofing of Below-grade Walls**

Dampproofing is defined as the treatment of a surface to resist the passage of moisture in the absence of hydrostatic pressure. Dampproofing materials need only resist the capillary action of moisture

as it attempts to pass into or through a structure. Dampproofing methods are generally employed above grade or below grade in the absence of groundwater to reduce dampness within the structure. For this reason, many of the design factors that are critical to the performance of a waterproofing system are not as critical to the successful performance of a dampproofing system.

Dampproofing methods should not be used for horizontal slabs on grade or foundation walls when these structures will be subject to hydrostatic pressure. Dampproofing methods also should not be used on suspended structural decks over habitable space or on planters, pools or other water-containment structures. Instead, waterproofing materials should be used in these locations.

Over aggregate fill, vapor retarder materials are often used for dampproofing floor slabs on grade that are not subject to hydrostatic pressure. In this type of application, aggregate fill is first placed on the earth. Polyethylene or premolded membrane sheets are laid over the aggregate fill, and the concrete slab is poured over the vapor retarder sheets. The vapor retarder reduces the moisture from the ground from penetrating into the floor slab. NRCA does not consider polyethylene sheets to be waterproofing membranes.

For concrete and masonry foundations, solvent-based bituminous mastic and bituminous emulsion are often used. The dampproofing material is generally sprayed, brushed or applied by trowel directly to the concrete wall surfaces. Masonry walls may be prepared with a minimum 1/2-inch- (13-mm-) thick parging.

Masonry load-bearing and cavity walls above grade are common locations where dampproofing materials are used. Above-grade masonry construction of this type may need to be protected from rain and prolonged water exposure. Such moisture penetration can threaten interior finishes. Dampproofing applied to the exterior of walls above grade is usually transparent or is a material that can provide an attractive finish. Transparent dampproofing materials usually consist of silicones, acrylics or polymeric resins that penetrate the surface of the masonry and seal its pores to reduce water absorption, leaving the color and texture of the wall unchanged. Opaque acrylic or cementitious dampproofing coatings are used on masonry walls and are available in a variety of colors.

## **3.2 Dampproofing Products**

### **3.2.1 Solvent-based Dampproofing Mastics**

Solvent-based dampproofing mastic is composed of asphalt compounds containing various amounts of fiber reinforcement depending on whether the material is to be installed by spray, brush or trowel.

Solvent-based dampproofing mastic is used to reduce water or moisture infiltration on foundation walls below grade where no hydrostatic pressure exists or on the interior side of masonry walls above grade. Solvent-based dampproofing mastic should not be installed when ambient conditions are below 40° F (4° C).

Solvent-based dampproofing mastic should conform to one of the following recognized standards:

Dampproofing mastic	ASTM D4479, Type I (for brushing or spraying application) ASTM D4586, Type I (for trowel application)
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#### **3.2.1.1 Installation**

Surfaces to receive solvent-based dampproofing mastic must be fully cured; broom-clean; adequately dry; and free of oil, form release agents, curing compounds, grease and loose materials.

Apply solvent-based mastic by spray, brush or trowel using a grade of product consistent with the method of application. Trowel applications should consist of one coat approximately 1/4 inch (6 mm) thick. Spray or brush applications should consist of two coats approximately 1/16 inch (1.6 mm) thick each, allowing material to dry between coats.

When a protection course is desired for below-grade applications, cover the dampproofing coating with a protection board as recommended by the membrane manufacturer. Allow dampproofing to cure at least 24 hours to prevent displacement before applying protection board.

#### **3.2.2 Bituminous-emulsion Dampproofing**

Bituminous-emulsion dampproofing materials are composed of water-soluble asphalt compounds containing various amounts of fiber reinforcement, depending on whether the material is to be installed by spray, brush or trowel. Unreinforced emulsions are also available.

Bituminous-emulsion dampproofing materials are used to reduce water or moisture infiltration on foundation walls below grade where drainage systems have been employed and on the interior side of masonry walls above grade.

Bituminous-emulsion dampproofing materials should not be stored or installed when ambient conditions are below

40° F (4° C). The completed application must be protected from water and from freezing until it is fully cured. Bituminous-emulsion dampproofing materials should conform to one of the following recognized standards:

Fibred, Bituminous Emulsion	ASTM D1227, Type I* or II, Class 1 ASTM D1187, Type I or II
Nonfibred Bituminous Emulsion	ASTM D1227, Type III, Class 1 ASTM D1187, Type I or II
*The materials defined by this specification may contain asbestos fibers.	

### 3.2.2.1 Installation

Surfaces to receive bituminous-emulsion dampproofing must be free of oil, form release agents, curing compounds, grease and loose materials. Dry surfaces may need to be dampened before applying the emulsion.

Apply bituminous emulsion by spray, brush or trowel using a grade of product consistent with the method of application. Trowel applications should consist of one coat approximately 1/8 inch (3 mm) thick. Spray or brush applications should consist of two coats approximately 1/16 inch (1.6 mm) thick each, allowing material to dry between coats. Some applications may employ a layer of reinforcing.

When a protection course is desired for below-grade applications, cover the dampproofing coating with a protection board as recommended by the membrane manufacturer. Allow dampproofing to cure at least 24 hours to prevent displacement before applying protection board. Protect application from rain and water until fully cured.

## 4. APPENDIX

### 4.1 Water Test Procedure

NRCA strongly recommends horizontal waterproofing membranes be water tested to prove their integrity before permitting subsequent construction. It is recommended to have the results of the water test witnessed and confirmed in writing in case a problem arises after job completion.

After the waterproofing test has been successfully completed, cover the membrane with a protection course, insulation and/or drainage course. Avoid all unnecessary traffic on the completed system before installation of the wearing surface or backfill. Install the wearing surface or backfill within 24 hours to 72 hours after completion of the waterproofing system. If surfaces are exposed to the sunlight or the waterproofing is being performed during extremely hot weather, installation of the protection course and backfilling should occur within 24 hours.

Before installation of overburden, a water test is conducted to evaluate whether a waterproofing system (but not a dampproofing system) is leak-free under hydrostatic (e.g., standing water) and/or nonhydrostatic conditions (e.g., flowing water). A water test is conducted in one of two ways.

- A water test is conducted by temporarily plugging or otherwise closing any deck drains and erecting temporary dams where required to retain water on the surface of the waterproofing material, then flooding the surface to a maximum depth of 2 inches (50 mm) at the high point and retaining the water for a minimum of 24 hours or as required by the manufacturer.
- A water test is conducted by applying continuously flowing water over the waterproofing membrane's surface for a minimum of 24 hours or as required by the manufacturer without closing drains or erecting dams.

Selecting the correct water test depends on the structural capacity of the deck/substrate and the slope of the deck/waterproofing system. However, job-site conditions may dictate the methodology of each project's water test. Decks without significant slope (e.g., a plaza deck) can be water tested using a flood test or flowing water test. Decks with significant slope (e.g., a parking garage ramp) can be water tested using a flowing water test. Determining the structural capacity of the deck is the responsibility of the designer.

Care must be taken so the weight of water retained does not exceed the load-carrying capacity of the structural deck and the height of the water does not exceed the height of the lowest flashing. The water should be allowed to remain on the waterproofing membrane for a minimum 24 hours for the flood test or for the flowing water test or as required by the manufacturer after which the areas beneath the membrane should be inspected for leaks. If leaks are detected, the test should be stopped, repairs made to the membrane and the area retested. The protection course should be installed over the tested area after successfully completing the water test unless a protection course is an integral part of the waterproofing system. The water test documents the performance of the waterproofing membrane before placement of overburden or topping material.

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# Waterproofing Construction Details

## Introduction

The Waterproofing Construction Details section of *The NRCA Roofing and Waterproofing Manual* has been written to provide technical information concerning the design and installation of construction details for quality waterproofing systems. This introduction is intended to supplement the special notes on the individual construction details.

Waterproofing practices vary considerably in different parts of North America because of the variety of conditions that exist and the various materials that are available for use. Many times, waterproofing systems are essentially customized, meaning they are designed for specific substrates and structures and applied on job sites. Adherence to the practices outlined in this manual is an option of each contracting firm. Area practices and the time-proven methods employed by individual firms are frequently given priority over these recommended general procedures.

*The NRCA Roofing and Waterproofing Manual* defines waterproofing as follows:

- Waterproofing: treatment of a surface or structure to prevent the passage of water under hydrostatic conditions

A waterproofing assembly consists of a substrate and a membrane and may incorporate a drainage/protection layer. Horizontal waterproofing assemblies often incorporate a topping for additional protection and/or aesthetic reasons.

Waterproofing systems can be divided into two primary categories: positive side and negative side, which are defined as follows:

- Positive (exterior) side waterproofing systems: a category of waterproofing systems where the waterproofing membrane/layer is installed between its substrate and the source or supply of water.
- Negative (interior) side waterproofing systems: a category of waterproofing systems where the substrate is between the waterproofing system and the source of water.

The waterproofing construction details provided in *The NRCA Roofing and Waterproofing Manual* provide design and installation information for:

- Asphalt Built-up Membrane
- Coal-tar Built-up Membrane
- Hot-fluid-applied Polymer-modified Asphalt Membrane
- APP- and SBS-polymer-modified Bitumen Sheet Membrane
- Self-adhering Polymer-modified Bitumen Sheet Membrane
- Butyl Rubber Membrane
- EPDM Membrane
- Polyvinyl Chloride (PVC) Membrane
- One- and Two-component, Fluid-applied Elastomeric Materials
- Bentonite Waterproofing
- Crystalline Waterproofing
- Cementitious Waterproofing
- Elastomeric Traffic Coatings

The information contained in this manual is intended to deal primarily with new construction and replacement waterproofing situations.

Because of the wide variety of waterproofing products, this manual cannot address all the different methods and practices for designing and installing all the products available to designers, contractors and building owners.

In this manual, the National Roofing Contractors Association (NRCA) attempts to present a consensus of opinions from knowledgeable, practicing waterproofing contractors throughout the United States as to the practices and procedures for good waterproofing. Where this manual provides specific suggestions or recommendations, it should be noted these may be a more conservative approach than may be commonly provided by individual product manufacturers, waterproofing designers or waterproofing contractors. The waterproofing design and application procedures included in this manual are recognized to be sound and time-proven and apply throughout the United States.

The recommendations contained in the Waterproofing Construction Details section of *The NRCA Roofing and Waterproofing Manual* should not be construed as the only methods for designing and installing waterproofing systems. Some design criteria and application techniques may vary according to climatic conditions, and some geographical areas employ “area practices” that are sound and time-proven. NRCA does not mean to imply by any statement or exclusion that time-tested and proven area practices are unsatisfactory or inappropriate. Users of this manual are encouraged to contact NRCA members in the geographical areas for specific advice concerning area practices and current technical information.

The Waterproofing Construction Details section is based on sheet membrane waterproofing systems. Detail specifics may need to be altered with other waterproofing system types.

NRCA suggests the Waterproofing Construction Details section of *The NRCA Roofing and Waterproofing Manual* be used in the design of waterproofing systems only after a number of criteria have been carefully considered, including:

- Climate and geographic location
- A building's intended use and design life expectancy
- Exterior and interior temperature, humidity and use conditions
- Code requirements
- Type and condition of substrate, including soil
- Structural system
- Slope and drainage
- Waterproofing system type including overburden
- Accessibility and building configuration
- Building movement
- Type and amount of insulation/protection/drainage needed
- Need for ventilation during installation
- Compatibility with adjacent building and/or system components
- Construction sequencing
- Worker safety
- Potential building additions
- Odors generated by certain system application methods
- Water table
- Construction traffic
- Penetrations

These criteria play important roles in the ultimate success or failure of every waterproofing assembly and must be considered by a designer to determine the appropriate components of a waterproofing assembly, applicable products and specifications, and construction details to be used.

In addition, a designer should be certain waterproofing product manufacturer's requirements are taken into account, as well as requirements of applicable insurance, building code enforcement and/or other regulatory agencies. It is recommended to consult material manufacturers' written specifications during the design of a waterproofing assembly.

Specific to a waterproofing system's construction details, NRCA recommends designers consider the following.

## **Waterstops**

Typically, waterstops are installed by a concrete contractor and are not the responsibility of the waterproofing contractor. In some cases, waterstops may be installed by the waterproofing contractor if the project conditions and schedule allow it. Waterstops require a minimum of 2 inches (50 mm) of concrete cover.

## **Drainage Systems**

For below-grade walls, drainage systems (e.g., perforated pipe set in aggregate bed) should be located at the low

points of a waterproofing system, which typically is adjacent to the bottom of the foundation wall, below any critical intersection of waterproofing systems and connected to a drainage field.

NRCA's details do not have a separate layer shown for filter fabric. The assumption is drainage layers are manufactured to have filter fabric included on the top surface and are often called geotextiles. Some assemblies, such as those with loose soil, require the use of a separate filter fabric.

## **Insulation**

Insulation used in horizontal applications with any type of overburden should have adequate compressive strength to support the expected loads. When insulation is used in vertical applications, the compressive strength is less critical, but the compressive strength should be capable of supporting the expected loads.

## **Termination Heights**

NRCA recommends waterproofing flashings terminate 4 inches (100 mm) above the top of the concrete wearing surface and be protected by counterflashing. However, in some cases where aesthetics are critical or damage is imminent, waterproofing membranes can be terminated at or just below the top of the concrete wearing surface with or without counterflashing and will perform.

## **Penetrations and Curbs**

The maximum amount of space (for horizontal and vertical applications) should be provided between pipes, walls and curbs to facilitate proper installation of waterproofing materials. NRCA recommends a minimum 12 inches (300 mm) of clearance between pipes, a minimum 12 inches (300 mm) of clearance between pipes and curbs or walls, and a minimum 12 inches (300 mm) of clearance between curbs and curbs or walls. Waterproofing systems have different installation methods that may require different spacings, and certain project conditions may not allow these recommended clearances. However, adequate space (i.e., clearance) is required for a mechanic to properly install the required flashings at these locations.

NRCA does not recommend a waterproofing system be used as direct support for HVAC units or other types of equipment. HVAC units and equipment should be supported on curbs and flashed appropriately.

## **Expansion Joints**

NRCA recommends expansion joints be elevated above the level of the membrane and drainage paths flow away from expansion joints. Elevated expansion joints can be installed where the thickness of the overburden is not critical, for example an elevated paver system or soil overburden. The thickness of soil can generally be reduced at the expansion joint, and there is typically adequate room under a paver system. Wood blocking used in elevated expansion joints is recommended to be preservative-treated.

Where an elevated expansion joint cannot be used, a low-profile expansion joint can be installed. A low-profile expansion joint is elevated to a reduced amount by eliminating the thickness of wood blocking. Drainage paths should be designed so water does not flow over an expansion joint.

When drainage paths must occur over an expansion joint, a level-surface expansion joint should be used so drainage is not prohibited. NRCA does not recommend the use of level-surface expansion joints unless all attempts at redirecting drainage paths have been exhausted or are not feasible.

NRCA's details are limited to a 1-inch- (25-mm-) wide maximum expansion joint.

## **Waterproofing Construction Detail Presumptions**

The majority of the waterproofing details are drawn in section or isometric because the selected view is more understandable and informative. Where both a section and isometric drawing are needed to provide the necessary information, both views are provided.

Structural members depicted in the Waterproofing Construction Details are for context only. NRCA is not attempting to depict properly sized or structurally sound structural members.

These details are considered a guide; manufacturer's recommendations must be followed.

For concrete wearing slabs at the intersection of a wearing slab and walls and curbs, a compressible strip with sealant and backer rod is recommended.

## **Other components**

Components may be provided or installed by other trades that are integrated into waterproofing systems and can be critical to the waterproof integrity of completed waterproofing systems. These components include:

- Metal counterflashings
- Flashings, drains and penetrations
- Drain heads, clamps and strainers
- Through-wall flashings
- Skylight components and flashings
- Seismic joints and related components
- Wood blocking and attachments
- Pipes or conduits and their supports
- Permanent safety anchors and guardrails
- Curbs
- Planters
- Overburden/topping materials

Note: The Waterproofing Construction Details are depicted on pages 1454-1505.

## APPENDIX 4

# Quality Control Guidelines for the Application of Built-up Roofing

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*Note:*

*This is a joint document produced by the Asphalt Roofing Manufacturers Association and NRCA. It was originally published in 1985. This document is not a specification. It does not supersede job specifications, which are the prerogative of the designer (specifier) and/or materials manufacturer. These guidelines merely provide general information for following accepted built-up roof system construction practices.*

## Statement of Purpose

This document provides guidelines for on-site evaluation of hot-applied built-up roof (BUR) systems during the application process.

## Introduction

This document addresses on-site evaluation guidelines during the application of hot-applied bituminous roof systems. It stresses thorough, continual inspections during construction to recognize and correct variances as they are detected. It provides guidelines to appraise the quality of application. It also gives information about the installation of specific components above a structural roof deck. Where appropriate, the guidelines describe expected variances in application parameters related to vapor retarders, insulations, fasteners, membranes, flashings and surfacings.

The application of bituminous built-up roofing is a construction process involving the skillful arrangement of several components in a specified process. The quality of workmanship during the application process is measured by application criteria and inspection procedures and is a critical element to roof system performance. Roof system performance also is determined by other factors including building design; job specifications and details; material quality and suitability for a specific application; and roof system maintenance.

Built-up roof system application is not an exact science. It is a craft involving people who work with a broad range of materials, designs, practices and techniques, climates and changing weather conditions. As a result, corrective action may be anticipated to some degree on every new roof system application. The Asphalt Roofing Manufacturers Association (ARMA) and National Roofing Contractors Association (NRCA) recognize the importance of these critical factors as they affect the quality of built-up roof systems.

The guidelines presented in this document are based on the technical knowledge and experience of practicing roofing professionals including roofing contractors, manufacturers and roofing technologists. Their collective experiences resulted in a consensus as expressed in this document.

Hot-applied Built-up Roofing Quality Control and Quality Assurance Application Checklists have been developed to assist quality control and quality assurance personnel who are performing inspections while roof system application is in progress. The checklists are located in Appendix 1.

Protected membrane roofing (PMR) and cold, liquid-applied built-up roof systems are not addressed in detail by this document.

## Terminology

Terminology used in this document can be found in Appendix 4, page 892B.

## Membrane Description

Built-up roof (BUR) membranes are composed of layers of bitumen or cold-applied adhesive that serve as the weatherproofing component of the membranes. Reinforcement plies, such as organic felt, glass-fiber ply sheet and polyester ply sheet, are installed between each layer of bitumen or cold-applied adhesive. Bituminous membranes are installed in multiple-ply configurations with bitumen or cold-applied adhesive between layers, or plies, of reinforcement to construct a “built-up” membrane.

The principal materials used for built-up roof system application are:

- Bitumen or cold-applied adhesive
- Roofing felts, or sheets, such as base sheets, ply sheets and cap sheets
- Surfacings
- Flashings and accessories

Bitumens include asphalt and coal tar. For roofing and waterproofing purposes, asphalts are graded into four types and coal-tars are graded into two types, both according to the temperature range at which they soften. Asphalt and coal tar also are available in polymer-modified products for both interply and top-pour applications. Asphalt and coal tar are available as solvent-based or cutback adhesives for adhering roof membrane plies and applying surfacings.

Built-up roofing and reinforcement sheets may serve as layers in a built-up roof system membrane. Some sheets only are used as base sheets or ply sheets; others only are used as cap or flashing sheets. Organic, bitumen-saturated roofing felts include asphalt-saturated organic felt (No. 15, perforated) and coal-tar-saturated organic felt (No. 15). Asphalt-saturated and coated roofing felts refer to coated organic felt base sheets. Glass-fiber mat roofing felts

are “impregnated.” These sheets include asphalt-coated, glass-fiber mat base sheets and venting base sheets; glass-fiber ply sheets (Type IV and Type VI); and coal-tar, glass-fiber ply sheets. Cold-applied roof system reinforcement sheets generally are unsaturated polyester ply sheets. Roll roofing materials generally used as the top layer in a BUR system consist of mineral-surfaced organic and asphalt-coated, glass-fiber cap sheets.

Surfacing materials protect bitumens, cold adhesives and roofing felts from direct sunlight and weather exposure. They also may provide fire resistance, thermal stability, reflectivity and impact resistance. Surfacing include aggregate, mineral-surfaced cap sheet, field-applied granules and liquid-applied coatings.

Flashings and accessories provide some of the finish components and detail work at curbs, penetrations, intersections and nonfield locations. These items may include polymer-modified base and cap sheet reinforcement sheets, bituminous cements, and polymer-modified cements and adhesives.

## **Quality Control and Quality Assurance**

Quality control and quality assurance are essential elements of BUR construction.

Quality control is performed by the roofing contractor. He designates an individual to be on-site during the entire application process, and that individual may be a working member of the crew. This person should understand the roof system being installed and have the authority to correct noncompliant work.

Quality assurance, when performed, is the responsibility of the building owner’s representative (e.g., architect, engineer, roof consultant) or a representative of the roof membrane manufacturer. The person performing quality assurance must understand the roof system being installed and methods of application. The quality-assurance person should tell the roofing contractor immediately if he observes noncompliant work so necessary corrective action can be taken. Written documentation should follow every inspection and copies should be distributed no later than the following day to field personnel and offices of all pertinent parties.

## **Visual Examination**

The most effective means to evaluate the quality of BUR system installation is by thorough, continual visual examination and evaluation at the time of application by a person who understands BUR technology and good workmanship practices.

The following lists will assist quality control and quality assurance inspectors before and during roof system inspections of an in-progress BUR system application. Many of the items referred to on these lists are addressed in further detail in this document. Detailed checklists are found in Appendix 1. If deficiencies are found during the inspection of a roof system application, corrective action should be taken as soon as practical.

Inspectors should visually examine the following components of the installation process before and during roof system application.

### **Before Application**

- Approved specifications and drawings are available for reference and review.
- All certifications and/or approvals have been received for the roof deck and roof system materials where applicable.
- Material manufacturers’ and suppliers’ literature, application specifications and recommendations are available for reference and review.
- Safety precautions and material safety data sheets (MSDSs) have been reviewed and are on-site during application.
- Specified and approved materials verified by on-site inspection of product labels are at the job site and visually suitable for application (e.g., packaging is not damaged, labels are intact, shelf life has not expired).
- Materials are stored according to the manufacturer’s and supplier’s recommendations (e.g., materials are stored at the proper temperature, covered if required, off the ground and on pallets).
- Equipment is in good working order and functioning properly (e.g., kettles, spreaders).
- When kettles, mop carts, luggers, etc., are being used for different bitumens, they should be used separately.
- Edge nailers, curbs, drains and penetrations have been properly installed in the areas to receive roof system application.
- Drainage patterns for proper roof membrane installation have been identified.
- When fastener pull-out tests are specified, tests have been conducted and the results have been approved by the specifier.

### **During Application**

- Weather, project conditions and installation sequencing are suitable for roof system application.
- The substrate is sufficiently dry, clean, reasonably smooth and suitably prepared to receive insulation and/or the roof membrane.
- Insulation boards are butted together with joints staggered and offset if more than one layer is being used.
- Insulation is firmly attached to the substrate or underlying insulation with the specified type and number of fasteners (if required) or embedded in bitumen or adhesive as specified.
- Temporary tie-ins are installed at the end of each day's work and removed before resuming the installation of insulation and/or the roof system.
- Bitumen is within the recommended equiviscous temperature (EVT) range at the point of the felt application, and the temperature is monitored throughout the day.
- Insulation application and flood-coat surfacing may require adjusted temperature of bitumen to assure the proper quantity of bitumen is applied.
- Temperature-measuring devices are readily available and working properly.
- If a mechanical spreader or felt layer is being used, it should be periodically checked to ensure all valves operate properly, holes to be used are open and the bitumen is flowing sufficiently for felt embedment.
- Appropriate-width felt layers or mechanical spreaders are used.
- For mopping applications, there is a continuous flow of bitumen in front of the roll being applied.
- Felts are being broomed or squeegeed (if required) into the hot bitumen so that a continuous film of bitumen exists between reinforcing plies.
- Foot or equipment traffic over freshly installed felt should not be allowed until the bitumen has been allowed to cool sufficiently.
- Felt laps are embedded in hot bitumen.
- The specified number of plies is being applied in shingle fashion and the plies are started at the low point of the roof or drain or as specified.
- Roofing plies are installed so sidelaps and endlaps are not bucking water.
- When envelopes are being used, they are installed at curbs, edges and deck penetrations.
- Field ply terminations are made watertight or membrane flashings are being installed along with each day's completed roof system area.
- The surfacing is being applied as specified.
- In high-traffic areas, protection is used over the newly completed membrane. (Note: Each trade is responsible for protecting the roof system[s] in its work area).
- When aggregate is used, it is continuously distributed and sufficiently embedded.
- Materials and installed roof system components are not being abused by other trades.

### **Decks—New Construction and Tear-off**

The quality control and quality assurance of roof decks is beyond the scope of this document; therefore, this document does not consider a roof deck as part of a built-up membrane roof system. However, there are important roof deck factors that affect final roof system performance. These factors include but are not limited to structural load capabilities, slope and drainage, expansion joints and flashing details.

The building owner, designer and deck manufacturer/installer are responsible for providing for the support, attachment, fastener pull-out testing (when specified), proper deck alignment, structural integrity, construction details, and provisions for expansion and contraction of the structural roof deck in a manner that will provide a stable base for the roof system.

Roofing contractors inspect and accept roof deck surfaces to schedule the roof system application. Attention to deck surface dryness and cleanliness during application also is essential.

## Decks—Existing Roof Substrates

When re-covering an existing roof system, the designer is responsible for performing an analysis of the structural roof deck (described under the section Decks—New Construction and Tear-off, page 880) including deck integrity, system compatibility, load capacity, damage, moisture condition, wind uplift and building code requirements.

<b>Evaluation</b>	
Visual examination at the time of application is the most effective means of evaluating new and existing roof system substrates. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
<b>Criterion</b>	<b>Corrective Action</b>
The substrate surface is reasonably smooth, sufficiently dry, clean, frost-free, and properly prepared to receive insulation and/or the roof membrane.	Delay installation until substrate conditions are acceptable or have been corrected.
Damaged or deteriorated decking has been identified, repaired or removed, and replaced.	Delay installation of the new roof system or temporarily cover the damaged or deteriorated section until the designated areas have been corrected.
The substrate is suitably prepared for a re-cover application. The surface should be suitably even and smooth.	As appropriate, cut, remove or repair blisters, ridges, splits and other defects that appear to affect the support attachment and/or placement of the new roof system.
Areas of the existing roof system that are determined to be unacceptable for re-cover have been removed. This includes but is not limited to moisture in the system and damaged insulation.	Delay installation of the new roof system until the designated areas have been removed and replaced.
All metal, masonry and existing substrate surfaces have been properly prepared and primed, if necessary.	Clean, prepare and prime metal, masonry and substrate surfaces designated by the designer or manufacturer/supplier before installing the membrane or flashing.
In re-cover situations, when adhering with bitumen or adhesives, the existing substrate's surface has been properly prepared and primed, if necessary.	Prepare and prime the substrates before installing membrane or flashings as designated by the designer or material manufacturer/supplier.

## Vapor Retarders

The entry of water vapor and its subsequent condensation can be detrimental to a roof system's performance. Vapor retarders can be used to inhibit migration of water vapor into a roof system. Determining the need for a vapor retarder, its compatibility with other materials and the details of its construction is the responsibility of the designer.

<b>Evaluation</b>	
Visual examination at the time of application is the most effective means of evaluating vapor retarder application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
<b>Criterion</b>	<b>Corrective Action</b>
The substrate surface is sufficiently dry, reasonably smooth and clear of potentially damaging objects.	Delay installation of the vapor retarder until substrate conditions are corrected.
Materials are protected from inclement weather and abuse from other trades.	Cover materials and remove damaged materials from the job site.
The location of the vapor retarder within the roof system is as specified.	Remove the vapor retarder from incorrect location and install it in the specified location.

<b>Criterion</b>	<b>Corrective Action</b>
Number of plies are as specified.	If the examination reveals missing plies, install additional plies to comply with the specification.
Hot bitumen/adhesives are applied as specified.	If the examination reveals improper adhesion to the substrate, remove and replace deficient areas. Surface damage may be corrected by installing additional plies in the affected area.
The vapor retarder is spread continuously throughout the deck plane and extends up vertical projections at least as high as the insulation thickness.	Install the specified vapor retarder to incomplete or noncontinuous areas.
End laps, side laps, openings and penetrations are sealed as specified.	Add additional plies or sealant to ensure adequate seals.
The vapor retarder is sealed at endlaps, sidelaps, the perimeter and penetrations as specified.	Adjust the work to ensure the perimeter detail and sealing complies with the specification.
The vapor retarder is tied into any other air and vapor retarders as specified.	Add additional plies or sealant to ensure adequate tie-in, and correct the work to comply with the specifications.

## Insulation

<b>Evaluation</b>	
Visual examination at the time of application is the most effective means of evaluating insulation application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
<b>Criterion</b>	<b>Corrective Action</b>
Insulation materials are as specified or approved.	Remove noncompliant materials from the project site.
Insulation is protected from inclement weather before, during and after installation.	Protect the material. Do not use damaged or wet material.
Finished surface of adjacent insulation boards should not be vertically offset more than 1/4 inch (6 mm).	Vertical offset of insulation boards may be corrected by one or more of the following: filling or leveling the gap with compatible material; adding tapered insulation as applicable; adding mechanical fasteners and plates; or, if shaving the insulation board, boards with facers should have the shaved area covered with a compatible material before ply/sheet installation.
No more insulation is installed than can be covered with the membrane on the same day.	Remove and replace all damaged materials. If sudden and unexpected weather or other unforeseen conditions prohibit installation of all specified plies/sheets over small sections of the roof on the same day, consult with the membrane manufacturer, roofing contractor and roof system designer for appropriate action.
When insulation is adhered in hot asphalt, the asphalt is applied at a rate sufficient to visually cover the surface area being bonded. The insulation is embedded in the asphalt while the asphalt still is hot and fluid. (Maximum size boards: 4 feet by 4 feet [1.2 m by 1.2 m].)	Remove unadhered insulation and replace it with properly embedded insulation.

Criterion	Corrective Action
When insulation is adhered with adhesives, apply it at the specified coverage rate and pattern. Follow recommended adhesive open times and application temperature requirements to ensure adequate adhesion. (Maximum size boards: 4 feet by 4 feet [1.2 m by 1.2 m].)	Replace unadhered insulation with properly attached insulation.
When insulation is mechanically attached, the number, pattern, spacing and placement of fasteners is as specified. Edges parallel to the direction of the metal deck flutes should rest on the top flange of the metal deck.	Install additional fasteners as needed and space appropriately.
Stagger insulation end joints unless otherwise specified.	Remove nonstaggered insulation boards. Adjust the boards to the appropriate stagger.
Insulation boards are butted together. Because of manufacturing tolerances, dimensional stability, variances during installation and the nature of insulation boards, some variance in joint spacing can be expected. Occasional gaps between boards not exceeding 1/4 inch (6 mm) are acceptable as long as the gaps are not continuous for more than the length of one insulation board.	Insulation gaps in excess of 1/4 inch (6 mm) shall be filled with appropriate insulation board or compatible material.
Insulation boards are reasonably square. To check for squareness, a diagonal measurement and evaluation should be made.	Do not use out-of-square boards without filling gaps in excess of 1/4 inch (6 mm). If the space between the boards appears to be wider than the anticipated variance because of out-of-square boards, consult the manufacturer or supplier.
At the end of each day's work, temporary tie-ins are applied to seal the insulation at the edge of the roof membrane from water entry. These temporary tie-ins are removed before the resumption of work.	Install temporary tie-ins at the end of each day's work. Replace damaged materials.

## Fasteners

Various types of plates and fasteners are used in the application of insulation, base sheets and flashings. They are specified by type, corrosion resistance, length and size.

Evaluation	
Visual examination at the time of application is the most effective means of evaluating fastener application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
The type, corrosion resistance, size, and length of fasteners and plates are as specified.	Immediately adjust to the proper fastener. Remove improper fasteners if necessary and add specified fasteners to meet attachment objectives.
The number, pattern, spacing and placement of fasteners is as specified; reasonable variances from spacing distances are to be expected.	Fastener deficiencies are corrected by installing additional fasteners as needed and spacing all fasteners appropriately.
Fasteners are properly driven.	Immediately adjust operations. Remove improperly driven fasteners if necessary and add fasteners to maintain the minimum number of fasteners with appropriate spacing.

## Bitumen

The specifier's appropriate selection of the bitumen type required for the slope of the roof and the quantities of interply moppings are critical factors. Interply bitumen should be applied in a continuous, uniform film within the equiviscous temperature (EVT) range. EVT is the temperature at which a bitumen attains the proper viscosity for application. The EVT range for the application of roof bitumens is the recommended temperature ( $\pm 25^{\circ}\text{F}$ ) ( $\pm 14^{\circ}\text{C}$ ) at the mop cart or mechanical spreader just before application. The EVT ranges for bitumen are defined as follows:

Asphalt:

- Mechanical Spreader Application: Temperature required to achieve viscosity of 75 centipoise ( $0.075\text{ Pa}\cdot\text{s}$ )  $\pm 25^{\circ}\text{F}$  ( $\pm 14^{\circ}\text{C}$ ).
- Mop Application: Temperature required to achieve viscosity of 125 centipoise ( $0.125\text{ Pa}\cdot\text{s}$ )  $\pm 25^{\circ}\text{F}$  ( $\pm 14^{\circ}\text{C}$ ).

Coal Tar:

- Mop and Mechanical Spreader Application: Temperature required to achieve viscosity of 25 centipoise ( $0.025\text{ Pa}\cdot\text{s}$ )  $\pm 25^{\circ}\text{F}$  ( $\pm 14^{\circ}\text{C}$ ).

It is reasonable to anticipate that bitumen applied within the above EVT guidelines generally will produce an interply weight of 18 pounds/ply to 32 pounds/ply per 100 square feet ( $0.9\text{ kg/m}^2$  -  $1.6\text{ kg/m}^2$ ).

Note: It should be realized that evaluations within this range do not assure adequate performance nor do evaluations outside this range assure inadequate performance.

EVT range information typically is found on the bitumen carton or bill of lading. If the EVT range for a particular bitumen is not known, check with the bitumen manufacturer for the correct application temperature range. If the EVT range cannot be readily determined, the following general recommended ranges can be used as an interim guideline:

Asphalt Type I, II, III and IV:

- Mechanical Spreader Application
  - Type I  $375^{\circ}\pm 25^{\circ}\text{F}$  ( $190^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
  - Type II  $400^{\circ}\pm 25^{\circ}\text{F}$  ( $205^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
  - Type III  $450^{\circ}\pm 25^{\circ}\text{F}$  ( $230^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
  - Type IV  $475^{\circ}\pm 25^{\circ}\text{F}$  ( $245^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
- Mop Application
  - Type I  $350^{\circ}\pm 25^{\circ}\text{F}$  ( $175^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
  - Type II  $400^{\circ}\pm 25^{\circ}\text{F}$  ( $205^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
  - Type III  $425^{\circ}\pm 25^{\circ}\text{F}$  ( $220^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )
  - Type IV  $450^{\circ}\pm 25^{\circ}\text{F}$  ( $230^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )

Coal Tar Type I:

- Mechanical Spreader and Mop Application
  - Type I  $360^{\circ}\pm 25^{\circ}\text{F}$  ( $180^{\circ}\text{C}\pm 14^{\circ}\text{C}$ )

## Bitumen Application

Evaluation	
Visual examination at the time of application is the most effective means of evaluating bitumen application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
Bitumen type is as specified. Verify labels on cartons or information on bill of lading.	Remove noncomplying bitumen from the job site.

Criterion	Corrective Action
Quantities of interply bitumen are as specified. Monitor EVT temperature at the point of application.	Assure bitumen is at the recommended application temperature and adjust rate of application.
Interply bitumen is applied in a continuous, uniform film.	Adjust work practices to provide a continuous film of bitumen.
Bitumen is being applied within the EVT range for the application method. Use thermometer or infra-red measuring device.	Adjust bitumen heating and/or handling to comply with EVT range.

## Membrane Construction

The physical characteristics of a membrane are dependent on the type and number of plies/sheets and the overall membrane construction. Membrane ply/sheet construction typically is defined by headlap, endlap and sidelap. Headlap is the distance of the overlap that exists between the lowermost and the uppermost plies/sheets of the shingled portion of a roof membrane when measured perpendicular to the long dimensions of the membrane. Endlap is the overlap distance that is measured from where one sheet/ply ends to where another begins. Sidelap is the overlap distance along the length of the sheet/ply where one sheet/ply overlaps the adjacent underlying sheet/ply. Exposure is the traverse dimension of a roofing element or component not overlapped by an adjacent element or component in a roof covering. The exposure of any ply in a built-up roof membrane may be computed by subtracting 2 inches (51mm) from the felt width then dividing the remaining felt width by the number of shingled plies. (See Figure 1.)

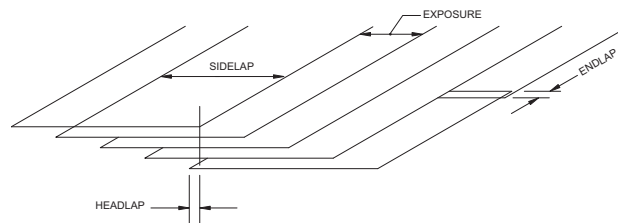


Figure 1 Headlap, endlap, sidelap and exposure.

When overlapping, some variance from specified values is to be expected. A variance on the plus side is not considered to be detrimental. On the minus side, minimum lap values should be maintained to preserve membrane integrity.

Evaluation	
Visual examination at the time of application is the most effective means of evaluating membrane construction. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
The installation of all plies of felt is completed on the same day.	If sudden and unexpected bad weather or other unforeseen conditions prohibit installation of all plies over small sections of the roof on the same day, consult with the membrane manufacturer, roofing contractor and roof system designer for appropriate action.
Roofing plies are installed so side laps and end laps are not bucking water.	Determine drainage patterns before application. Adjust application to ensure laps do not buck water drainage.
Number of plies of felt is as specified. Measurement of the exposed width (see Figure 1) of each ply establishes the exact number of plies without the need for a roof cut when all plies have been installed shingle fashion.	If the examination reveals missing plies, install a minimum of two additional plies of specified felt, shingle fashion, in the appropriate bitumen over the area determined to be deficient.

Criterion	Corrective Action
Felt is firmly and continuously embedded in a uniform application of hot bitumen.	Adjust work practices to ensure felt embedment, as follows: <ul style="list-style-type: none"> <li>• Keep bitumen in the recommended EVT application temperature range.</li> <li>• Use brooms or squeegees when necessary.</li> <li>• Embed the felt quickly while the bitumen is still hot.</li> </ul> If the examination reveals “fishmouths,” voids or bitumen displacement, cut and install a minimum of two additional plies of the specified felt, shingle fashion, in the appropriate bitumen over the area determined to be deficient.
Before mopping felts to concrete or masonry surfaces, properly prime the surface to ensure adequate adhesion. Allow the primer to dry thoroughly.	Prime surfaces before application.
Felt Laps: <ul style="list-style-type: none"> <li>• Headlap: as specified, less 1-inch (25-mm), or a 1-inch (25-mm) minimum, whichever is greater. (No maximum limit.)</li> <li>• End lap: as specified, less 2 inches (50 mm), or a 2-inch (50-mm) minimum, whichever is greater. (No maximum limit.)</li> <li>• Side lap: as specified, less 2 inches (50 mm), or a 2-inch (50-mm) minimum, whichever is greater. (No maximum limit.)</li> </ul>	If the examination reveals less than the minimum width headlaps, end laps or side laps, install a minimum of two additional plies of the roofing felt specified, shingle fashion, in the appropriate bitumen over the area determined to be deficient.
Organic felt is surfaced with the specified surfacing on the same day the membrane is applied.	Apply specified surfacing on the same day or obtain an alternate surfacing option from the roof designer. If weather or other conditions prohibit installation of the specified surfacing on the same day, apply a glaze coat of bitumen. When work resumes and surface conditions permit, examine the installation, remove all damaged material and proceed with the application of the specified surfacing.

## Membrane Base Flashings

There are a variety of base flashings, counterflashings, metal-edge flashings, copings and special flashing conditions. There are designs and materials that can be used to meet these conditions. Counterflashings are required to waterproof and/or protect the top of the membrane base flashing.

This section addresses base flashings, which extend from the surface of the roof up the vertical surface of a parapet, wall or curb. A cant strip should be specified and installed at the base of a vertical wall or penetration to provide a transition for the roofing material.

Consideration must be given to the height of base flashings and their termination at the parapet, wall or curb. Most manufacturers restrict base flashing height. Wall waterproofing or covering generally is not covered by roofing warranties; consult the manufacturer’s requirements for the warranty provisions.

Evaluation	
Visual examination at the time of application is the most effective means of evaluating membrane base flashing application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
Metal and masonry surfaces are primed with appropriate primer before bituminous material is applied.	Properly prime surfaces and allow primer to dry.

Criterion	Corrective Action
Base flashings are completed or made watertight as specified daily.	Adjust work practices to complete flashings daily or as specified.
The base flashing height is as specified. Recommended minimum flashing height above the membrane is 8 inches (200 mm).	<ul style="list-style-type: none"> <li>• Adjust work practices to bring work into specification.</li> <li>• Remove and replace nonconforming flashings.</li> </ul>
Base flashing plies/sheets should be firmly and continuously adhered with the specified bitumen or adhesive or by heat welding. (Refer to appropriate safety precautions for heat welding.)	Adjust work practices to meet specifications.
Cant strips are installed as specified.	Remove installed field plies and/or flashings and install cant strips as specified.
The specified types of flashing plies/sheets are installed.	Remove flashing materials that do not meet the specifications and replace them with the correct flashing ply/sheet.
Number of base flashing plies/sheets is as specified.	Install additional plies/sheets to meet the specifications.
Base flashings are securely fastened and/or attached as specified.	Properly secure the base flashing to comply with the specifications.
Laps in base flashings are continuously sealed.	<ul style="list-style-type: none"> <li>• Adjust work practices to meet the specifications.</li> <li>• Seal lap with adhesive or heat weld defective area.</li> </ul>
Top edge of base flashing is waterproofed daily.	Adjust work practices to comply with the criterion.
Surface coating protection is properly applied when specified.	Apply coating to comply with the specifications.

## Metal Flashings

For low-slope roof systems, metal flashings can be divided into three general categories: water conveyance flashings, watershedding independent flashings, and integral component and edge flashings.

Water conveyance flashings include exterior water collector boxes/heads, downspouts and gutters.

Watershedding independent flashings are attached, sealed and mounted above the top edge of the membrane base and penetration flashings. These flashings prevent moisture penetration into wall cavities, behind base flashings, through curb-mounted equipment and into/behind penetration flashings. Metal coping/cap flashing, surface-mounted counterflashing, curb caps, rain collars, heavy-gauge raised metal edge and through-wall flashings all are examples of watershedding independent flashings.

Integral component and edge flashings include metal roof jacks, pipe flashings, through-wall scuppers, electrical utility line penetration flashings and low profile—light gauge (i.e., 22 gauge, 24 gauge [0.76 mm, 0.61 mm])—metal edge flashings (“gravel stops” and “drip edges”). These types of flashings differ from the other categories in one primary way—they require integration/sealing of the membrane directly to their metal flanges. The other two categories of flashings (water conveyance flashings and watershedding independent flashings) are independent from the membrane. Metal flashing flanges typically provide a minimum 3½-inches (90-mm) sealing surface.

The following criteria address only integral component and edge flashings as they relate to BUR systems.

Evaluation	
Visual examination at the time of application is the most effective means of evaluating metal flashing application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
Metal sealing flanges are primed with the appropriate primer.	Properly prime them and allow them to dry before sealing them in.

Criterion	Corrective Action
Metal flanges are set in a bed of roof cement or molten modified bitumen compound and secured as specified.	Remove flashings and reinstall them as specified or add fasteners as required to meet specified spacing.
Metal edge laps are sealed as detailed before shipped-in with the specified sealant.	Remove flashings sufficiently to install inter-lap sealant.
Metal flanges are set into the completed membrane as specified.	Remove defective or noncompliant material and replace it as specified.
Edge metals are supported by continuous wood blocking/decking and flanges are not extended over insulated surfaces without wood blocking support.	Install wood blocking before the membrane and metal edge flashing are installed to support metal flanges adequately.

## Surfacing

Built-up roofing requires a final protective surfacing designed to shield the membrane from a variety of climatic conditions while also providing various degrees of resistance to fire, impact and physical wear. These surfacings include but are not limited to bitumen pour coat followed by embedment of aggregate, a hot asphalt glaze coat, cold-applied coating, field-applied granules or mineral-surfaced cap sheet. The surfacing should be applied according to the specifications. Surface preparations and aging (weathering) periods may be required before application of protective coatings. Consult with the appropriate manufacturers/suppliers for their recommended guidelines.

Evaluation	
Visual examination at the time of application is the most effective means of evaluating roof surfacing application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
The surface of the existing membrane is sufficiently dry, clean, frost-free and prepared for application of a protective surface coating.	Delay installation until surface conditions are corrected.
At the time of application, aggregate should be reasonably dry and free of excessive fines, dirt or other foreign matter and adhere to hot bitumen.	Replace material on the job or wait until material is adequately dry.
Coal tar flood coat application rate is as specified—normally approximately 75 pounds per 100 square feet (3.5 kg/m <sup>2</sup> ).	Immediately adjust the application rate to ensure a continuous film, and reapply the pour coat on deficient areas.
Asphalt flood coat application rate is as specified—normally approximately 60 pounds per 100 square feet (3 kg/m <sup>2</sup> ).	Immediately adjust the application rate to ensure a continuous film, and reapply flood coat on deficient areas.
Surfacing aggregate weight is normally not less than 400 pounds per 100 square feet (20 kg/m <sup>2</sup> ), with an adhered aggregate weight of approximately 200 feet (10 kg/m <sup>2</sup> ).	Immediately adjust operations to ensure proper embedment of the specified amount. Whenever visual observation indicates an inadequate amount of adhered aggregate, loose aggregate is to be removed, and then the flood coat and aggregate are to be reapplied.
Surfacing slag weight is normally not less than 300 pounds per 100 square feet (15 kg/m <sup>2</sup> ), with an adhered slag weight of approximately 150 pounds per 100 square feet (7.5 kg/m <sup>2</sup> ).	Immediately adjust to ensure proper embedment of the specified amount. Whenever visual observation indicates an inadequate amount of adhered slag, loose slag is to be removed, and then the pour coat and slag are to be reapplied.
Asphalt glaze coat application rate is as specified, with a maximum of approximately 20 pounds per 100 square feet (1 kg/m <sup>2</sup> ). Asphalt is applied in a thin, smooth, uniform, continuous bonded film.	Immediately adjust to ensure a uniform continuous thin film. If visual observations reveal skips and voids (holidays), reapply the glaze coat over the holidays.

Criterion	Corrective Action
Cold-applied coating application rate is as specified and is applied in a uniform continuous film. A wet film gauge may be used to determine thickness. Reasonable variances from specified quantities are to be expected.	Adjust application to comply with the specified quantity. On deficient areas, reapply the coating. Some coatings may require two applications.
Granules are applied in a continuous layer of wet coating at the specified coverage rate to achieve a continuous embedded surfacing. (Granule weight is normally approximately 60 pounds per 100 square feet [3 kg/m <sup>2</sup> ].)	Immediately adjust operations to ensure embedment of the specified amount. Whenever visual observation indicates an insufficient amount of adhered granules, loose granules are to be removed, and then coating and granules are to be reapplied.
Nonpolymer modified bitumen cap sheets: minimum 2 inches (50 mm) side laps and minimum 4 inches (100 mm) end laps with visible bitumen bleedout with sealed laps.	Immediately make adjustments to ensure continuous moppings of hot asphalt and all laps are sealed.
Cap sheets are installed so side laps and end laps are not bucking water.	Adjust application to ensure laps do not buck water drainage.

## **Appendix 1—Hot-applied Built-up Roofing Quality Control and Quality Assurance Application Checklists**

These checklists are offered to assist quality control and quality assurance inspectors during roof system inspection while roof system application is in progress. They are not specifications, and they do not cover every detail of BUR system application inspection procedures.

The intent of these checklists is to provide guidelines for quality control and quality assurance inspectors by highlighting the key application areas affecting successful BUR system application.

### **Before Application**

- Approved specifications and drawings are available for reference and review.
- All certifications and/or approvals have been received for the roof deck and roofing materials where applicable.
- Material manufacturers' and suppliers' literature, application specifications and recommendations are available for reference and review.
- Safety precautions and material safety data sheets (MSDSs) have been reviewed and are on-site during application.
- Specified and approved materials verified by on-site inspection of product labels are at the job site and visually suitable for application (e.g., packaging is not damaged, labels are intact, shelf life has not expired).
- Materials are stored according to the manufacturer's and supplier's recommendations (e.g., materials are stored at the proper temperature, covered if required, off the ground on pallets).
- Equipment is in good working order and functioning properly (e.g., kettles, spreaders).
- When kettles, mop carts, luggers, etc., are being used for different bitumens, they should be used separately.
- Edge nailers, curbs, drains and penetrations have been properly installed in the areas to receive roof system application.
- Drainage patterns for proper roof membrane installation have been identified.
- When fastener pull-out tests are specified, tests have been conducted and the results have been approved by the specifier.

### **During Application**

- Weather, project conditions and installation sequencing are suitable for roof system application.
- The substrate is sufficiently dry, clean, reasonably smooth and suitably prepared to receive insulation and/or the roof membrane.
- Insulation boards are butted together with joints staggered and offset when more than one layer is being used.
- Insulation is firmly attached to the substrate or underlying insulation with specified type and number of fasteners (if required) or properly embedded in bitumen or adhesive as specified.
- Temporary tie-ins are installed at the end of each day's work and removed before resuming the installation of insulation and/or the roof system.
- Bitumen is within the recommended EVT range at the point of the felt application, and the temperature is monitored throughout the day.
- Insulation application and flood-coat surfacing may require adjusted temperature of bitumen to assure the proper quantity of bitumen is applied.
- Temperature-measuring devices are readily available and working properly.
- If a mechanical spreader or felt layer is being used, it should be checked periodically to ensure all valves operate properly, holes to be used are open and the bitumen is flowing sufficiently for proper felt embedment.
- Appropriate-width felt layers or mechanical spreaders are used.
- For mopping applications, there is a continuous flow of bitumen in front of the roll being applied.
- Felts are being broomed or squeegeed (if required) into the hot bitumen so a continuous film of bitumen exists between reinforcing plies.

- ❑ Foot or equipment traffic over freshly installed felt should not be allowed until the bitumen has been allowed to cool sufficiently.
- ❑ Felt laps are embedded in hot bitumen.
- ❑ The specified number of plies is being applied in shingle fashion and the plies are started at low point of the roof or drain or as specified.
- ❑ Roofing plies are installed so sidelaps and endlaps are not bucking water.
- ❑ When envelopes are being used, they are installed at curbs, edges and deck penetrations.
- ❑ Field ply terminations are made watertight or membrane flashings are being installed along with each day's completed roof system area.
- ❑ The surfacing is being applied as specified.
- ❑ In high-traffic areas, protection is used over newly completed membrane. (Note: Each trade is responsible for protecting the roof system[s] in its work area).
- ❑ When aggregate is used, it is continuously distributed and sufficiently embedded.
- ❑ Materials and installed roof system components are not being abused by other trades.

## **Appendix 2—Test Cuts**

Test cuts are not considered to be a part of a routine quality control or quality assurance program. Test cuts should not be substituted for in-process quality control and quality assurance provided by continuous visual examination.

Test cuts may assist in the evaluation of the extent and magnitude of problems observed during routine quality control or quality assurance.

When test cuts are taken, a minimum of three random samples from the roof system applied that day should be taken before the installation of surfacing material. Sampling should be done in accordance with ASTM D 3617, “Sampling and Analysis of New Built-Up Membranes.” ASTM D 3617 only applies to 36-inch wide ply sheet membranes, not metric-width material. When a test cut is made, the cut immediately should be measured and weighed. The results must then be calculated and an evaluation should be made about the continuity of the interply bitumen. The test cut sample should then be put back in place and re-adhered. Additional plies equal to the original number of plies specified should then be applied over the sample location feathered out on to the adjacent membrane before proceeding to install surfacing materials.

Normally, small test cuts are taken from large areas of a built-up roofing membrane. Test cuts may not represent the overall membrane construction. The greater the quantity of test cuts, the more accurate the evaluation may be. However, this may result in more damage to the in-place built-up roof membrane. Focusing solely on roof test cuts may, however, give undue emphasis to the weight of interply bitumen while ignoring other critical aspects of the roof system.

Care must be taken to protect the sample from damage. A small loss of even part of the test cut can have a dramatic effect on the test results.

### **Appendix 3—Interply Analysis**

The interply void examination is to be based on visual analysis of a rectangular roof cut specimen obtained before surfacing in accordance with ASTM D 3617 using a 4 inch by 40 inch (100 mm by 1 m) sample size. The lengths of all voids visible at the edge of the specimen are to be measured and compared against the following criteria:

- Overlapping voids between two or more plies are not acceptable.
- The maximum acceptable length of any individual void that is encapsulated in bitumen is 2 inches (50 mm).
- The total length of all voids that are encapsulated in bitumen shall not be greater than 4 inches (100 mm) between any two plies.
- Dry voids (the absence of bitumen between plies) are not acceptable.
- Voids continuous through the specimen are not acceptable.
- Visual interply moisture in voids is not acceptable.

If observation and measurement indicate a lack of proper quantities of bitumen, additional ASTM D 3617 test cuts should be taken at four locations diagonally—10 feet (3 m) in each direction—from the original test cut. Repeat this step until the deficiency no longer is apparent.

(Note: See “Membrane Construction, page 885,” in this document for Criterion and Corrective Action.)

## Appendix 4—Terminology

**Built-up roof (BUR):** A continuous, semiflexible roof membrane consisting of multiple plies of saturated felts, coated felts, fabrics or mats assembled in place with alternate layers of bitumen and surfaced with mineral aggregate, bituminous materials, a liquid-applied coating or a granule-surfaced cap sheet.

**Cold Process Built-up roof:** A continuous, semi-flexible roof membrane, consisting of a ply or plies of felts, mats or other reinforcement fabrics that are laminated together with alternate layers of liquid-applied (usually asphalt-solvent based) roof cements or adhesives installed at ambient or a slightly elevated temperature.

**Equiviscous temperature (EVT):** The temperature at which a bitumen attains the proper viscosity for built-up membrane application.

**Equiviscous temperature (EVT) application range:** The recommended bitumen application temperature range. The range is approximately 25° F (14° C) above or below the EVT, giving a range of approximately 50° F (28° C). The EVT range temperature is measured in the mop cart of a mechanical spreader just before application of the bitumen to the substrate.

**Fishmouth** (also referred to as an edge wrinkle): A half-cylindrical or half-conical shaped opening or void in a lapped edge or seam, usually caused by wrinkling or shifting of ply sheets during installation.

**Membrane:** A flexible or semiflexible material used in multiple plies in a BUR system bonded with bitumen, which functions as the waterproofing component in a roofing or waterproofing assembly and whose primary function is the exclusion of water.

**Modified bitumen:** (1) A bitumen modified by including one or more polymers (e.g., atactic polypropylene, styrene butadiene styrene); (2) composite sheets consisting of a polymer-modified bitumen often reinforced with various types of mats or films and sometimes surfaced with films, foils or mineral granules.

**Phased application:** The installation of a roofing or waterproofing system during two or more separate time intervals or different days. Application of surfacings at different time intervals are typically not considered phased application. A roof system not installed in a continuous operation.

**Ply:** A layer of felt or ply sheet in a built-up roof membrane or roof system.

**Roof system:** A system of interacting roof components, generally consisting of a membrane or primary roof covering and roof insulation (not including the roof deck) designed to weatherproof and sometimes improve a building's thermal resistance.

**Temporary tie-in:** The transitional seal used to terminate a roofing or waterproofing application by forming a water-tight seal with the substrate, membrane or adjacent roof or waterproofing system.

**Viscosity:** The resistance of a material to flow under stress. For bitumen, it is measured in centipoise. The optimum viscosity for bitumen is achieved when the bitumen is applied within the EVT range.

## APPENDIX 5

# Quality Control Guidelines for the Application of Polymer-modified Bitumen Roofing

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**Note:**

*This is a joint document produced by the Asphalt Roofing Manufacturers Association and NRCA. It was originally published in 1985. This document is not a specification. It does not supersede job specifications, which are the prerogative of the designer (specifier) and/or materials manufacturer. These guidelines merely provide general information for following accepted built-up roof system construction practices.*

## Statement of Purpose

This document provides guidelines for on-site evaluation of polymer-modified bitumen roof systems during the application process.

## Introduction

This document addresses on-site evaluation guidelines during the application of polymer-modified bitumen roof systems. It stresses thorough, continual inspections during construction to recognize and correct variances as they are detected. It provides guidelines to appraise quality aspects of application. It also gives information about the installation of specific components above a structural deck. Where appropriate, the guidelines describe expected variances in application parameters related to vapor retarders, insulations, fasteners, membranes, flashings and surfacings.

The application of modified bituminous roofing is a construction process involving the skillful arrangement of several components in a specified process. The quality of workmanship during the application process is measured by application criteria and inspection procedures and is a critical element to roof system performance. Roof system performance also is determined by other factors including building design; job specifications and details; material quality and suitability for a specific application; and roof system maintenance.

Modified bitumen roof system application is not an exact science. It is a craft involving people who work with a broad range of materials, designs, practices and techniques, climates and changing weather conditions. As a result, corrective action may be anticipated to some degree for every new roof system application. The Asphalt Roofing Manufacturers Association (ARMA) and National Roofing Contractors Association (NRCA) recognize the importance of these critical factors as they affect the quality of modified bitumen roof systems.

The guidelines presented in this document are based on the technical knowledge and experience of practicing roofing professionals including roofing contractors, manufacturers and roofing technologists. Their collective experiences resulted in a consensus as expressed in this document.

Modified Bitumen Roofing Quality Control and Quality Assurance Application Checklists have been developed to assist quality control and quality assurance personnel who are performing inspections while roof system application is in progress. The checklists are located in Appendix 1, page 910.

Styrene ethylene butylene styrene (SEBS) modified mopping asphalt also can be field-applied between multiple reinforcing plies to construct a modified bitumen/BUR membrane. Because an SEBS system is a modified built-up roof system, systems with this configuration are not addressed in detail by this document. Additionally, protected membrane roofing (PMR), self-adhering modified bitumen (SAM) and coal-tar modified bitumen roof systems are not addressed in detail by this document.

## Terminology

Terminology used in this document can be found in Appendix 4, page 914.

## Membrane Description

Modified bitumen sheet materials are primarily composed of polymer modified bitumen reinforced with one or more layers of scrim (woven, nonwoven or knitted fabric) such as polyester, glass fiber or a combination of both. Assembled in a factory using high quality control standards, modified bitumen sheets are manufactured to have uniform thickness and consistent physical properties throughout the sheet. The finished roof system may consist of one or more modified bitumen sheets or be composed of combinations of built-up roofing (BUR) felts and one or more modified bitumen sheets; this is commonly referred to as a hybrid system. The type of substrate and the performance objectives influence the selection of the construction specification of modified bitumen roof membrane systems.

Because of the variety of modifiers and types of reinforcements and surfacings available, there are modified bitumen membranes tailored to almost every type of construction design and climate. They can be used for new roofing or reroofing of commercial buildings, residential high-rise buildings, domes, spires, and most categories of low-slope or steep-slope roofing.

Asphalt used in manufacturing modified bitumen sheets generally is modified with one of two primary modifiers, atactic polypropylene (APP) or styrene butadiene styrene (SBS). There are additional modifiers used to a much lesser extent. Modifiers create a uniform matrix within the asphalt that alters the physical properties of the asphalt.

The combination of asphalt, modifiers and reinforcements determines the characteristics of a specific modified bitumen membrane. To obtain the optimum roof system, the designer, building owner and/or contractor should understand the dynamics of the roof, as well as the roof system when specifying APP, SBS or other modified bitumen roof systems.

## Quality Control and Quality Assurance

Quality control and quality assurance are essential elements of modified bitumen roof system construction.

Quality control is performed by the roofing contractor. He designates an individual to be on-site during the entire application process, and that individual may be a working member of the crew. This person should understand the roof system being installed and have the authority to correct noncompliant work.

Quality assurance, when performed, is the responsibility of the building owner's representative (e.g., architect, engineer, roof consultant) or a representative of the roof membrane manufacturer. The person performing quality assurance must understand the roof system being installed and methods of application. The quality-assurance person should tell the roofing contractor immediately if he observes noncompliant work so necessary corrective action can be taken. Written documentation should follow every inspection and copies should be distributed no later than the following day to field personnel and offices of all pertinent parties.

## Visual Examination

The most effective means to evaluate the quality of a modified bitumen roof system installation is by thorough, continual visual examination and evaluation at the time of application by a person who understands polymer modified bitumen roofing technology and good workmanship practices.

The following lists will assist quality control and quality assurance inspectors before and during roof inspections of an in-progress modified bitumen roof system application. Many of the items referred to on these lists are discussed in further detail in the following sections of this document. Detailed checklists are found in Appendix 1, page 910. If deficiencies are found during the inspection of a roof system application, corrective action should be taken as soon as practical.

Inspectors should visually examine the following components of the installation process before and during roof system application.

### Before Application

- Approved specifications and drawings are available for reference and review.
- All certifications and/or approvals have been received for the roof deck and roof system materials where applicable.
- Material manufacturers' and suppliers' literature and application specifications and recommendations are available for reference and review.
- Safety precautions and material safety data sheets (MSDSs) have been reviewed and are on-site during application.
- Specified and approved materials verified by on-site inspection of product labels are at the job site and visually suitable for application (e.g., packaging is not damaged, labels are intact, shelf life has not expired).
- Materials are stored according to manufacturer's and supplier's recommendations (e.g., materials are stored at the proper temperature, covered if required, off the ground on pallets).
- Adhesives and roll goods should be warmed or stored per manufacturer's recommendations for cool-weather application (typically below 50° F [10° C]).
- Equipment is in good working order and functioning properly (e.g., kettles, torches, sprayers, fire extinguishers, heaters, hot air welders).
- Edge nailers, curbs, drains and penetrations have been properly installed in the areas to receive roof system application.
- Drainage patterns for proper roof membrane installation have been identified.
- When fastener pull-out tests are specified, tests have been conducted and the results have been approved by the specifier.

### During Application

- Weather, project conditions and installation sequencing and job conditions are suitable for the roof system application.
- The substrate is sufficiently dry, clean, reasonably smooth and suitably prepared to receive insulation and/or the roof membrane.
- Insulation boards are butted together with joints staggered and offset if more than one layer is being used.
- Insulation is firmly attached to the substrate or underlying insulation with the specified type and number of fasten-

ers or is embedded in the specified bitumen or adhesive as specified.

- Asphalt is within the recommended temperature range at the point of application; asphalt temperature is monitored throughout the day.
- Adhesive is being applied at the specified coverage rate.
- Temperature-measuring devices are readily available and working properly.
- If a mechanical spreader is being used, it should be periodically checked to ensure all valves operate properly, holes to be used are open and the bitumen is flowing sufficiently for proper ply/sheet embedment.
- For hot asphalt applications, there is a continuous flow of asphalt in front of the roll being applied.
- Manufacturers of modified bitumen sheets should provide written recommendations for mop lead, and if it is more than 5 feet (1.5 m), caution is urged.
- Plies/sheets are being embedded into the hot asphalt/adhesive.
- Side and end laps are fully embedded and continuously bonded.
- The specified number of plies/sheets are being applied in shingle fashion and started at the low point of the roof or drain or as specified.
- Roofing plies/sheets are installed so sidelaps and endlaps are not bucking water.
- When envelopes are being used, they are installed at curbs, edges and deck penetrations.
- Temporary tie-ins are installed at the end of each day's work and are removed before resuming the installation of insulation and/or roof system.
- Field ply terminations are made watertight or membrane flashings are being installed along with each day's completed roof area.
- The surfacing is being applied as specified.
- In high traffic areas, protection is being used over newly completed membrane. Solvent-based adhesives may make finished membranes temporarily "tender" requiring additional precautions for subsequent traffic and storage. (Note: Each trade is responsible for protecting the roof system(s) in its work area.)
- Materials and installed roof system components are not being abused by other trades.

## Decks—New Construction and Tear-off

The quality control and quality assurance of roof decks is beyond the scope of this document; therefore, this document does not consider a roof deck as part of a modified bitumen roof system. However, there are important roof deck factors that affect final roof system performance. These factors include but are not limited to structural load capabilities, slope and drainage, expansion joints and flashing details.

The building owner, designer and deck manufacturer/installer are responsible for providing the support, attachment, fastener pull-out testing (when specified), proper deck alignment, structural integrity, smoothness, construction details and provisions for expansion and contraction of the structural roof deck in a manner that will provide a stable base for the roof system.

Roofing contractors inspect and accept roof deck surfaces to schedule the roof system. Attention to deck surface dryness and cleanliness during application also is essential.

## Decks—Existing Roof Substrates

When re-covering an existing roof system, the designer is responsible for performing an analysis of the structural roof deck (described under the section Decks—New Construction and Tear-off, page 896), including deck integrity, system compatibility, load capacity, drainage, moisture conditions, wind uplift and building code requirements.

### Evaluation

Visual examination at the time of application is the most effective means of evaluating new and existing roof system substrates. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

<b>Criterion</b>	<b>Corrective Action</b>
The substrate surface is sufficiently dry, clean, reasonably smooth, frost-free and properly prepared to receive insulation and/or the roof membrane.	Delay installation until substrate conditions are acceptable or have been corrected.
Damaged or deteriorated decking has been identified, repaired or removed, and replaced.	Delay installation of the new roof system or temporarily cover the damaged or deteriorated section until the designated areas have been corrected.
The substrate is suitably prepared for re-cover application. The surface should be suitably even and smooth.	As appropriate, cut, remove or repair blisters, ridges, splits and other defects that appear likely to affect the support, attachment and/or placement of the new roof system.
Areas of the existing roof system that are determined to be unacceptable for re-cover have been removed. This includes but is not limited to moisture in the system and damaged insulation.	Delay installation of the new roof system until the designated areas have been removed and replaced.
Metal, masonry and existing substrate surfaces have been properly prepared and primed, if necessary.	Clean, prepare and prime metal, masonry and substrate surfaces designated by the designer or manufacturer/supplier before installing the membrane or flashing.
Existing base flashings have been removed. (Note: In some situations, it may be impractical to remove fully adhered existing base flashings. The designer must address these situations.)	Bring work into compliance.

## Vapor Retarders

The entry of water vapor and its subsequent condensation can be detrimental to a roof system's performance. Vapor retarders can be used to inhibit migration of water vapor into a roof system. Determining the need for a vapor retarder, its compatibility with other materials and the details of its construction is the responsibility of the designer.

<b>Evaluation</b>	
Visual examination at the time of application is the most effective means of evaluating vapor retarder application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
<b>Criterion</b>	<b>Corrective Action</b>
The substrate surface is sufficiently dry, suitably smooth and clear of potentially damaging objects.	Delay installation of the vapor retarder until substrate conditions are corrected.
Materials are protected from inclement weather and abuse from other trades.	Cover materials and remove damaged materials from the job site.
The location of the vapor retarder within the roof system is as specified.	Remove the vapor retarder from incorrect areas and install it in the specified location.
Number of plies are as specified.	If examination reveals missing plies, install additional plies to comply with the specification.
Application by hot bitumen, adhesives or heat welding is as specified.	If the examination reveals improper adhesion to the substrate, remove and replace deficient areas. Surface damage may be corrected by installing additional plies in the affected area.
The vapor retarder is spread continuously throughout the deck plane and extends up vertical projections at least as high as the insulation thickness.	Install the specified vapor retarder to incomplete or noncontinuous areas.

Criterion	Corrective Action
Endlaps, sidelaps, openings and penetrations are sealed as specified.	Add additional plies or sealant to ensure adequate seals.
The vapor retarder is sealed at the perimeter and penetrations as specified.	Adjust the work to ensure the perimeter detail and sealing complies with the specification.
The vapor retarder is tied into any other air and vapor retarders as specified.	Add additional plies or sealant to ensure adequate tie-in, and correct the work to comply with the specification.

## Insulation

Evaluation	
Visual examination at the time of application is the most effective means of evaluating insulation application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
Insulation materials are as specified or approved.	Remove noncompliant materials from the project site.
Insulation is protected from inclement weather before, during and after installation.	Protect the material. Do not use damaged or wet material.
Finished surface of adjacent insulation boards should not be vertically offset more than 1/4 inch (6 mm).	Vertical offset of insulation boards may be corrected by one or more of the following: filling or leveling the gap with compatible material; adding tapered insulation as applicable; adding mechanical fasteners and plates; or, if shaving the insulation board, boards with facers should have the shaved area covered with a compatible material before ply/sheet installation.
No more insulation is installed than can be covered with the membrane on the same day.	Remove and replace all damaged materials. If sudden and unexpected weather or other unforeseen conditions prohibit installation of all specified plies/sheets over small sections of the roof on the same day, consult with the membrane manufacturer, roofing contractor and roof system designer for appropriate action.
When insulation is adhered in hot asphalt, the asphalt is applied at a rate sufficient to visually cover the surface area being bonded. The insulation is embedded in the asphalt while the asphalt still is hot and fluid. (Maximum size boards: 4 feet by 4 feet [1.2 m by 1.2 m].)	Remove unadhered insulation and replace it with properly embedded insulation.
When insulation is adhered with adhesives, apply it at the specified coverage rate and pattern. Follow recommended adhesive open times and application temperature requirements to ensure adequate adhesion. (Maximum size boards: 4 feet by 4 feet [1.2 m by 1.2 m].)	Replace unadhered insulation with properly attached insulation or provide supplemental attachments as appropriate.
When insulation is mechanically attached, the number, pattern, spacing and placement of fasteners is as specified. Edges parallel to the direction of the metal deck flutes should rest on the top flange of the metal deck.	Install additional fasteners as needed and space appropriately.
Stagger insulation end joints unless otherwise specified.	Remove nonstaggered insulation boards. Adjust the boards to the appropriate stagger.

Criterion	Corrective Action
Insulation boards are butted together. Because of manufacturing tolerances, dimensional stability, variances during installation and the nature of insulation boards, some variance in joint spacing can be expected. Occasional gaps between boards not exceeding 1/4 inch (6 mm) are acceptable as long as the gaps are not continuous for more than the length of one insulation board.	Insulation gaps in excess of 1/4 inch (6 mm) shall be filled with appropriate insulation board or compatible material.
Insulation boards are reasonably square. To check for squareness, a diagonal measurement and evaluation should be made.	Do not use out-of-square boards without filling gaps in excess of 1/4 inch (6 mm). If the space between the boards appears to be wider than the anticipated variance because of out-of-square boards, consult the manufacturer or supplier.
At the end of each day's work, temporary tie-ins are applied to seal the insulation at the edge of the roof membrane from water entry. These temporary tie-ins are removed before the resumption of work.	Install temporary tie-ins at the end of each day's work. Replace damaged materials.

## Fasteners

Various types of plates and fasteners are used in the application of insulation, base sheets and flashings. They are specified by type, corrosion resistance, length and size.

Evaluation	
Visual examination at the time of application is the most effective means of evaluating fastener application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
The type, corrosion resistance, size, and length of fasteners and plates are as specified.	Immediately adjust to the proper fastener. Remove improper fasteners if necessary and add specified fasteners to meet attachment objectives.
The number, pattern, spacing and placement of fasteners is as specified; reasonable variances from spacing distances are to be expected.	Fastener deficiencies are corrected by installing additional fasteners as needed and spacing all fasteners appropriately.
Fasteners are properly driven.	Immediately adjust operations. Remove improperly driven fasteners if necessary and add fasteners to maintain the minimum number of fasteners with appropriate spacing.

## Mopping Asphalt for Nonmodified Glass-fiber Ply Sheets (ASTM D 2178) and Glass-fiber Base Sheets (ASTM D 4601)

The specifier's appropriate selection of the asphalt type required for the slope of the roof and the quantities of interply moppings are critical factors. Interply asphalt should be applied in a continuous, uniform film within the equiviscous temperature (EVT) range. EVT is the temperature at which asphalt attains the proper viscosity for application. The EVT range for the application of roof bitumens is the recommended temperature ( $\pm 25^{\circ}\text{F}$  [ $14^{\circ}\text{C}$ ]) at the mop cart or mechanical spreader just before application. The EVT ranges for asphalt are as follows:

### Asphalt

- Mechanical Spreader Application: Temperature required to achieve viscosity of 75 centipoise (0.075 Pa•s)  $\pm 25^{\circ}\text{F}$  ( $14^{\circ}\text{C}$ ).

- Mop Application: Temperature required to achieve viscosity of 125 centipoise (0.125 Pa•s) ± 25°F (14° C).

It is reasonable to anticipate that asphalt applied within the above EVT guidelines generally will produce an interply weight of 18 pounds to 32 pounds per 100 square feet (0.9-1.6 kg/ply/m<sup>2</sup>).

(Note: It should be realized that evaluations within this range do not ensure adequate performance nor do evaluations outside this range ensure inadequate performance.)

EVT range information typically is found on the asphalt carton or bill of lading. If the EVT range for a particular asphalt is not known, check with the asphalt manufacturer for the correct application temperature range. If the EVT range cannot be readily determined, the following general recommended ranges can be used as interim guidelines:

**Asphalt Type**

- Mechanical Spreader Application
  - III 450° F (230° C) ± 25° F (14° C)
  - IV 475° F (245° C) ± 25° F (14° C)
- Mop Application
  - III 425° F (220° C) ± 25° F (14° C)
  - IV 450° F (230° C) ± 25° F (14° C)

**Asphalt for Mopping Modified Bitumen Sheet Materials**

The EVT concept is applicable to asphalt that is used to adhere nonmodified base sheets or ply sheets but may not be applicable to the application of modified bitumen sheets. For modified bitumen sheets, some manufacturers recommend the asphalt temperature be a minimum of 425° F (220° C) in the mop cart or mechanical spreader just before its application to the substrate and a minimum of 400° F (205° C) at the point of contact with the modified bitumen sheet. For specific requirements for asphalt application temperature, consult the modified bitumen sheet manufacturer. Asphalt applied at the appropriate temperature should result in an interply asphalt weight of 15 pounds to 30 pounds per 100 square feet (0.7 to 1.5 kg/ply/m<sup>2</sup>). Refer to the manufacturer’s recommendations for specific products.

**Asphalt Application**

Evaluation	
Visual examination at the time of application is the most effective means of evaluating asphalt application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
Asphalt type is as specified. Verify labels on cartons or information on bill of lading.	Remove noncompliant asphalt from the job site.
Quantities of interply asphalt are as specified for glass-fiber ply sheets and base sheets. Monitor EVT temperature at the point of application.	Assure asphalt is at the recommended application temperature and adjust rate of application.
Interply asphalt is applied in a continuous, uniform film.	Adjust work practices to provide a continuous film of asphalt.
Asphalt is being applied within the recommended range for the application of modified bitumen sheets. Use thermometer or infra-red measuring device.	Adjust asphalt heating and/or handling to comply with recommended temperature range.

**Cold-applied Adhesives for Modified Bitumen Membranes**

The term “cold-applied” generally is used to describe a product that can be applied at ambient temperature. The base component for modified bitumen adhesives generally is asphalt, although coal tar and other base components can be used. Additional components may include polymer modifiers, petroleum based solvents, fibers and fillers depending on the final properties desired. The adhesive should be applied at the manufacturer’s recommended rate and application temperature range.

Cold-applied adhesives should not be used with membranes that have a plastic-backed surface or topside film. Solvent-based adhesives should not be used with foil-faced membrane.

Typically, cold-applied adhesive systems can be installed in temperatures ranging from 50° F to 100° F (10° C to 38° C). Below 50° F (10° C), adhesives should be warmed before application. Modified bitumen membranes should be installed in cold-applied adhesives while the adhesive surface is still “wet” and before formation of a “skin” on the adhesive surface. Set times are dependent on various drying factors such as temperature, wind, humidity and coverage rates. Proper safety precautions should be observed when handling solvent-based materials.

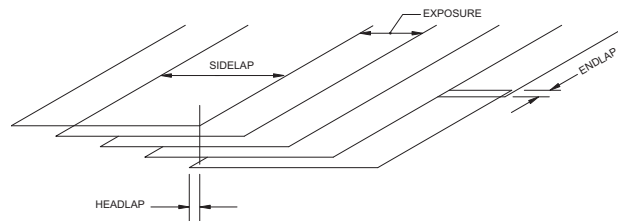
### Cold-applied Adhesive Application

Evaluation	
Visual examination at the time of application is the most effective means of evaluating cold-applied adhesive application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	Corrective Action
Cold adhesive is as specified. Verify labels on containers.	Remove noncompliant adhesive from the job site.
Adhesive temperature at the point of application is within the accepted range, generally 70° F to 100° F (21° C to 38° C).	Heating is suggested for most applications.
Quantities of interply adhesive are as specified.	Adjust rate of application.
Interply adhesives are applied in a continuous, uniform film.	Adjust work practices to provide a continuous, uniform film.

### Membrane Construction

The physical characteristics of a membrane are dependent on the type and number of plies/sheets and overall membrane construction. (See Membrane Description section, page 894.) Membrane ply/sheet construction typically is defined by endlap and sidelap. Endlap is the overlap distance that is measured from where one sheet/ply ends to where another begins. Sidelap is the overlap distance along the length of the sheet/ply where one sheet/ply overlaps the adjacent underlying sheet/ply. A T-joint is the condition created by the overlapping intersections of three or four sheets in the membrane. (See Figures 2-5, pages 906, for constructions details.)

For hybrid modified bitumen systems that incorporate multiple shingled ply-sheet configurations, headlap and exposure also define the membrane system. Headlap is the distance of the overlap that exists between the lowermost and the uppermost plies/sheets of the shingled portion of a roof membrane when measured perpendicular to the long dimensions of the membrane. Exposure is the transverse dimension of a roofing element or component not overlapped by an adjacent element or component in a roof covering. The exposure of any ply in a built-up roof membrane may be computed by subtracting 2 inches (50 mm) from the felt width then dividing the remaining felt width by the number of shingled plies. (See Figure 1.)



When overlapping, some variance from specified values is to be expected. A variance on the plus side is not considered to be detrimental. On the minus side, minimum lap values should be maintained to preserve membrane integrity.

<b>Evaluation</b>	
<p>Visual examination at the time of application is the most effective means of evaluating membrane construction. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.</p>	
<b>1. Membrane Construction: General Criteria</b>	
<b>Criterion</b>	<b>Corrective Action</b>
<p>The installation of all plies including the modified bitumen sheet(s) is completed on the same day or as specified.</p>	<p>If sudden and unexpected weather or other unforeseen conditions prohibit installation of all plies/sheets over small sections of the roof on the same day, consult with the membrane manufacturer, roofing contractor and roof system designer for appropriate action.</p>
<p>Roofing plies/sheets are installed so sidelaps and endlaps are not bucking water.</p>	<p>Determine drainage patterns before application. Adjust application to ensure laps do not buck water drainage.</p>
<p>Number of plies is as specified; verify before the installation of a cap sheet. Measurement of the exposed width of each ply establishes the exact number of plies without the need for a roof cut when all plies have been installed shingle fashion.</p>	<p>If the examination reveals missing plies, the missing ply sheet should be added over the area determined to be deficient before the cap sheet is installed.</p>
<p>Ply/sheet laps are flat and without “fishmouths” before the installation of an additional ply/sheet.</p>	<p>If the examination reveals “fishmouths,” cut and install a minimum of one additional ply/sheet of the specified material, shingle fashion, in the appropriate asphalt or adhesives beyond the area determined to be deficient. Adjust work practices to ensure plies/sheets are being unrolled straight and the substrate is suitably smooth.</p>
<p>Plies/sheets are firmly and continuously embedded in a uniform application of hot asphalt or adhesive at the appropriate temperature or are uniformly heat-welded. Walking in or applying pressure to modified bitumen rolls or using an appropriate following tool on sheet materials immediately behind the hot asphalt application may reduce voids in the interply.</p>	<p>Adjust work practices to ensure ply/sheet embedment, as follows:</p> <ul style="list-style-type: none"> <li>• Keep asphalt in the recommended application temperature range.</li> <li>• Embed the ply/sheet quickly while the asphalt is still hot or before the adhesive skins over.</li> </ul> <p>If unacceptable voids are found, remove and replace them with the specified material, shingle fashion, in the appropriate asphalt or adhesive beyond the area determined to be deficient.</p> <ul style="list-style-type: none"> <li>• If interply voids are suspected, refer to Appendix 3, page 913.</li> <li>• If an alternative corrective action is desired, contact the membrane manufacturer for repair requirements.</li> </ul>
<p>Before mopping and/or heat welding plies/sheets to metal or masonry surfaces, properly prime the surface to ensure adequate adhesion. Allow primer to dry thoroughly.</p>	<p>Prime surfaces before application.</p>
<p>Interply Laps:</p> <ul style="list-style-type: none"> <li>• Headlap: as specified, less 1 inch (25 mm) or a 1-inch (25 mm) minimum, whichever is greater. (No maximum limit.)</li> <li>• Endlap: as specified, less 2 inches (50 mm) or a 2-inch (50 mm) minimum, whichever is greater. (No maximum limit.)</li> <li>• Sidelap: as specified, less 2 inches (50 mm) or a</li> </ul>	<p>If the examination reveals less than the minimum width headlaps, endlaps or sidelaps, install a minimum of two additional plies of the roofing ply/sheet specified, shingle fashion, in the specified asphalt/adhesive over the area determined to be deficient. If an alternative corrective action is proposed, contact the membrane manufacturer for repair guidelines.</p>

Criterion	Corrective Action
2-inch (50 mm) minimum, whichever is greater. (No maximum limit.)	
<p>Cap Sheet Laps:</p> <ul style="list-style-type: none"> <li>• Endlap:                             <ol style="list-style-type: none"> <li>(1) Lap distance as specified, less 1 inch (25 mm) or a 3-inch (75 mm) minimum, whichever is greater. (No maximum limit.)</li> <li>(2) Stagger as specified. (3 feet [900 mm] minimum or use header ply if approved by the designer, membrane manufacturer and contractor.)</li> </ol> </li> <li>• Sidelap:                             <ol style="list-style-type: none"> <li>(1) Sidelap as specified or a 3-inch (75 mm) minimum, whichever is greater. (No maximum limit.)</li> <li>(2) Offset from base sheet sidelaps as specified.</li> </ol> </li> </ul>	<p>Adjust work practices to ensure adequate lapping.</p> <ul style="list-style-type: none"> <li>• Add a stripping ply of the specified sheet (8-inches [200-mm] wide minimum) or shingle in an additional ply of the sheet as the job progresses.</li> <li>• If an alternative corrective action is desired, contact the membrane manufacturer for repair guidelines.</li> <li>• Stop application, cut roll and reset sidelap line.</li> </ul>
Selvage should not be exposed.	<p>Adjust work practices to ensure adequate lapping.</p> <ul style="list-style-type: none"> <li>• For granule-surfaced sheets, apply matching mineral granules with a compatible cold-applied adhesive. For foil-surfaced sheets, apply a 6-inch (150-mm) wide minimum stripping ply of foil-surfaced sheet.</li> <li>• If an alternative corrective action is desired, contact the membrane manufacturer for repair requirements.</li> </ul>
Plies/sheets are free of factory splices.	Cut out factory splices before installing the ply/sheet.
There are no open cap sheet T-laps.	<p>If the examination reveals “open” cap sheet T-laps, adjust work practices to ensure embedment and consider installation practice as illustrated in Figure 4.</p> <ul style="list-style-type: none"> <li>• Install an additional 12 inch by 12 inch (300 mm by 300 mm) minimum piece of the cap sheet over the area determined to be deficient.</li> <li>• For alternative corrective action, contact the membrane manufacturer.</li> </ul>
<b>2. Membrane Construction: Criteria for Mop-applied Modified Bitumen Sheets Only</b>	
Criterion	Corrective Action
Sheets are firmly and continuously embedded in a uniform application of hot asphalt at appropriate temperature.	<p>Adjust work practices to ensure sheet embedment, as follows:</p> <ul style="list-style-type: none"> <li>• Keep asphalt in the recommended application temperature range.</li> <li>• Embed the sheet quickly while the asphalt still is hot. If appropriate, maintain a rolling bank of asphalt ahead of the roll.</li> </ul> <p>If unacceptable voids are found, remove and replace them with the specified material in the appropriate asphalt beyond the area determined to be deficient. (See Appendix 3, page 913.)</p> <ul style="list-style-type: none"> <li>• If an alternative corrective action is desired, contact the membrane manufacturer for repair guidelines.</li> <li>• Maintain recommended manufacturer distance for mop lead.</li> </ul>

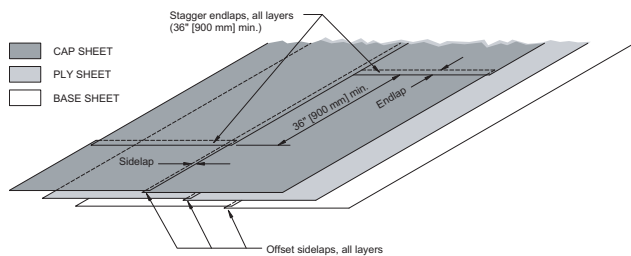
Criterion	Corrective Action
Sheet laps are flat and without “fishmouths.”	If the examination reveals “fishmouths,” cut and install an additional ply with rounded corners, (12 inches by 12 inches [300 mm by 300 mm] minimum) of the specified sheet in the appropriate asphalt or adhesive beyond the area determined to be deficient. Adjust work practices to ensure sheets are being unrolled straight and substrate is suitably smooth.
Laps are continuously embedded in asphalt. Asphalt should be visible at all laps. Where lap adhesion is suspect, lightly run a round-ended trowel along the laps to determine whether the lap is open. Intermittent dry lap edges shall not exceed 3/8 inch (10 mm) in depth.	Adjust work practices to ensure asphalt adhesion at all laps making sure the asphalt is being applied within the EVT range or other specified temperature range. (See pages 899-900.). <ul style="list-style-type: none"> <li>• If intermittent dry lap edges exceed 3/8 inch (10 mm) in depth or are frequent, adjust work practices and adhere with the recommended adhesive.</li> </ul>
<b>3. Membrane Construction: Criteria for Heat-welded Sheets Only</b>	
Criterion	Corrective Action
Sheets are firmly bonded to the substrate. Observe a continuous film of molten modified bitumen compound, and verify that the sheet is applied in a fashion ensuring proper embedment. APP and heat-weldable SBS materials typically react differently to heat during application. Also, products within a generic modifier type (SBS or APP) may not all react the same. (Refer to appropriate safety precautions for heat welding.)	Adjust work practices to ensure sheet embedment, as follows: <ul style="list-style-type: none"> <li>• Keep the heating device (e.g., torch) at an appropriate distance from the roll.</li> <li>• Keep the heating device properly adjusted.</li> <li>• Keep the heating device at an appropriate angle to facilitate adequate heating.</li> <li>• Use proper techniques or hand-held devices.</li> <li>• Avoid work during extremely windy conditions.</li> <li>• Embed the sheet quickly while the modified bitumen compound is hot. If unacceptable voids are found, remove and replace them with the specified material-heat welded, beyond the area determined to be deficient. (Refer to Appendix 3.)</li> <li>• If an alternative corrective action is desired, contact the membrane manufacturer for repair guidelines.</li> </ul>
Sheet laps are flat and without “fishmouths.”	If the examination reveals “fishmouths,” cut and heat weld an additional ply with rounded corners under 12 inches by 12 inches (300 mm by 300 mm) minimum of the specified sheet beyond the area determined to be deficient. Adjust work practices to ensure sheets are being unrolled straight and the substrate is suitably smooth.

Criterion	Corrective Action
<p>Laps are continuously embedded in molten modified bitumen compound. Observe a continuous flow-out of bituminous compound and verify the sheet is applied in a fashion ensuring proper embedment. Where lap adhesion is suspect, lightly run a round-ended trowel along the laps. (For recommendations for flow-out using SBS materials, consult the individual manufacturer. Some manufacturers do not require flow-out at laps.) Laps onto granular surfaced sheets should have the receiving sheet surface granules properly prepared to achieve adequate bond. The selvage of the previously installed (bottom) sheet and underside of the overlapping sheet should be sufficiently heated to achieve a proper weld.</p>	<p>If the examination reveals insufficient flow-out, lift the lap edge with a trowel and gently heat the underside of the lap edge with heating device and reset it. Press the lap into place with a trowel. Alternatively, a heated trowel may be wedged in the deficient area and slowly removed applying hand pressure to ensure the bond. Adjust work practices to ensure adhesion at all laps as follows:</p> <ul style="list-style-type: none"> <li>• Use a weighted roller to help set the lap.</li> <li>• Keep the heating device at an appropriate distance from the roll. Overheating can damage the material; underheating can result in an inadequate bond.</li> <li>• Keep the heating device properly adjusted.</li> <li>• Use proper heating device techniques to ensure lap integrity.</li> <li>• Keep the heating device at an appropriate angle to facilitate adequate heating.</li> </ul>
<p>Heat welding temperature is suitable.</p>	<p>Adjust work practices to is suitable.ensure that heating device is properly adjusted.</p>

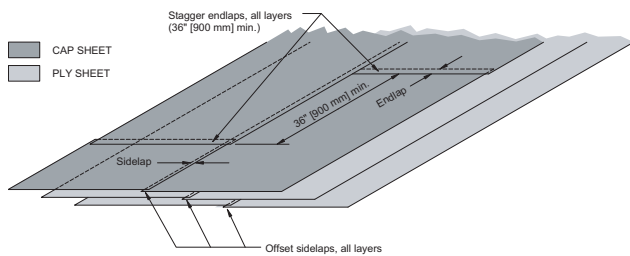
**4. Membrane Construction: Criteria for Cold-applied Modified Bitumen Sheets Only**

Criterion	Corrective Action
<p>Adhesives are stored in a heated facility to maintain workable viscosity. Warming units (“hot boxes”) may be used to improve workability.</p>	<p>Stop work if viscosity is too high to attain specified usage or the quality of work is jeopardized.</p>
<p>Apply adhesive evenly in uniform, continuous film. A wet film gauge or marking squares on the roof may be used to determine and maintain the proper application rate.</p>	<p>Adjust application to comply with the recommended manufacturer’s coverage rate. Reapply adhesive on deficient areas.</p>
<p>Maintain the specified quantity of interply adhesive. Less than the specified amount can cause poor adhesion; more than specified can cause excessive setup time and damage (soften) modified bitumen sheets. Interply quantity guidelines generally range from 1.5 gallons to 2.5 gallons per 100 square feet (0.6 to 1.0 liter/m<sup>2</sup>). Refer to the manufacturer’s recommendations for specific rates.</p>	<p>Modify work practices to ensure specified usage. Quantity can be spot-checked using a wet film gauge or by calculating material usage. Notched squeegees wear and should be checked periodically. Visual examination is difficult because of varied appearance of notched and smooth squeegees, spray applications and certain mechanical application.</p>
<p>Comply with the adhesive manufacturer’s “open time” recommendations.</p>	<p>Immediately modify installation practices to accommodate for actual field conditions.</p>
<p>Ensure sheets lay flat without buckles, air pockets or voids and are fully bonded.</p>	<p>Unroll and/or cut sheets and allow them to relax.</p>
<p>In cool temperatures, typically below 50° F (10° C), extra precautions may be necessary to ensure rolls lay flat.</p>	<p>Place rolls and adhesives in a warm area before application and unroll and/or cut sheets to allow them to relax per the manufacturer’s recommendations.</p>

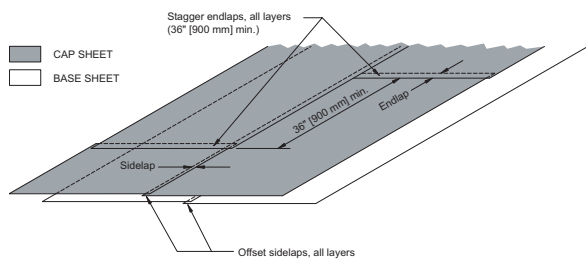
Criterion	Corrective Action
<p>Modified bitumen sheets are continuously embedded in cold adhesive. Blisters, wrinkles or voids can result from membrane rolls not fully embedded.</p>	<p>Adjust work practices to ensure sheet embedment, as follows:</p> <ul style="list-style-type: none"> <li>• If unacceptable voids or wrinkles are found, remove and replace them shingle fashion, with the specified material in the appropriate adhesive beyond the area determined to be deficient.</li> <li>• If interply voids are suspected, refer to Appendix 3, page 913.</li> <li>• If an alternative corrective action is desired, contact the membrane manufacturer for repair requirements.</li> </ul>
<p>Laps are properly adhered when using heat welding and embedded when using adhesive.</p>	<p>Adjust work practices to ensure lap adhesion or embedment. Consult the manufacturer if problems persist.</p>
<p>Sheets are more susceptible to surface damage during the curing or setup period.</p>	<p>Stage work to eliminate or minimize work or traffic over finished sheets.</p>



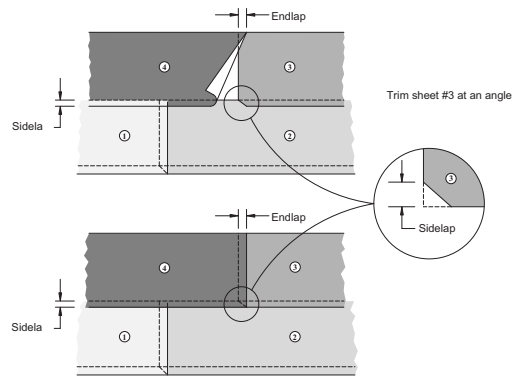
**Figure 2: Base, Ply and Cap Sheet Installation**  
 (Note: If approved by the designer, membrane manufacturer and contractor, a header ply may be used in lieu of staggered endlaps.)



**Figure 3: Two-ply With Cap Sheet**  
 Note: If approved by the designer, membrane manufacturer and contractor, (a header ply may be used in lieu of staggered endlaps.)



**Figure 4: Base Sheet and Cap**  
 Note: If approved by the designer, membrane manufacturer and contractor, (a header ply may be used in lieu of staggered endlaps.)



**Figure 5: Cap Sheet T-lap Detail**  
 (Note: This is an optional detail that may be used to minimize open cap sheet T-laps.)

## Membrane Base Flashings

There are a variety of base flashings, counterflashings, metal edge flashings, copings and special flashing conditions. There are designs and materials that can be used to meet these conditions. Counterflashings are required to waterproof and/or protect the top of the membrane base flashings.

This section addresses base flashings, which extend from the surface of the roof up the vertical surface of a parapet, wall or curb. A cant strip should be specified at the base of a vertical wall or penetration to provide a transition for the roofing material.

Consideration must be given to the height of base flashings and their termination at the parapet, wall or curb. Most manufacturers of modified bitumen sheets restrict the base flashing height. Wall waterproofing or covering generally is not covered by roofing warranties; consult the manufacturer's requirements for the warranty provisions.

<b>Evaluation</b>	
Visual examination at the time of application is the most effective means of evaluating membrane base flashing application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
<b>Criterion</b>	<b>Corrective Action</b>
Metal and masonry surfaces are primed with the appropriate primer before bituminous material is applied.	Properly prime surfaces and allow the primer to dry.
Base flashings are completed or made watertight as specified daily.	Adjust work practices to complete flashings daily or as specified.
The base flashing height is as specified. Recommended minimum flashing height above the membrane is 8 inches (200 mm).	<ul style="list-style-type: none"> <li>• Adjust work practices to bring work into specification.</li> <li>• Remove and replace nonconforming flashings.</li> </ul>
Base flashing plies/sheets should be firmly and continuously adhered with the specified bitumen or adhesive or by heat welding. (Refer to appropriate safety precautions for heat welding.)	Adjust work to meet the specification.
Cant strips are installed as specified.	Remove installed field plies and/or flashings and install cant strips as specified.
The specified types of flashing plies/sheets are installed.	Remove flashing materials that do not meet the specification and replace them with the correct flashing ply/sheet.
Number of base flashing plies/sheets is as specified.	Install additional plies/sheets to meet the specification.
Base flashings are securely fastened and/or attached as specified.	Properly secure the base flashing to comply with the specification.
Laps in base flashing are continuously sealed.	<ul style="list-style-type: none"> <li>• Adjust work practices to meet the specification.</li> <li>• Seal lap with adhesive or heat weld defective area.</li> </ul>
Top edge of base flashing is waterproofed daily.	Adjust work practices to comply with the criterion.
Surface coating protection is properly applied when specified.	Apply coating to comply with the specification.

## Metal Flashings

For low-slope roof systems, metal flashings can be divided into three general categories: water conveyance flashings, watershedding independent flashings, and integral component and edge flashings.

Water conveyance flashings include exterior water collector boxes/heads, downspouts and gutters.

Watershedding independent flashings are attached, sealed and mounted above the top edge of the membrane base and penetration flashings. These flashings prevent moisture penetration into wall cavities, behind base flashings, through curb-mounted equipment and into/behind penetration flashings. Metal coping/cap flashing, surface-mounted counterflashing, curb caps, rain collars, heavy gauge raised metal edge and through-wall flashings all are examples of watershedding independent flashings.

Integral component and edge flashings include metal roof jacks, pipe flashings, through-wall scuppers, electrical utility line penetration flashings and low profile-light gauge (i.e., 22 gauge, 24 gauge [0.76 mm, 0.61 mm]) metal edge flashings (“gravel stops” and “drip edges”). These types of flashings differ from the other categories in one primary way—they require integration/sealing of the membrane directly to their metal flanges. The other two categories of flashings (water conveyance metal flashings and watershedding independent flashings) are independent from the membrane. Metal flashing flanges typically provide a minimum 3½-inch (90-mm) sealing surface.

The following criteria addresses only integral component and edge flashings as they relate to modified bitumen roof systems.

<b>Evaluation</b>	
Visual examination at the time of application is the most effective means of evaluating metal flashing application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviations from any particular criterion should be corrected as soon as possible.	
<b>Criterion</b>	<b>Corrective Action</b>
Metal sealing flanges are primed with the appropriate primer.	Properly prime them and allow them to dry before sealing them in.
Metal flanges are set in a bed of roof cement or molten modified bitumen compound and secured as specified.	Remove flashing and reinstall it as specified or add asteners as required to meet specified spacing.
Metal edge laps are sealed as detailed before they are stripped-in with the specified sealant.	Remove flashings sufficiently to install inter-lap sealant.
Metal flanges are set into the completed membrane as specified.	Remove defective or noncompliant material and replace it as specified.
Edge metals are supported by continuous wood blocking/decking and flanges are not extended over insulated surfaces without wood blocking support.	Install wood blocking before the membrane and metal edge flashing are installed to support metal flanges adequately.

## Surfacing

Modified bitumen membranes are smooth-surfaced or covered with factory-applied mineral granules or metal foil. If required or specified, modified bitumen membrane systems may receive additional field-applied surfacing. Field-applied surfacings may be used to provide added protection against exposure and physical wear while also providing various degrees of added fire resistance, impact resistance and improved reflectivity. These surfacings include but are not limited to cold-applied coatings, coating and granules, and asphalt pour coat followed by embedment of aggregate. The surfacing should be applied according to the specification. Surface preparation and aging (weathering) may be required before application of protective coatings. Consult with the appropriate manufacturers and suppliers for their recommended guidelines.

<b>Evaluation</b>
Visual examination at the time of application is the most effective means of evaluating roof surfacing application. Visual examination may include routine measurements where applicable. Common sense should be used in the evaluation of the application, and reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
The surface of the existing membrane is sufficiently dry, clean, frost-free and prepared for application of a protective surface coating.	Delay installation until surface conditions are corrected.
Cold-applied coating application rate is as specified and applied in a uniform continuous film. A wet film gauge may be used to determine thickness. Reasonable variances from specified quantities are to be expected.	Adjust application to comply with the specified coverage rates. On deficient areas, reapply the coating. Some coatings may require two applications.
Granules are applied in a continuous layer of wet coating at the specified coverage rate to achieve a continuous embedded surfacing. (Granule weight is normally approximately 60 lb./100 ft. [3 kg/m <sup>2</sup> ].)	Immediately adjust operations to ensure embedment of the specified amount. Whenever visual observation indicates an inadequate amount of adhered granules, loose granules are to be removed, and then the coating and granules are to be reapplied.
At the time of application, aggregate should be reasonably dry and free of excessive fines, dirt or other foreign matter and adhere to hot bitumen.	Replace material on the job or wait until the material is adequately dry.
Asphalt flood coat application rate is as specified—normally approximately 60 lb./100 ft. (3 kg/m <sup>2</sup> ).	Immediately adjust to ensure a continuous film and reapply the flood coat on deficient areas.
Surfacing aggregate weight is normally not less than 400 lb./100 ft. (20 kg/m <sup>2</sup> ) with an adhered aggregate weight of approximately 200 lb./100 ft. (10 kg/m <sup>2</sup> ).	Immediately adjust operations to ensure embedment of the specified amount. Whenever visual observation indicates an inadequate amount of adhered aggregate, loose aggregate is to be removed, and then the flood coat and aggregate are to be reapplied.

## **Appendix 1—Modified Bitumen Roofing Quality Control and Quality Assurance Application Checklists**

These checklists are offered to assist quality control and quality assurance inspectors during roof system inspection while the roof system application is in progress. They are not specifications, and they do not cover every detail of modified bitumen roof system application inspection procedures.

The intent of these checklists is to provide guidelines for quality control and quality assurance inspectors by highlighting the key application areas affecting successful modified bitumen roof system application.

### **Before Application**

- Approved specifications and drawings are available for reference and review.
- All certifications and/or approvals have been received for the roof deck and roof system materials where applicable.
- Material manufacturers' and suppliers' literature and application specifications and recommendations are available for reference and review.
- Safety precautions and material safety data sheets (MSDSs) have been reviewed and are on-site during application.
- Specified and approved materials verified by on-site inspection of product labels are at the job site and visually suitable for application (i.e., packing is not damaged, labels are intact, shelf life has not expired).
- Materials are stored according to manufacturers' and suppliers' recommendations (e.g., materials are stored at the proper temperature, covered if required, off the ground on pallets).
- Adhesives and roll goods should be warmed or stored per the manufacturer's recommendations for cool-weather application (typically below 50° F [10° C]).
- Equipment is in good working order and functioning properly (e.g., kettles, torches, sprayers, fire extinguishers, heaters, hot air welders).
- Edge nailers, curbs, drains and penetrations have been properly installed in the areas to receive roof system application.
- Drainage patterns for proper roof membrane installation have been identified.
- When fastener pull-out tests are specified, tests have been conducted and the results have been approved by the specifier.

### **During Application**

- Weather, project job conditions and installation sequencing are suitable for roof system application.
- The substrate is sufficiently dry, clean, reasonably smooth and suitably prepared to receive insulation and/or the roofing membrane.
- Insulation boards are butted together with joints staggered and offset if more than one layer is being used.
- Insulation is firmly attached to the substrate or underlying insulation with specified type and number of fasteners (if required) or properly embedded in bitumen or adhesive as specified.
- Asphalt is within the recommended temperature range at the point of application; asphalt temperature is monitored throughout the day.
- Adhesive is being applied at the specified coverage rate.
- Temperature-measuring devices are readily available and working properly.
- If a mechanical spreader is being used, it should be checked periodically to ensure all valves operate properly, holes to be used are open and the bitumen is flowing sufficiently for proper ply/sheet embedment.
- For hot asphalt applications, there is a continuous flow of bitumen in front of the roll being applied.
- Side and end laps are fully embedded and continuously bonded.
- Plies/sheets are being embedded into the hot asphalt/adhesive.
- Manufacturers of modified bitumen sheets should provide written recommendations for mop lead, and if it is more than 5 feet (1.5 m), caution is urged.

- ❑ The specified number of plies/sheets are being applied in shingle fashion and are started at the low point of the roof or drain or as specified.
- ❑ Roofing plies/sheets are installed so sidelaps and endlaps are not bucking water.
- ❑ When envelopes are being used, they are installed at curbs, edges and deck penetrations.
- ❑ Temporary tie-ins are installed at the end of each day's work and removed before resuming the installation of insulation and/or roof system.
- ❑ Field ply terminations are made watertight or membrane flashings are being installed along with each day's completed roof area as specified.
- ❑ Surfacing is being applied as specified.
- ❑ In high traffic areas, protection is being used over newly completed membrane. Solvent-based adhesives may make finished membranes temporarily "tender," requiring additional precautions for subsequent traffic/storage. (Note: Each trade is responsible for protecting the roof system[s] in its work area.)
- ❑ Materials and installed roofing components are not being abused by other trades.

## **Appendix 2—Test Cuts**

Test cuts are not considered to be part of a routine quality control or quality assurance program. Test cuts should not be substituted for in-process quality control and quality assurance provided by continuous visual examination.

Test cuts may assist in the evaluation of the extent and magnitude of problems observed during routine quality control or quality assurance.

When test cuts are taken, a minimum of three random samples from the roof system applied that day should be taken before the installation of surfacing material. The test cut should be taken before the installation of the top sheet unless problems are suspected with the installation of the top ply. Sampling should be done in accordance with ASTM D 3617, "Sampling and Analysis of New Built-Up Membranes." (Development of a standard method of sampling and analyzing new modified bitumen membranes is underway at ASTM. Until that standard is available, D 3617 is recommended using a 4 inch by 44 inch [100 mm by 1120 mm] sample size.)

When a test cut is made, the cut should immediately be measured and weighed. The results must then be calculated and an evaluation made about the continuity of the interply asphalt/adhesive and interply adhesion. Calculations of the interply asphalt/adhesive weights must be adjusted for any sheets that were heat-welded in place. The test cut samples should then be put back in place and re-adhered. Additional plies/sheets, equal to the original number of plies/sheets specified, then should be applied over the sample location before proceeding to install the top modified bitumen sheet (if not already applied) and/or surfacing materials.

Normally, small test cuts are taken from large areas of a modified bitumen roofing membrane. Test cuts may not represent the overall membrane construction. The greater the quantity of test cuts, the more accurate the evaluation may be. Each test cut is, however, a hole in the continuity of the new membrane system that must be patched. Focusing solely on roof test cuts may, on the other hand, give undue emphasis to the weight of interply asphalt/adhesive while ignoring other critical aspects of the roof system.

Care must be taken to protect the sample from damage. A small loss of even part of the test cut can have a dramatic effect on the test results.

## Appendix 3—Interply Analysis

### Mop or Cold Adhesive Applied Systems

The interply void examination is to be based on visual analysis of a rectangular roof cut specimen obtained before surfacing in accordance with ASTM D 3617 using a 4 inch by 44 inch (100 mm by 1120 mm) sample size. (Development of a standard method of sampling and analyzing new modified bitumen membranes is underway at ASTM. Until that standard is available, D 3617 is recommended using a 4 inch by 44 inch [100 mm by 1120 mm] sample size.) The lengths of all voids visible at the edge of the specimen are to be measured and compared against the following criteria:

- Overlapping voids between two or more plies are not acceptable.
- The maximum acceptable length of any individual void that is encapsulated in asphalt/adhesive is 2 inches (50 mm).
- The total length of all voids that are encapsulated in asphalt/adhesive shall not be greater than 4 inches (100 mm) between any two plies.
- Dry voids (the absence of asphalt/adhesive between plies) are not acceptable.
- Voids continuous through the specimen are not acceptable.
- Visual interply moisture in voids is not acceptable.

If observation and measurement indicate a lack of proper quantities of asphalt/adhesive, additional ASTM D 3617 test cuts should be taken at four locations diagonally—10 feet (3 m) in each direction—from the original test cut. Repeat this step until the deficiency no longer is apparent (refer to Appendix 2, page 912).

### Heat-welded Systems

The interply void examination is to be based on visual analysis of a rectangular roof cut specimen obtained before surfacing, in accordance with ASTM D 3617, using a 4 inch by 44 inch (100 mm by 1120 mm) sample size. (Development of a standard method of sampling and analyzing new modified bitumen membranes is underway at ASTM. Until that standard is available, D 3617 is recommended using a 4 inch by 44 inch [100 mm by 1120 mm] sample size.) The lengths of all voids visible at the edge of the specimen are to be measured and compared against the following criteria:

- The maximum acceptable length of any individual void is 2 inches (50 mm).
- The total length of all voids shall not be greater than 4 inches (100 mm) between any two plies.
- Voids continuous through the specimen are not acceptable.
- Visual interply moisture in voids is not acceptable.

If observation and measurement indicate a lack of adhesion, additional ASTM D 3617 test cuts should be taken at four locations diagonally—10 feet (3 m) in each direction—from the original test cut. Repeat this step until the deficiency no longer is apparent. (Refer to Appendix 2, page 912.)

Note: See “Membrane Construction” on pages 901-907 for criteria and corrective action.

## Appendix 4—Terminology

For the purposes of this document, the following definitions apply:

**Atactic Polypropylene (APP):** A thermoplastic polymer that forms a uniform matrix within the asphalt. APP modified bitumen sheets generally are applied using a propane-fueled torch. Applicators use the heat to soften the modified bitumen on the underside of the sheet. The sheet's bottom surface becomes a molten adhesive that flows upon the substrate and then cools to form a waterproof adhesive bond. Some APP sheets also can be applied with cold-process adhesives.

**Equiviscous temperature (EVT):** The temperature at which a bitumen attains the proper viscosity for built-up membrane application.

**Equiviscous temperature (EVT) application range:** The recommended bitumen application temperature range. The range is approximately 25° F (14° C) above or below the EVT, giving a range of 50° F (28° C). The EVT range temperature is measured in the mop cart or a mechanical spreader just before application of the bitumen to the substrate.

**Heat Welding:** A method of melting and fusing together the overlapping edges of separate sheets or sections of polymer modified bitumen materials by the application of heat (in the form of hot air or open flame) and pressure.

**Membrane:** The completed waterproofing element, consisting of the modified bitumen sheet and base and/or interply sheets.

**Modified Bitumen:** A term commonly used to describe composite sheets consisting of a polymer modified bitumen, typically reinforced. These sheets are sometimes surfaced with various types of mats, films, foils or mineral granules. The term also can be used to describe mopping asphalt containing a polymer modifier.

**Modified Bitumen Sheet:** A factory-fabricated polymer modified bitumen composite sheet or base sheet (that may or may not be manufactured with polymer modified bitumen).

**Ply:** An interply sheet that was not manufactured with polymer modified bitumen; a layer of felt or nonpolymer modified base sheet.

**Roof System:** A system of interacting roof components, generally consisting of a membrane or primary roof covering and roof insulation (not including the roof deck), designed to weatherproof and sometimes improve a building's thermal resistance.

**Styrene Butadiene Styrene (SBS):** A polymer that modifies the asphalt by forming a polymer network within the bitumen. Most SBS modified bitumen sheets are either set in hot mopping asphalt, torch-applied or adhered with cold-process adhesives. SBS modified bitumen sheets that do not have factory-applied granule or foil surfacing need some form of field-applied ultraviolet protective coating.

**T-joint:** Often referred to as T-lap, it is the condition created by the overlapping intersection of three sheets in a membrane.

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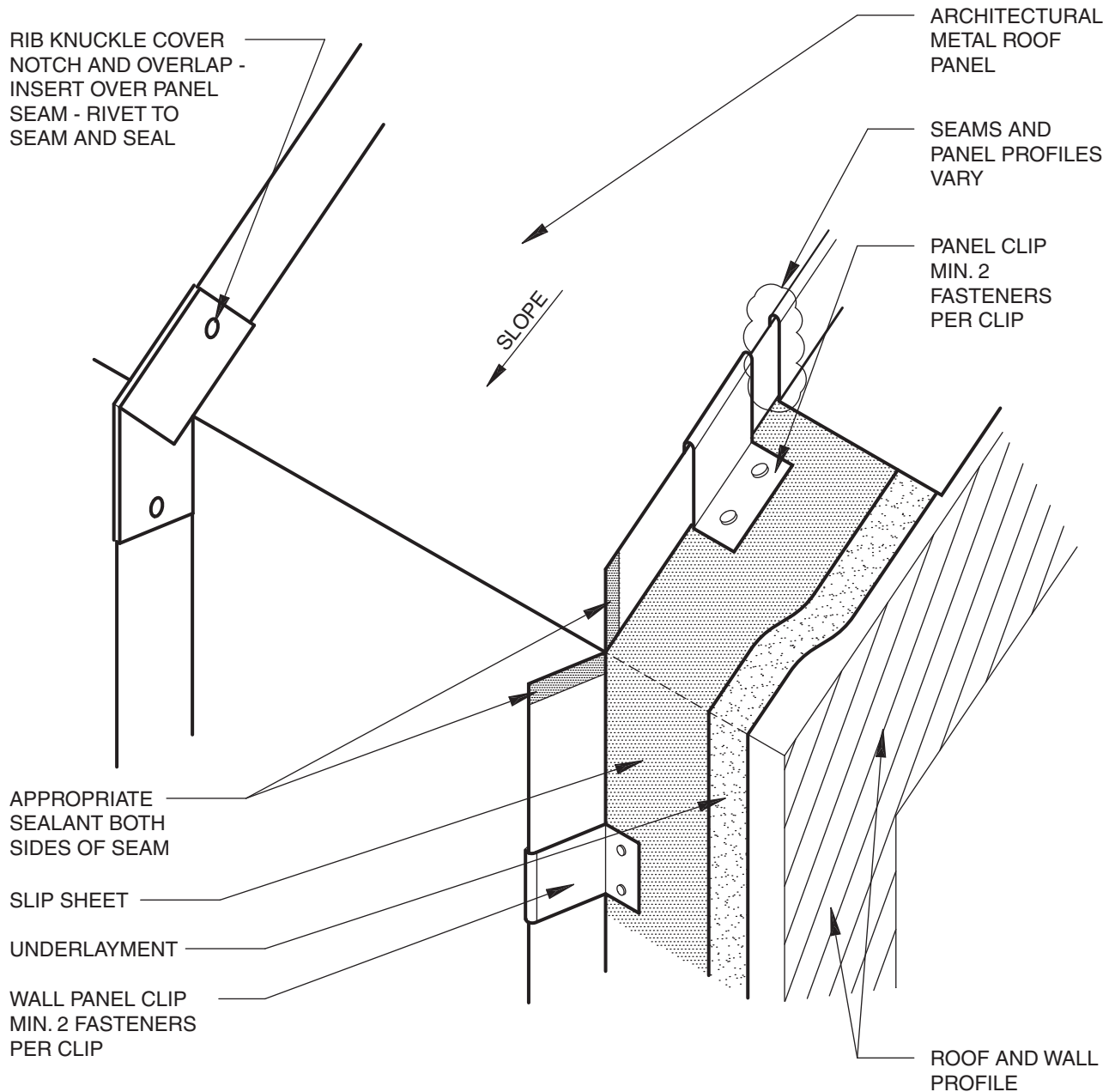
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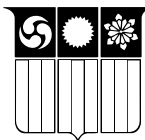
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NOTES :

1. THIS DETAIL IS APPLICABLE WHEN ROOF AND WALL PANEL ARE CONTINUOUS FROM ROOF TO WALL.
2. THIS DESIGN MAY BE SUSCEPTIBLE TO ICE DAMAGE.
3. THIS DETAIL IS APPROPRIATE WHEN THE LOWER PORTION OF THE METAL PANEL IS RELATIVELY SHORT.
4. THIS DETAIL FIXES THE PANEL AT THIS LOCATION.



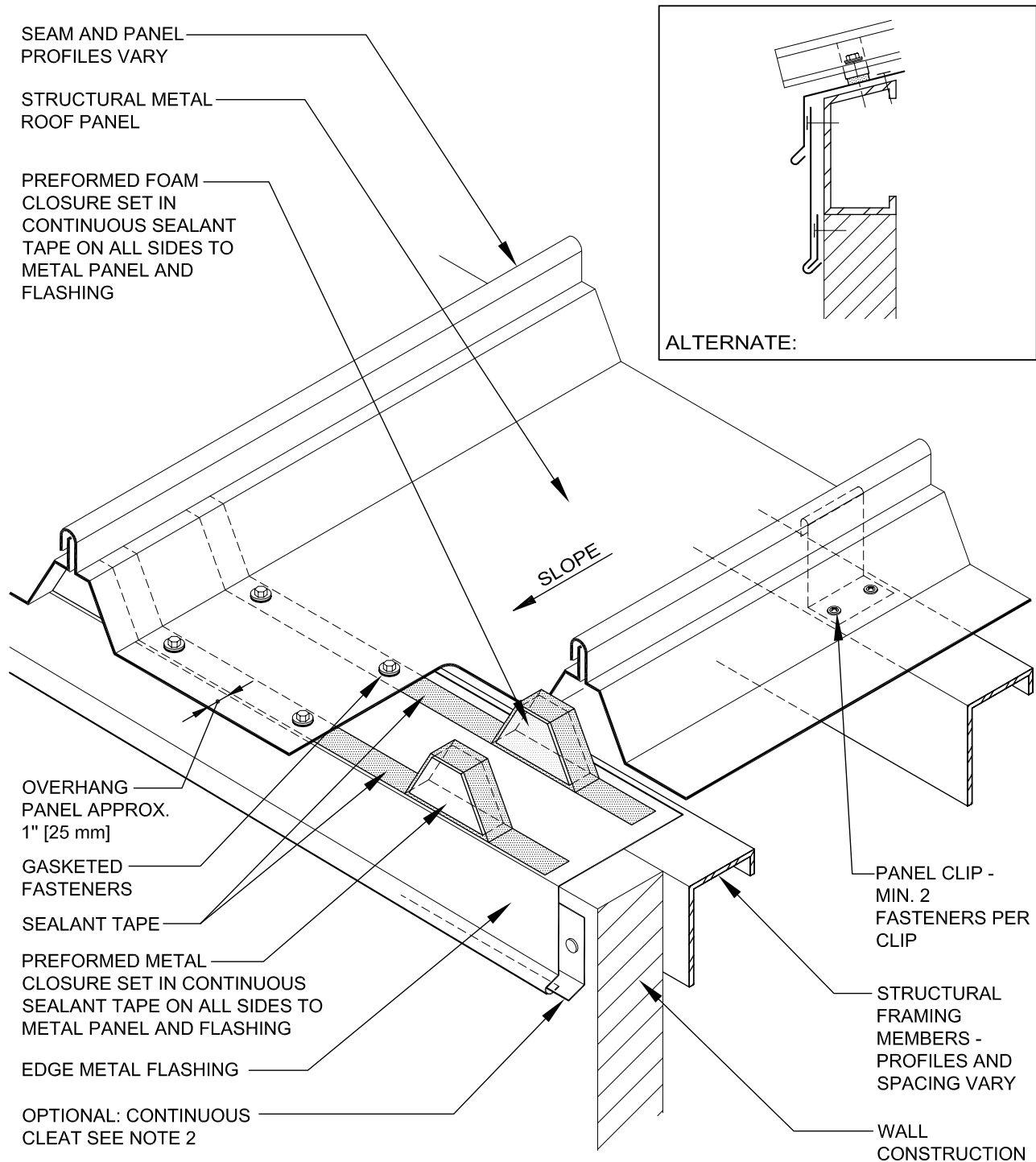
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**CONTINUOUS ROOF-TO-WALL  
PANEL TRANSITION**

2001

NOT DRAWN TO SCALE

**A-MTL-19**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS AND CLEAT RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. THIS DETAIL FIXES THE PANEL AT THE EAVE.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

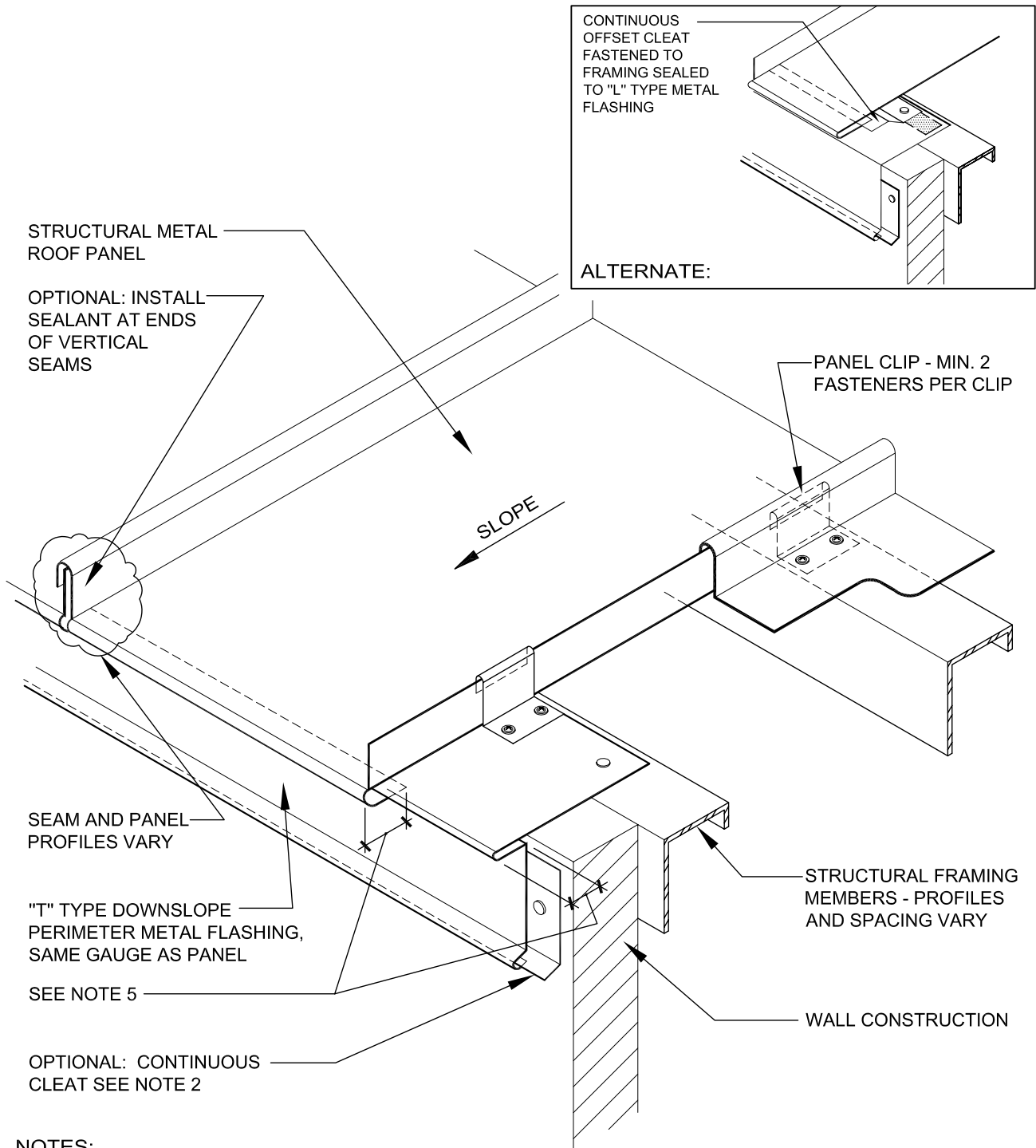


**DOWNSLOPE PERIMETER EDGE METAL FLASHING - "L" TYPE**

2006

NOT DRAWN TO SCALE

**S-MTL-1**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS AND CLEAT RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. THIS DETAIL CAN ONLY BE USED WHEN FIXED POINT IS NOT AT THE EAVE.
5. DIMENSIONS SHOULD ACCOMODATE EXPECTED MOVEMENT AT EAVE.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

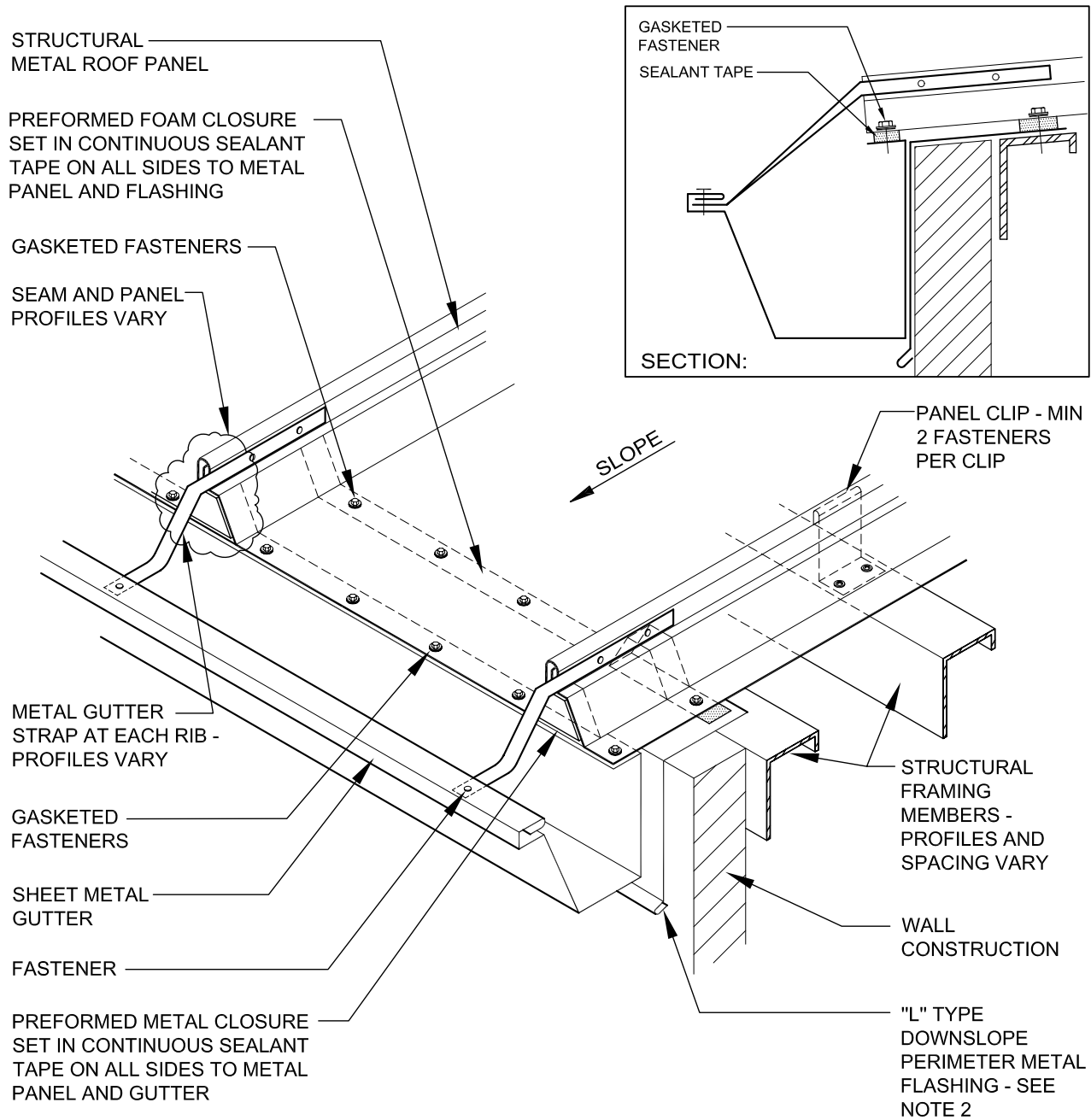


**DOWNSLOPE PERIMETER EDGE METAL FLASHING - "T" TYPE**

2006

NOT DRAWN TO SCALE

S-MTL-2



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. DESIGN GUTTER EXPANSION JOINTS FOR PLACEMENT AT INTERVALS APPROPRIATE TO GUTTER LENGTH AND TYPE OF METAL.
5. GUTTER PROFILE AND SIZE VARY ACCORDING TO ROOF AREA SIZE, ROOF SLOPE, BUILDING CODE AND REGIONAL PRACTICES.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

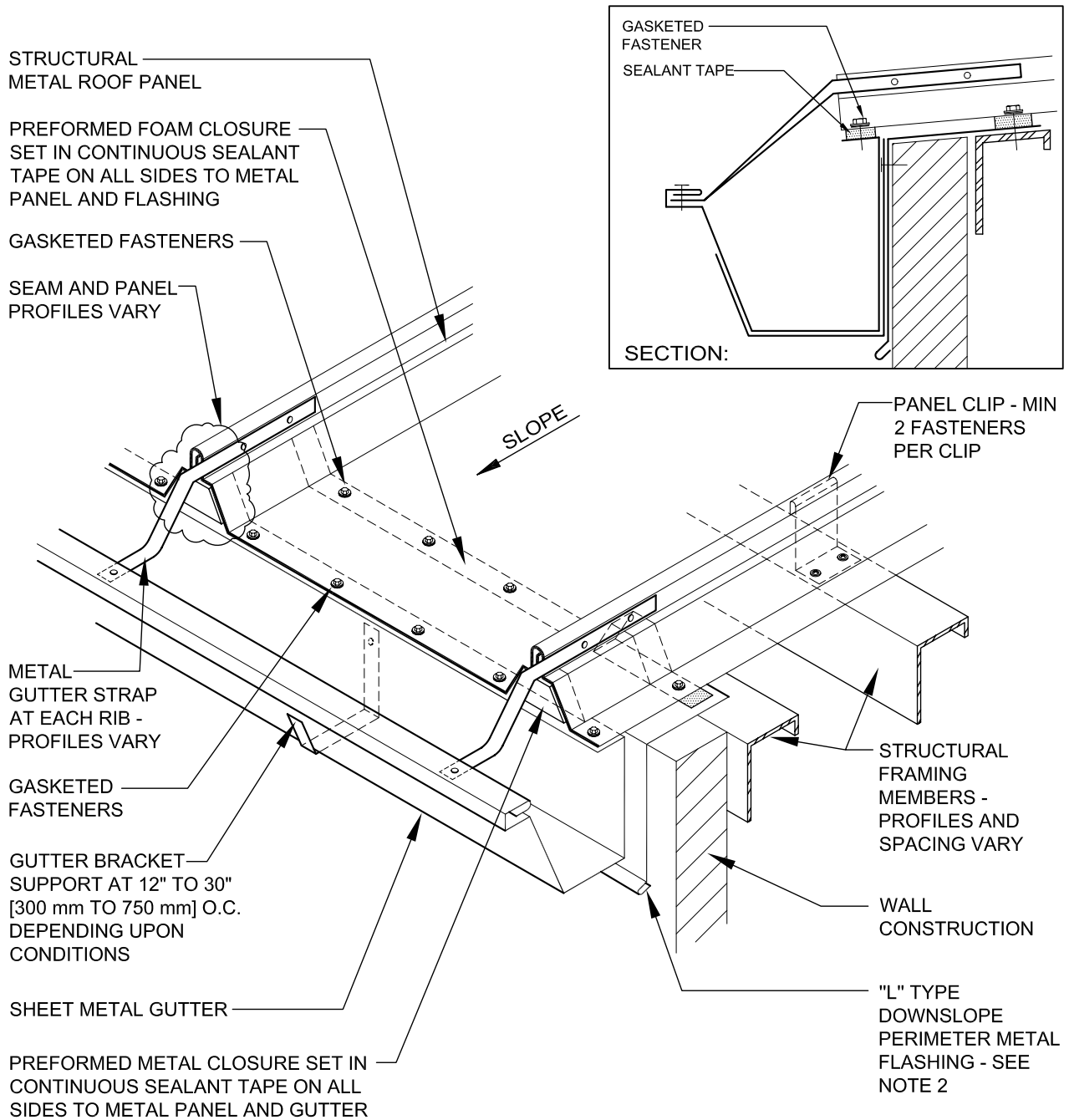


**DOWNSLOPE FLASHING WITH GUTTER WITH STRAPS**

2006

NOT DRAWN TO SCALE

**S-MTL-3**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. DESIGN GUTTER EXPANSION JOINTS FOR PLACEMENT AT INTERVALS APPROPRIATE TO GUTTER LENGTH AND TYPE OF METAL.
5. GUTTER PROFILE AND SIZE VARY ACCORDING TO ROOF AREA SIZE, ROOF SLOPE, BUILDING CODE AND REGIONAL PRACTICES.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

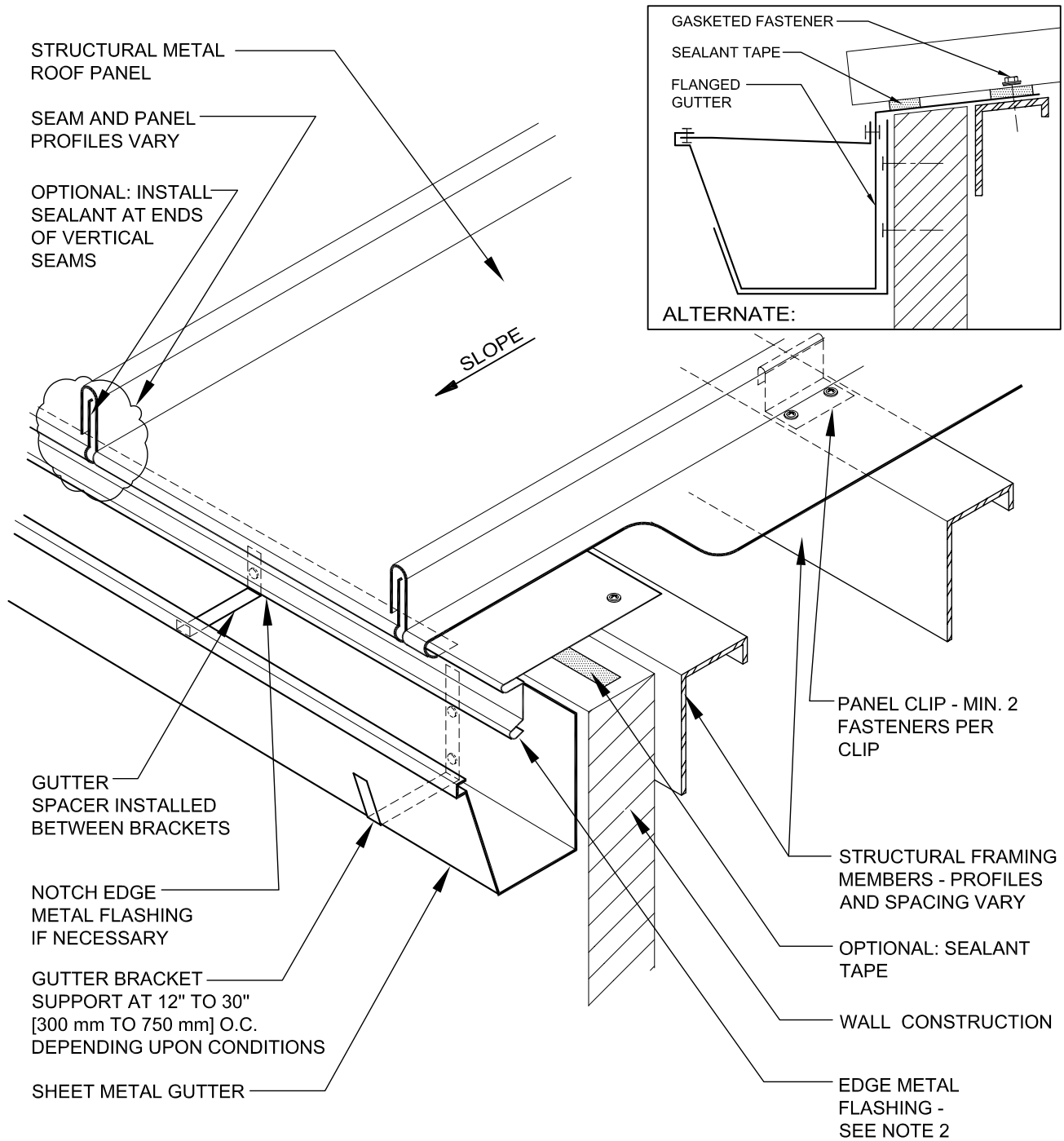


**DOWNSLOPE FLASHING WITH GUTTER WITH BRACKETS**

2006

NOT DRAWN TO SCALE

**S-MTL-3A**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. DESIGN GUTTER EXPANSION JOINTS FOR PLACEMENT AT INTERVALS APPROPRIATE TO GUTTER LENGTH AND TYPE OF METAL.
5. GUTTER PROFILE AND SIZE VARY ACCORDING TO ROOF AREA SIZE, ROOF SLOPE, BUILDING CODE AND REGIONAL PRACTICES.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

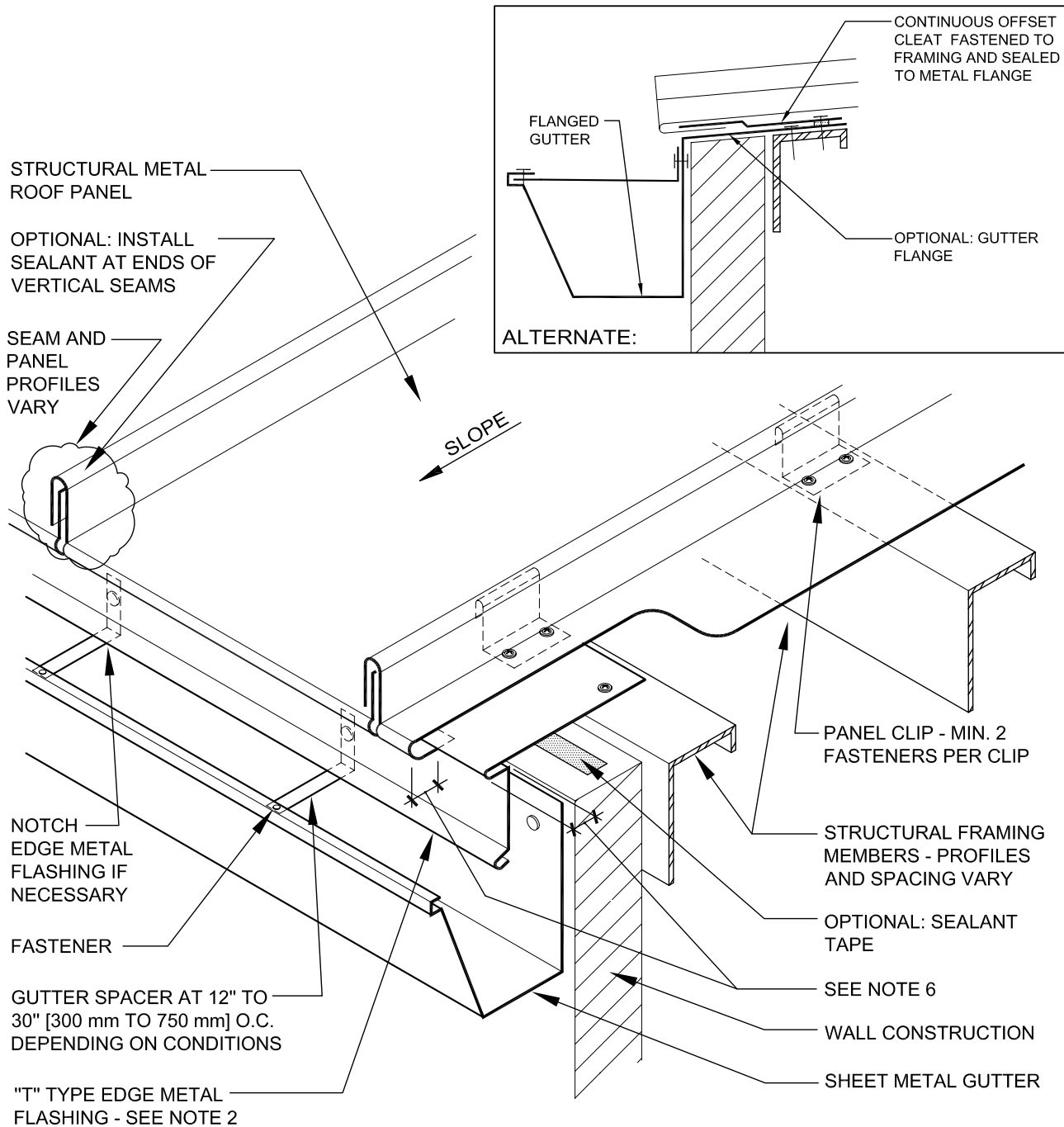


**DOWNSLOPE FLASHING WITH GUTTER WITH BRACKETS- "T" TYPE**

2006

NOT DRAWN TO SCALE

S-MTL-3B



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER ROF ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. DESIGN GUTTER EXPANSION JOINTS FOR PLACEMENT AT INTERVALS APPROPRIATE TO GUTTER LENGTH AND TYPE OF METAL.
5. GUTTER PROFILE AND SIZE VARY ACCORDING TO ROOF AREA SIZE, ROOF SLOPE, BUILDING CODE AND REGIONAL PRACTICES.
6. DIMENSIONS SHOULD ACCOMODATE EXPECTED MOVEMENT AT EAVE.
7. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

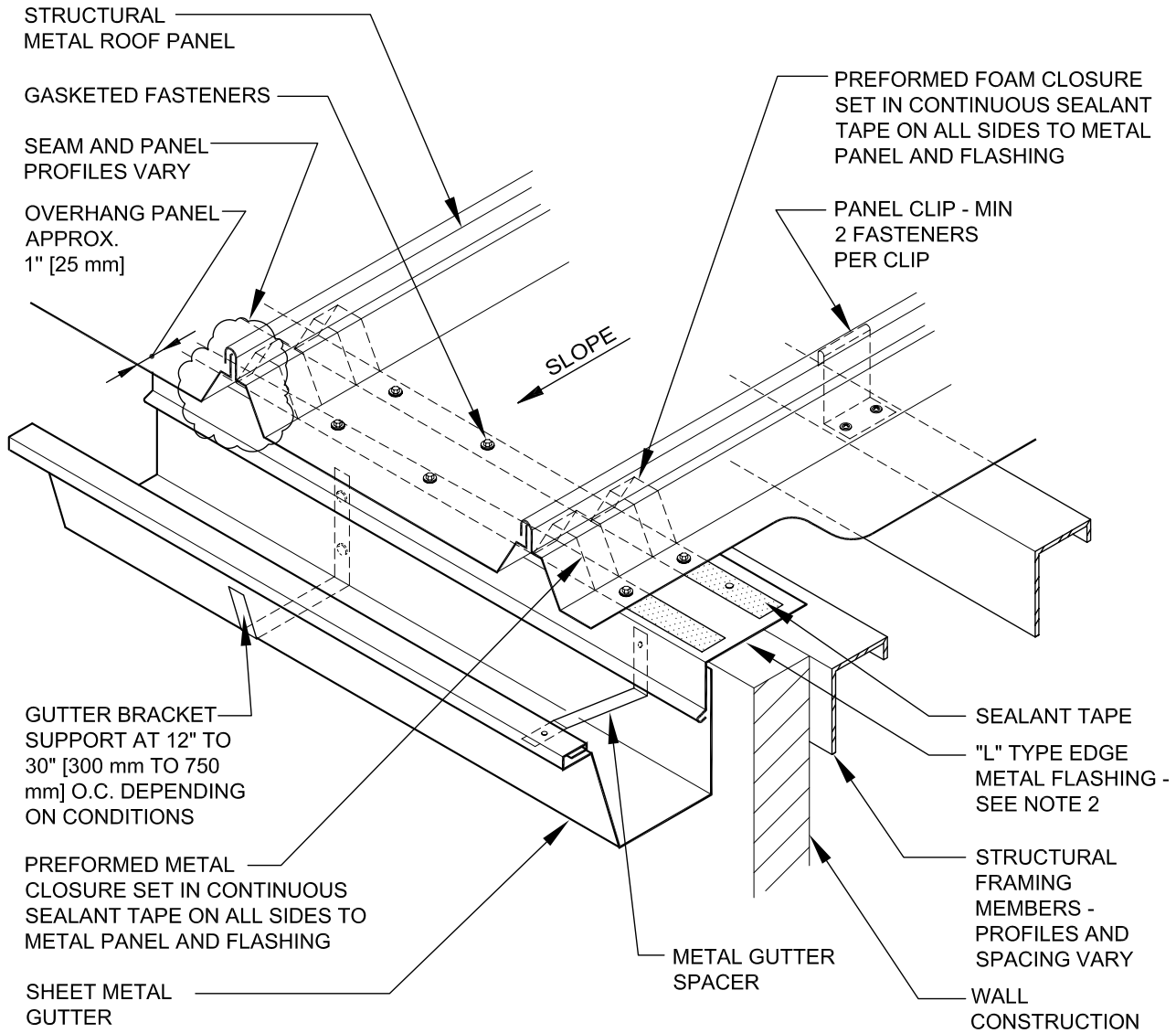


**DOWNSLOPE FLASHING WITH GUTTER - "T" TYPE**

2006

NOT DRAWN TO SCALE

S-MTL-3C



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. DESIGN GUTTER EXPANSION JOINTS FOR PLACEMENT AT INTERVALS APPROPRIATE TO GUTTER LENGTH AND TYPE OF METAL.
5. GUTTER PROFILE AND SIZE VARY ACCORDING TO ROOF AREA SIZE, ROOF SLOPE, BUILDING CODE AND REGIONAL PRACTICES.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

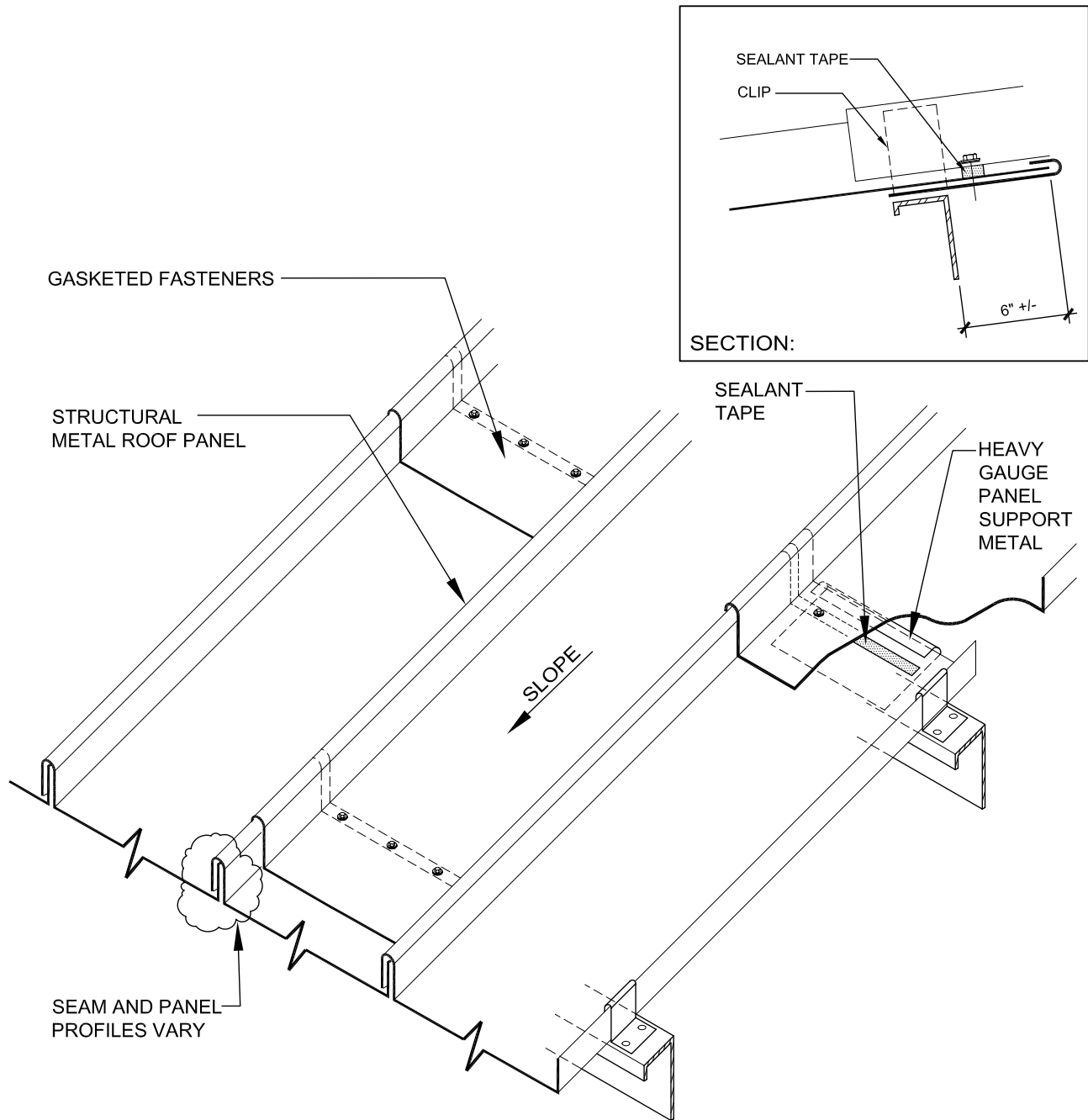


**DOWNSLOPE FLASHING WITH GUTTER - "L" TYPE**

2006

NOT DRAWN TO SCALE

**S-MTL-3D**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. HEAVY GAUGE PANEL SUPPORT METAL PROFILE AND ATTACHMENT MAY VARY DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS.
3. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

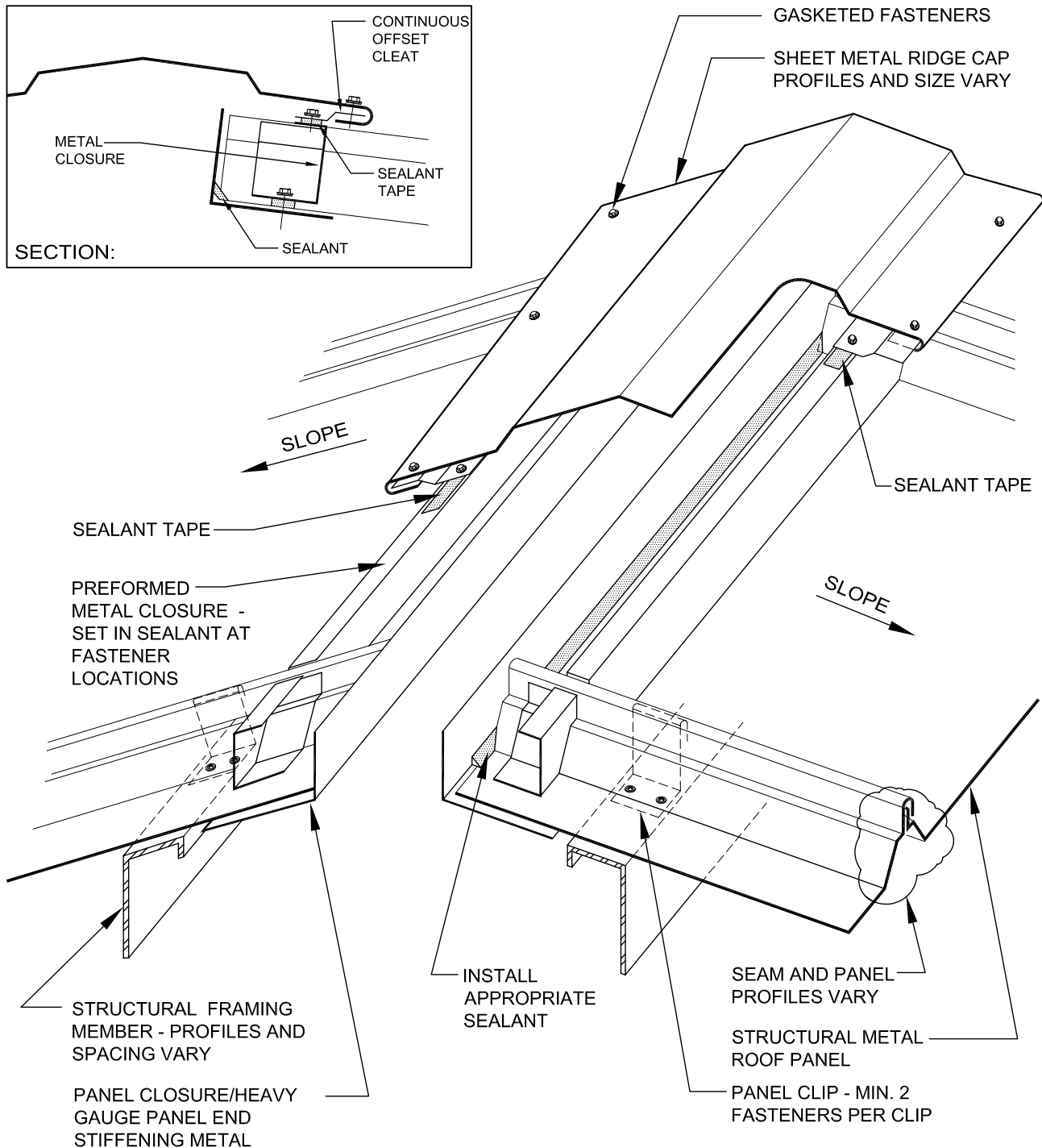


STAGGERED PANEL END LAPS

2006

NOT DRAWN TO SCALE

S-MTL-4



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE RIDGE.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

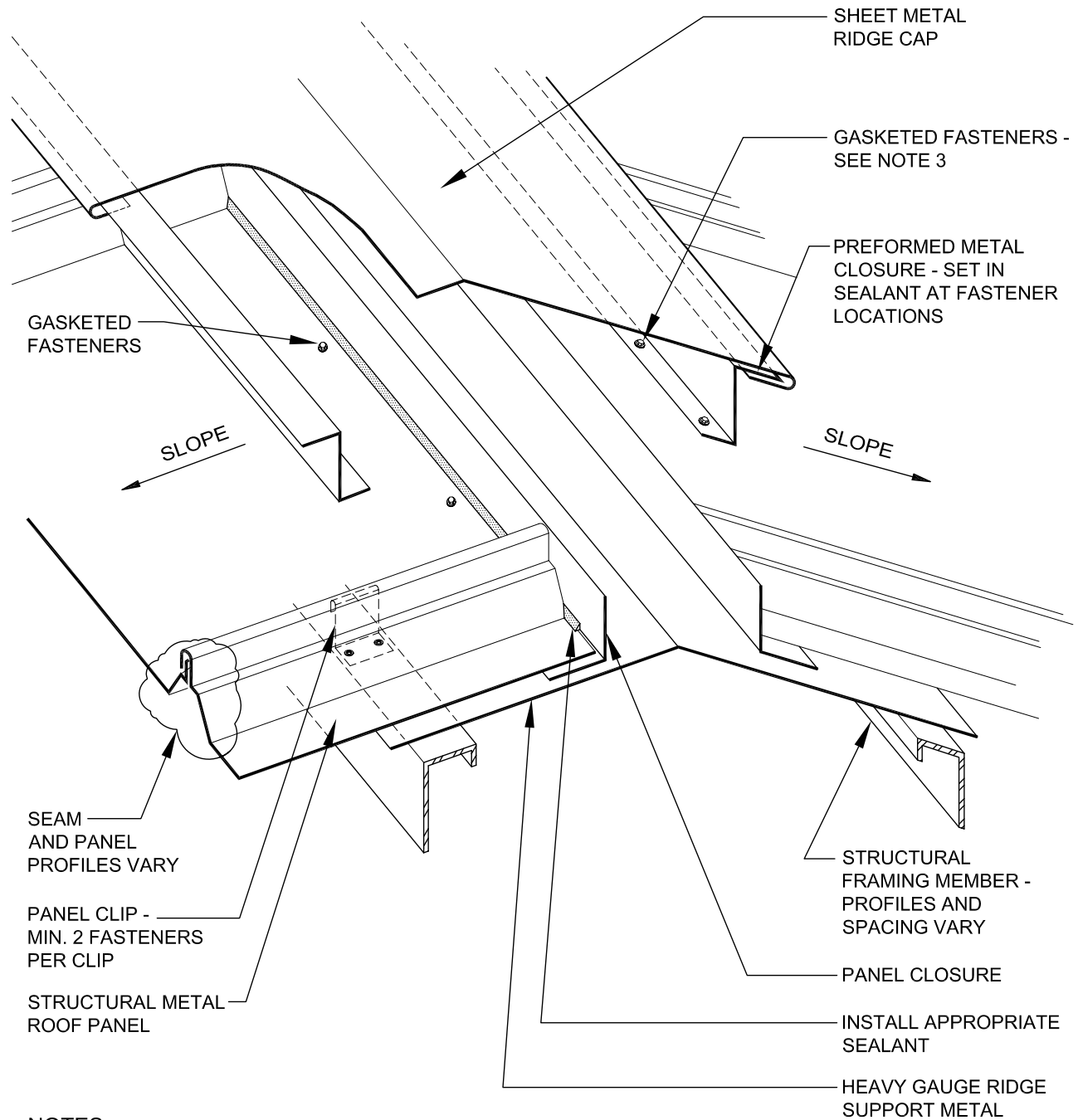


**RIDGE CAP FLASHING**

2006

NOT DRAWN TO SCALE

**S-MTL-5**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE RIDGE.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

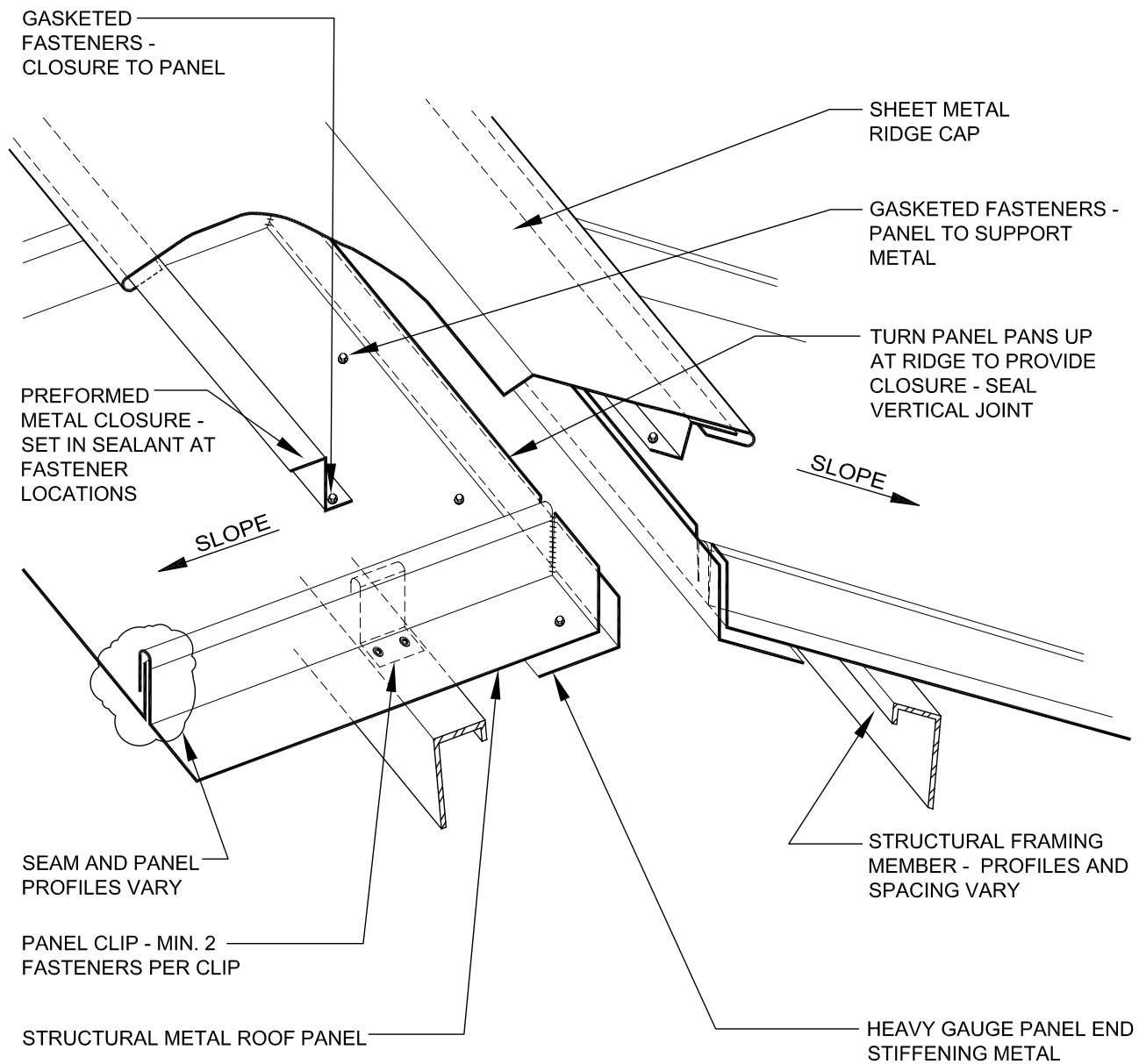


**RIDGE CAP FLASHING WITH SUPPORT METAL**

2006

NOT DRAWN TO SCALE

**S-MTL-5A**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE RIDGE.
4. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

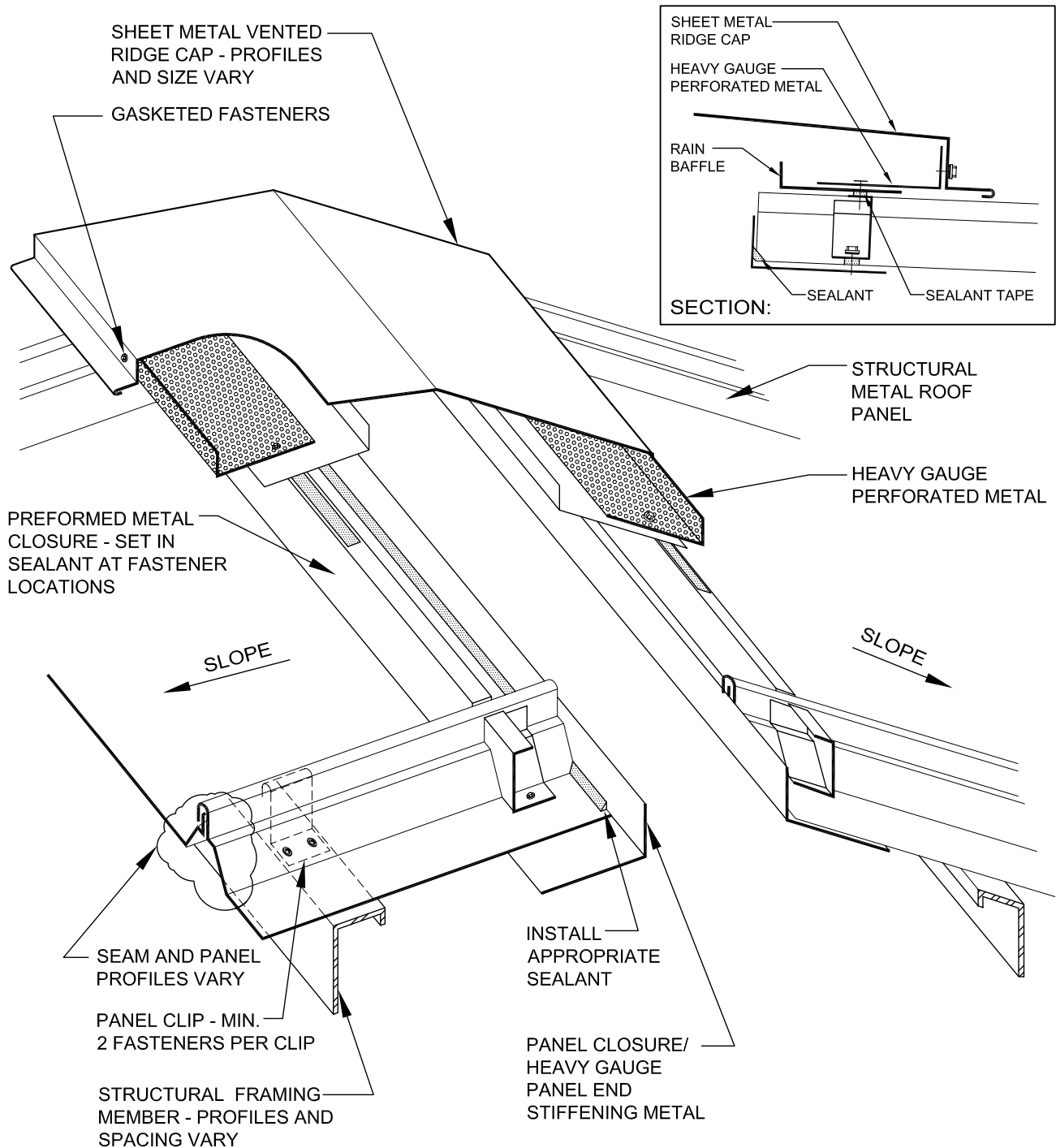


**RIDGE CAP FLASHING**

2006

NOT DRAWN TO SCALE

**S-MTL-6**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE RIDGE.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

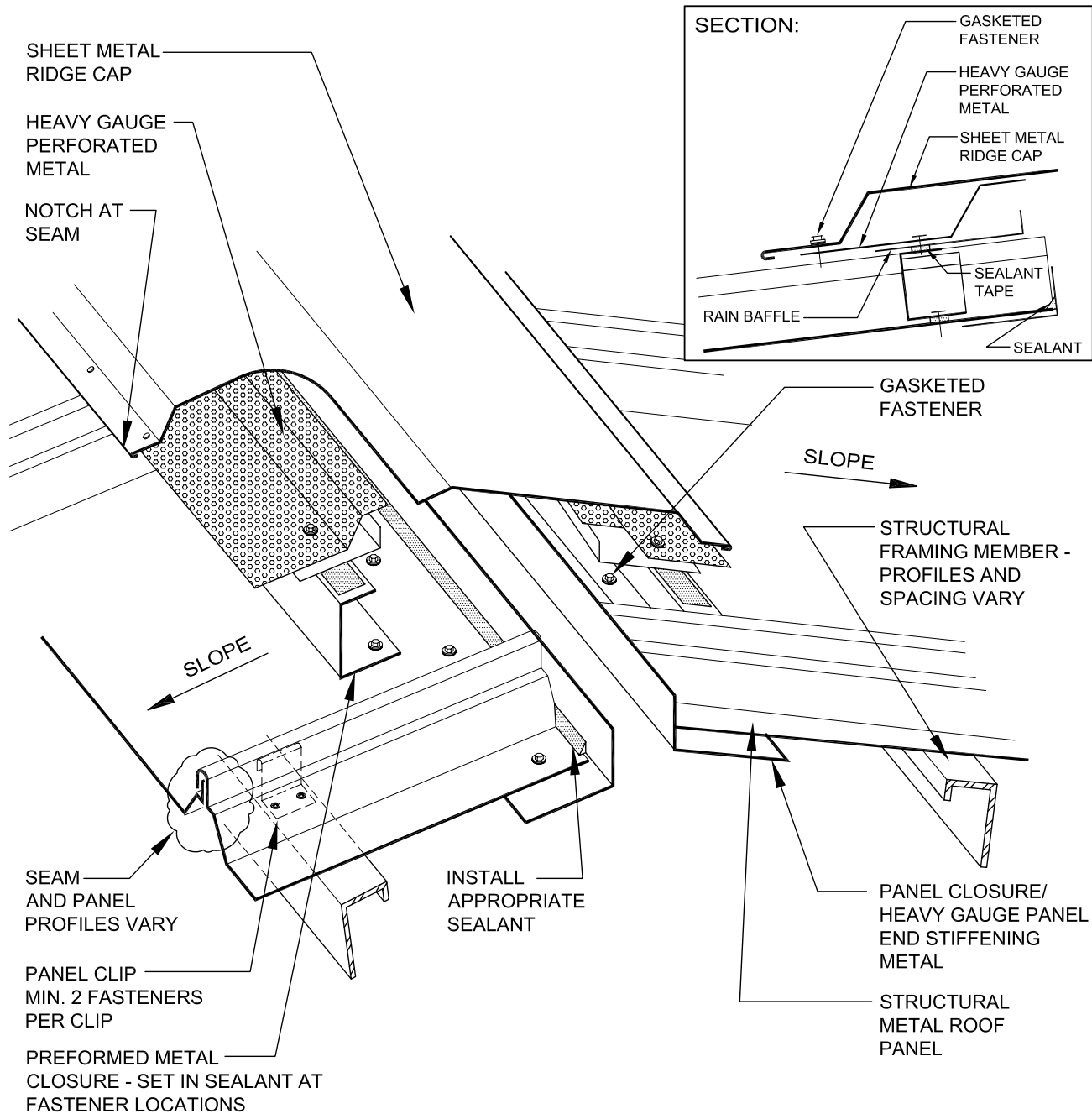


**VENTED RIDGE CAP FLASHING WITH PERFORATED METAL**

2006

NOT DRAWN TO SCALE

S-MTL-7



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANELS ALONG THE RIDGE.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

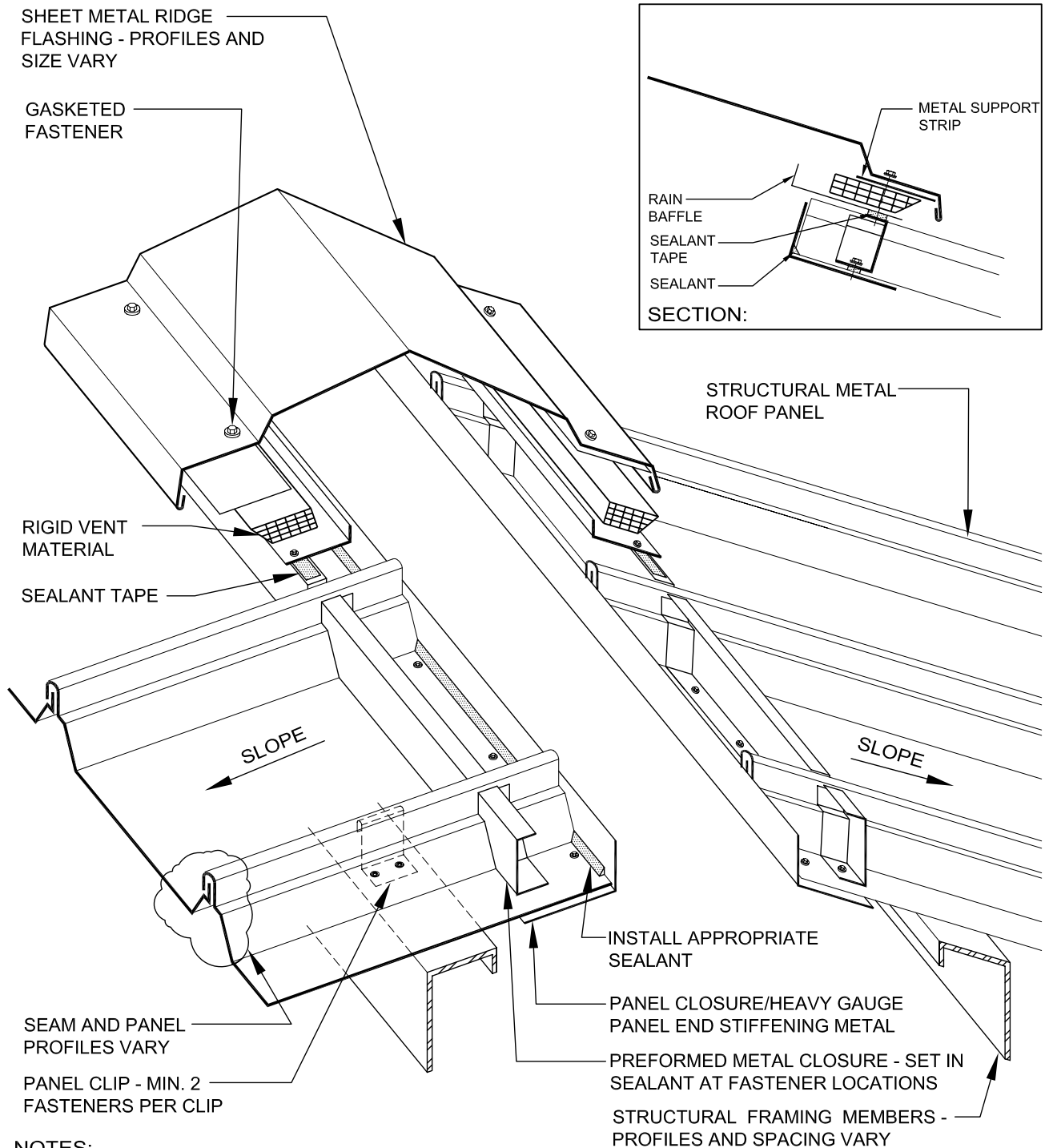


**VENTED RIDGE CAP FLASHING WITH PERFORATED METAL**

2006

NOT DRAWN TO SCALE

**S-MTL-7A**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANELS ALONG THE RIDGE.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

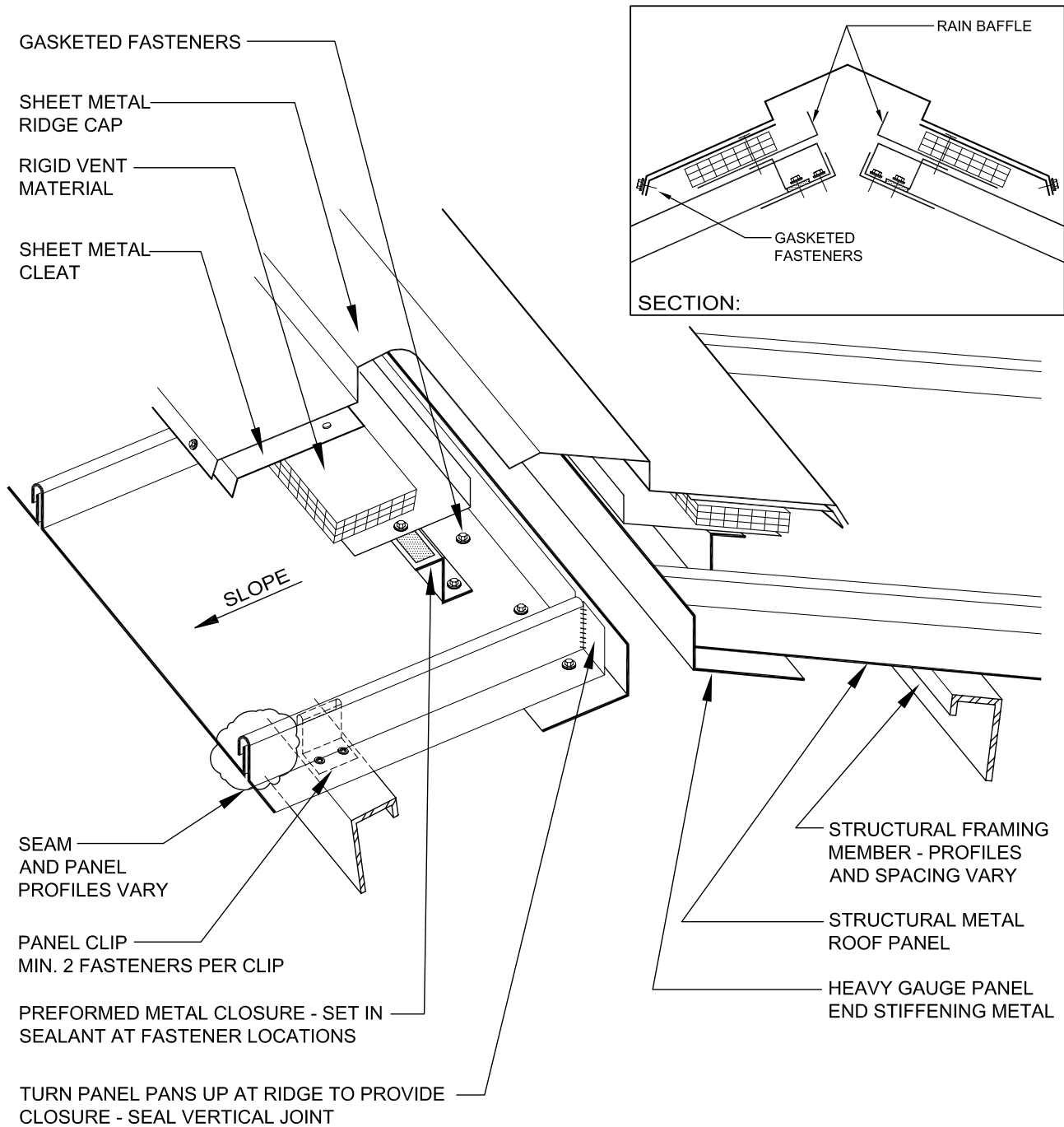


**VENTED RIDGE CAP FLASHING WITH VENT MATERIAL**

2006

NOT DRAWN TO SCALE

**S-MTL-7B**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANELS ALONG THE RIDGE.
4. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

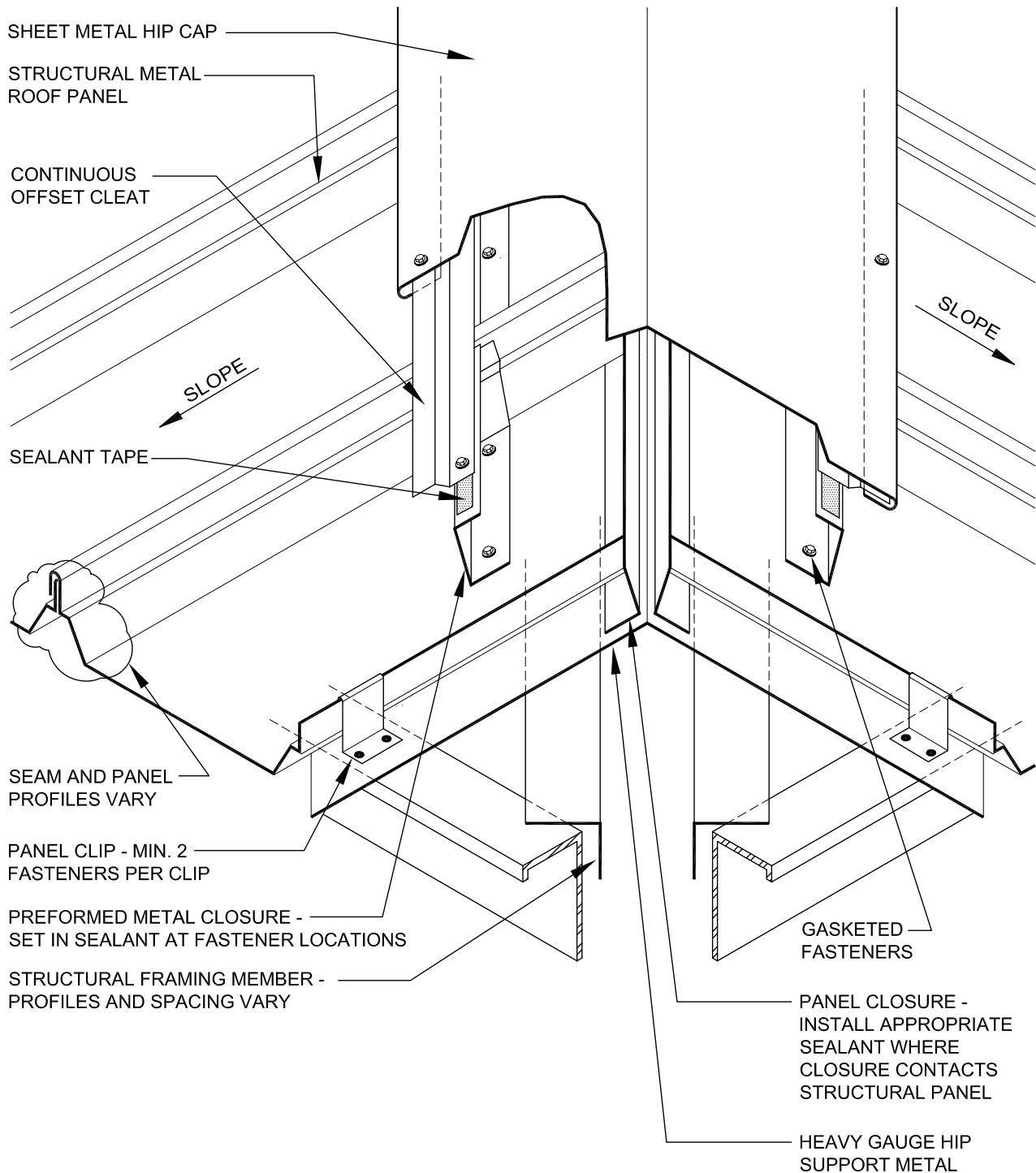


**VENTED RIDGE CAP FLASHING WITH VENT MATERIAL**

2006

NOT DRAWN TO SCALE

**S-MTL-7C**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING MEMBER, THIS FIXES THE PANEL ALONG THE HIP.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

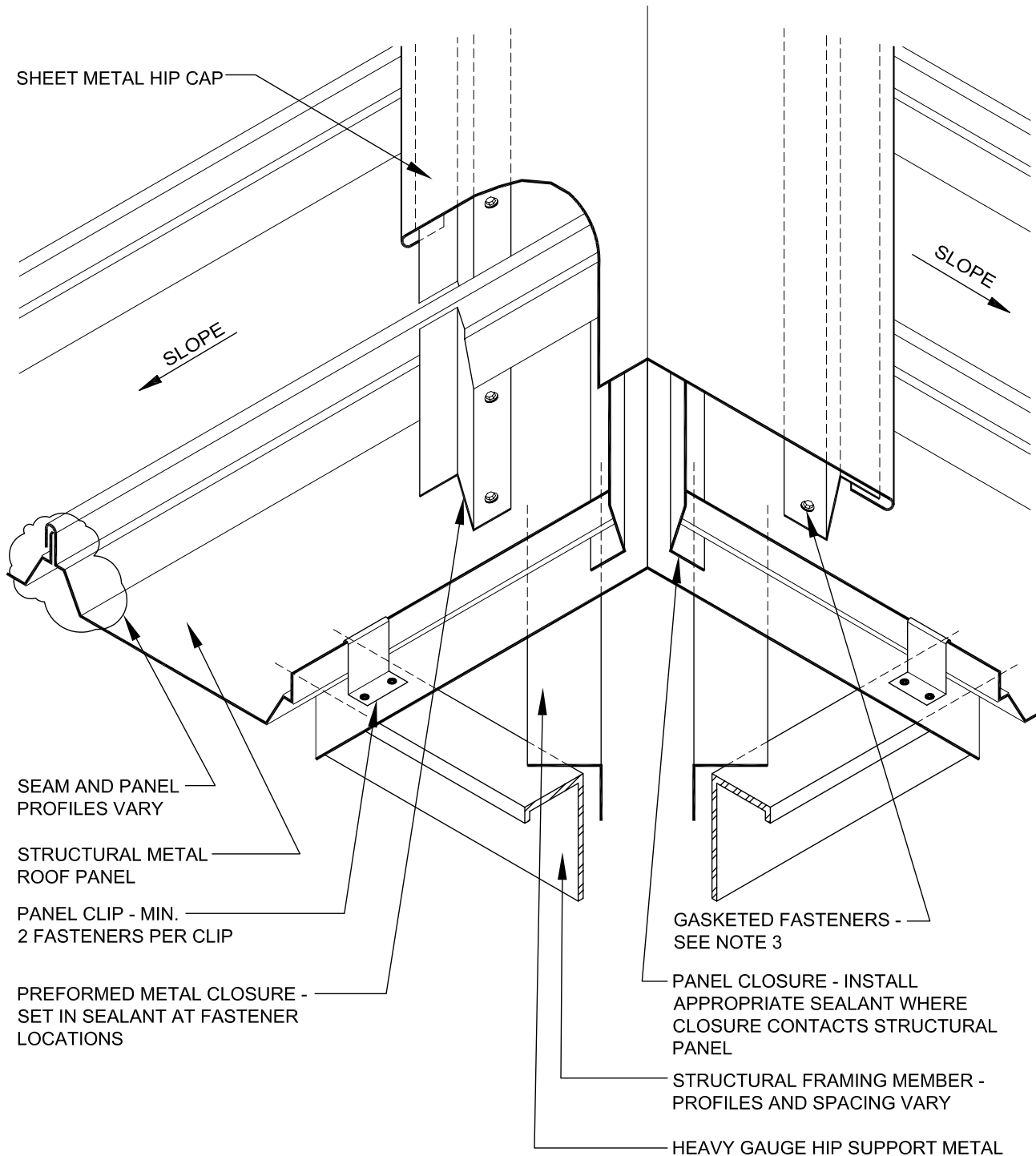


**HIP CAP FLASHING WITH HIP SUPPORT METAL**

2006

NOT DRAWN TO SCALE

**S-MTL-8**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING MEMBER, THIS FIXES THE PANEL ALONG THE HIP.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

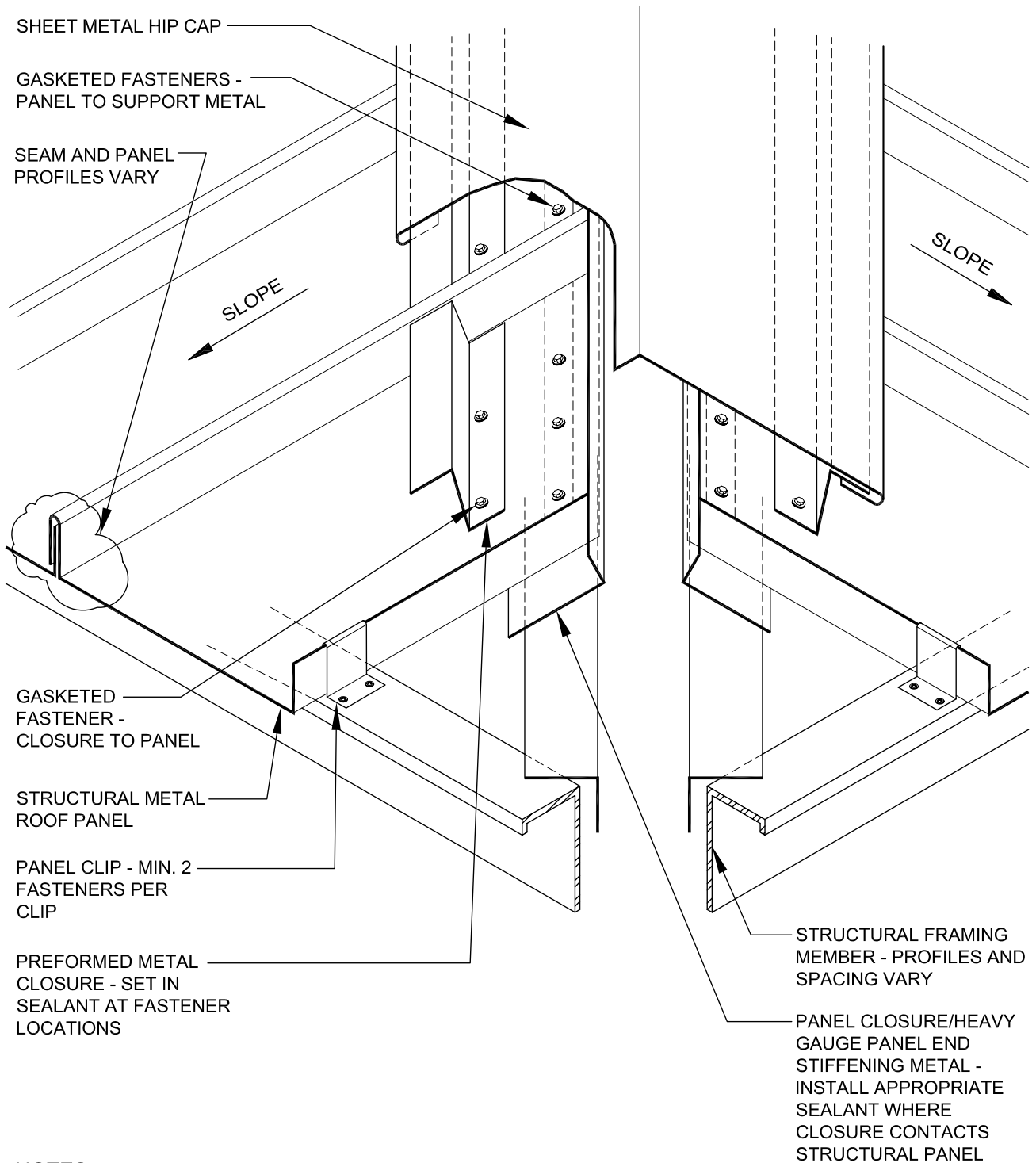


**HIP CAP FLASHING WITH HIP SUPPORT METAL**

2006

NOT DRAWN TO SCALE

**S-MTL-8A**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE HIP .
4. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

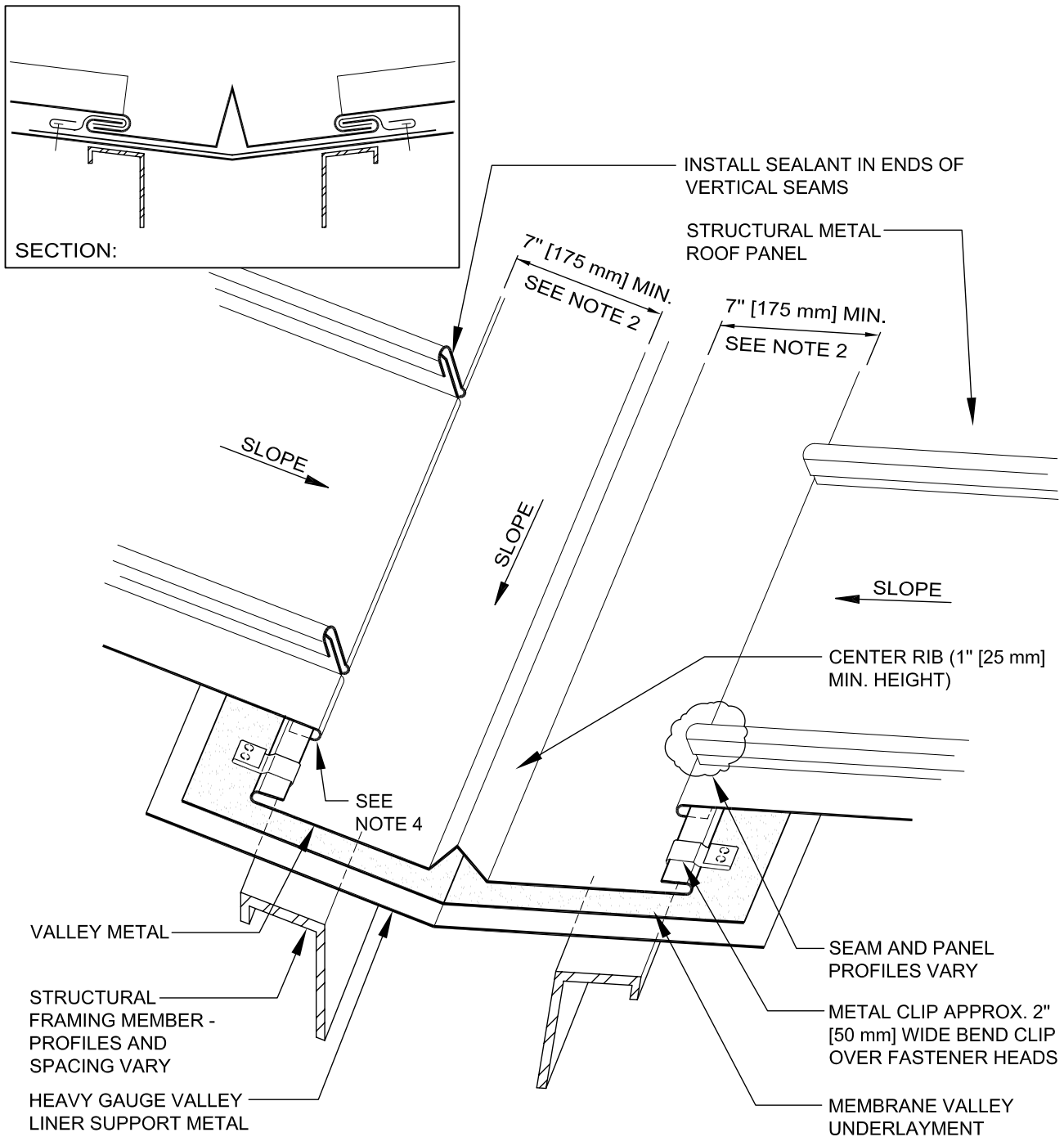


**HIP CAP FLASHING WITH PANEL END STIFFENING METAL**

2006

NOT DRAWN TO SCALE

**S-MTL-8B**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. MINIMUM VALLEY FLANGE WIDTHS FOR SLOPES 2:12 (9 DEGREES) OR LESS. MINIMUM VALLEY FLANGE WIDTHS INCREASE AS SLOPES DECREASE.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. PANEL TO VALLEY ENGAGEMENT DETERMINED BY PANEL LENGTH AND TYPE OF MATERIAL.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

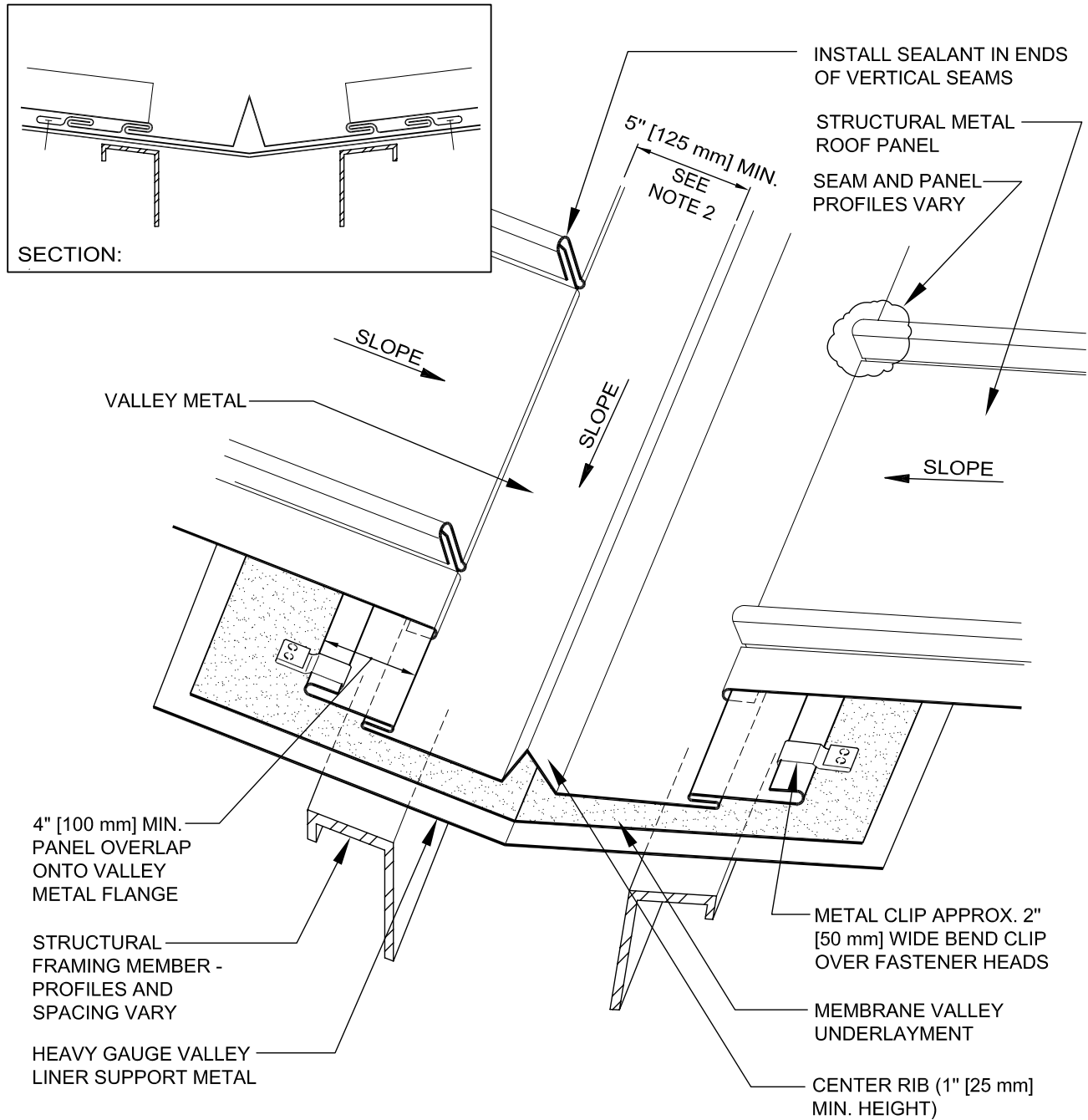


**OPEN VALLEY METAL (CLEATED)**

2006

NOT DRAWN TO SCALE

S-MTL-9



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. MINIMUM VALLEY FLANGE WIDTHS FOR SLOPES 2:12 (9 DEGREES) OR LESS. MINIMUM VALLEY FLANGE WIDTHS INCREASE AS SLOPES DECREASE.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. PANEL TO VALLEY ENGAGEMENT DETERMINED BY PANEL LENGTH AND TYPE OF MATERIAL.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

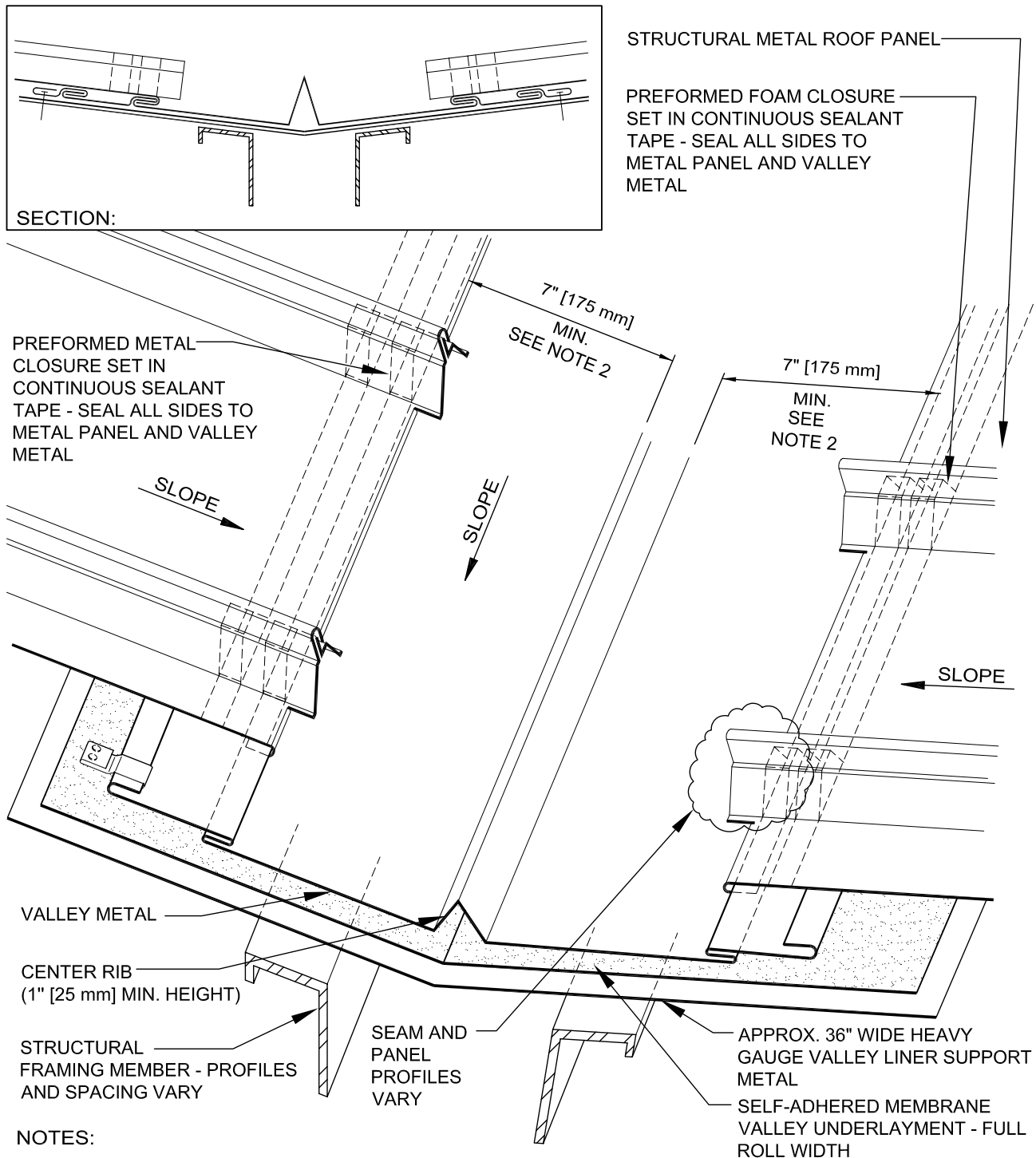


**OPEN VALLEY METAL WITH SIDE LOCKS (CLEATED)**

2006

NOT DRAWN TO SCALE

**S-MTL-9A**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. MINIMUM VALLEY FLANGE WIDTHS FOR SLOPES 2:12 (9 DEGREES) OR LESS. MINIMUM VALLEY FLANGE WIDTHS INCREASE AS SLOPES DECREASE.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. THIS DETAIL CAN BE INSTALLED WITH FLAT PAN, VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

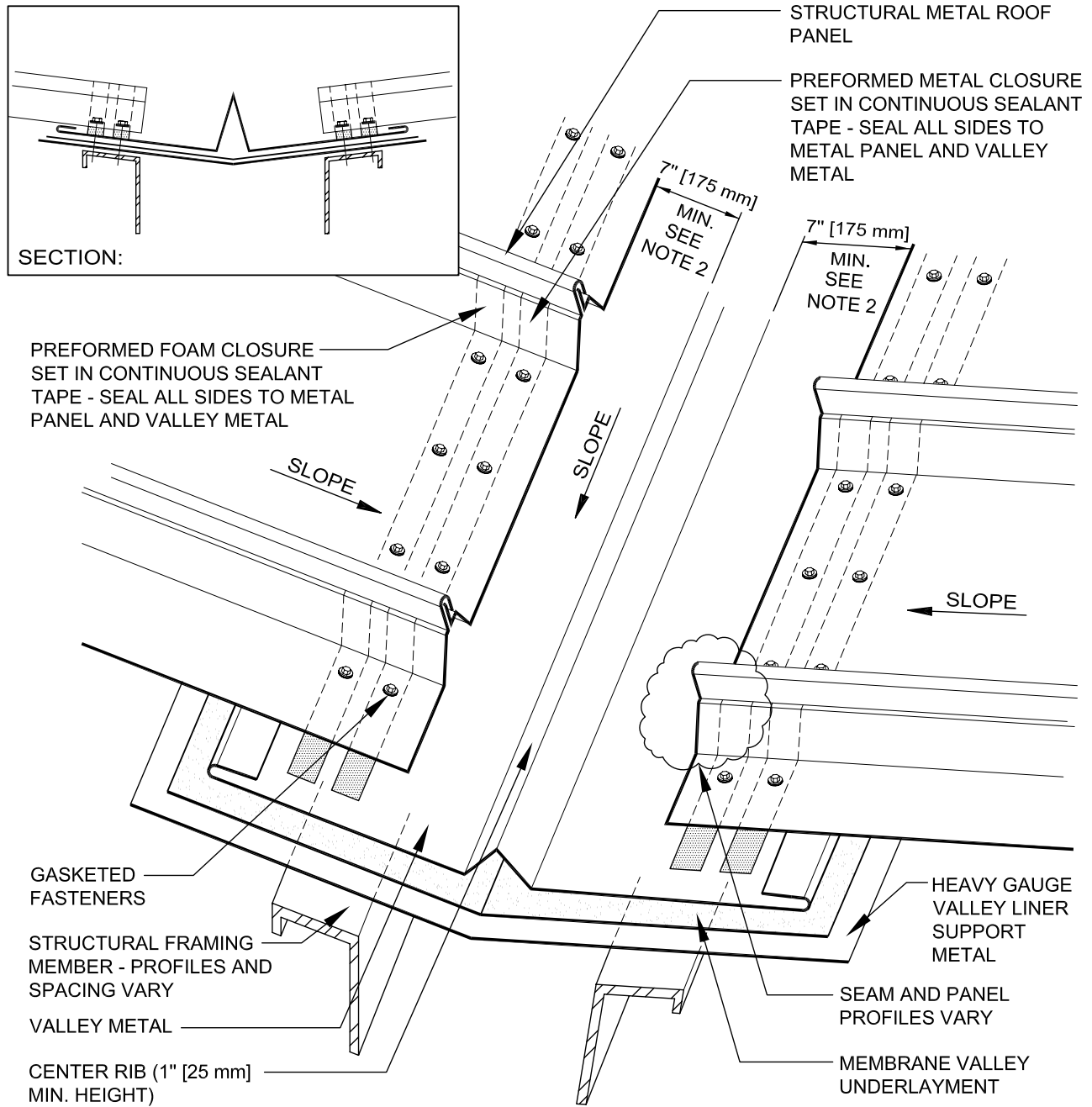


**OPEN VALLEY METAL WITH SIDE LOCKS (CLEATED)**

2006

NOT DRAWN TO SCALE

S-MTL-9B



**NOTES:**

1. THIS DETAIL IS NOT THE PREFERRED VALLEY FLASHING METHOD BECAUSE IT MAY BE A CONSTANT MAINTENANCE PROBLEM. SEE DETAIL S-MTL-9 FOR THE PREFERRED FLASHING METHOD.
2. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
3. MINIMUM VALLEY FLANGE WIDTHS FOR SLOPES 2:12 (9 DEGREES) OR LESS. MINIMUM VALLEY FLANGE WIDTHS INCREASE AS SLOPES DECREASE.
4. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
5. THIS DETAIL FIXES THE PANELS AT THE VALLEY.
6. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
7. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

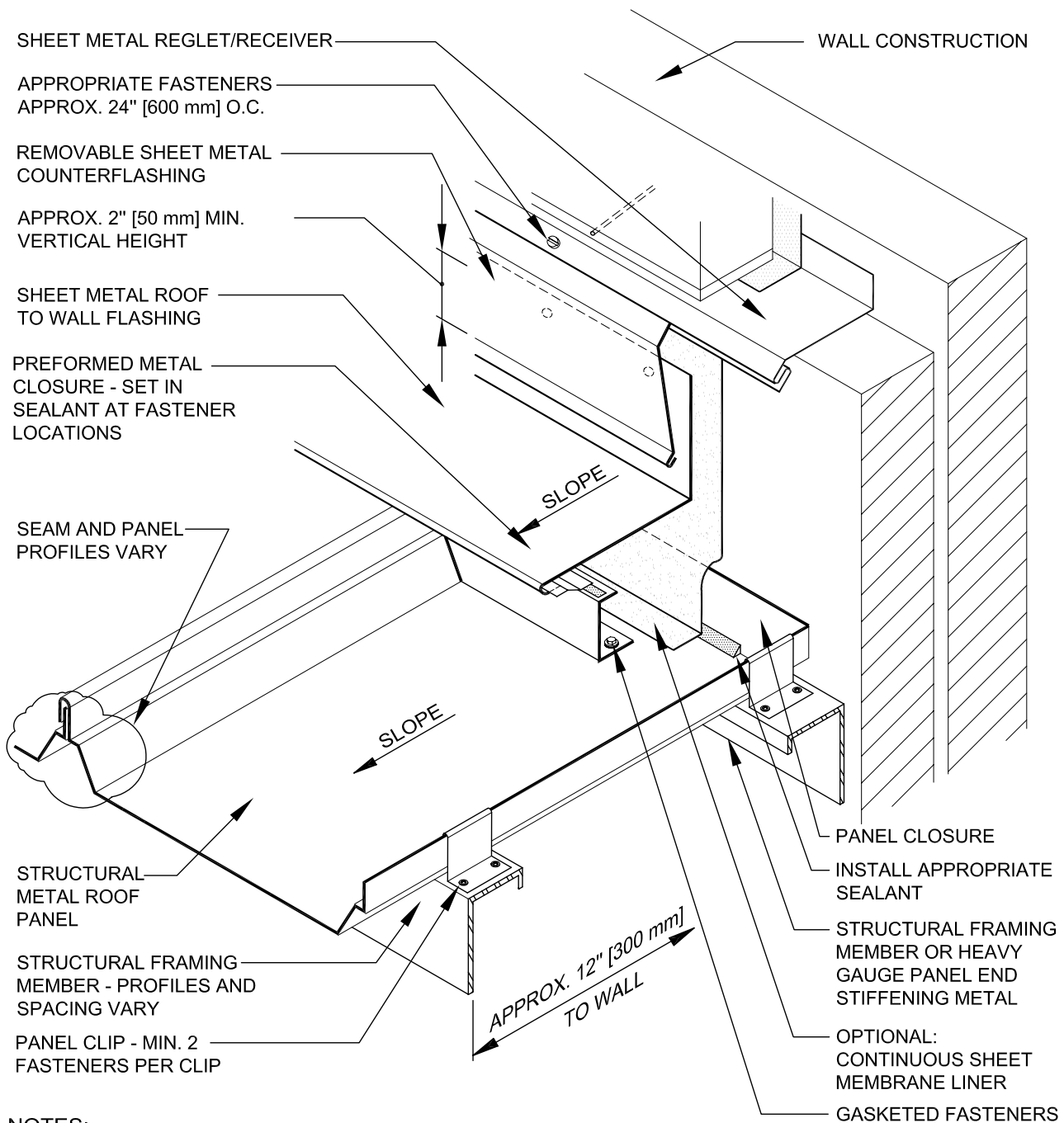


**OPEN VALLEY METAL (FASTENED)**

2006

NOT DRAWN TO SCALE

**S-MTL-9C**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANELS ALONG THE UPSLOPE END OF THE ROOF.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR ADDITIONAL COUNTERFLASHING OPTIONS.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

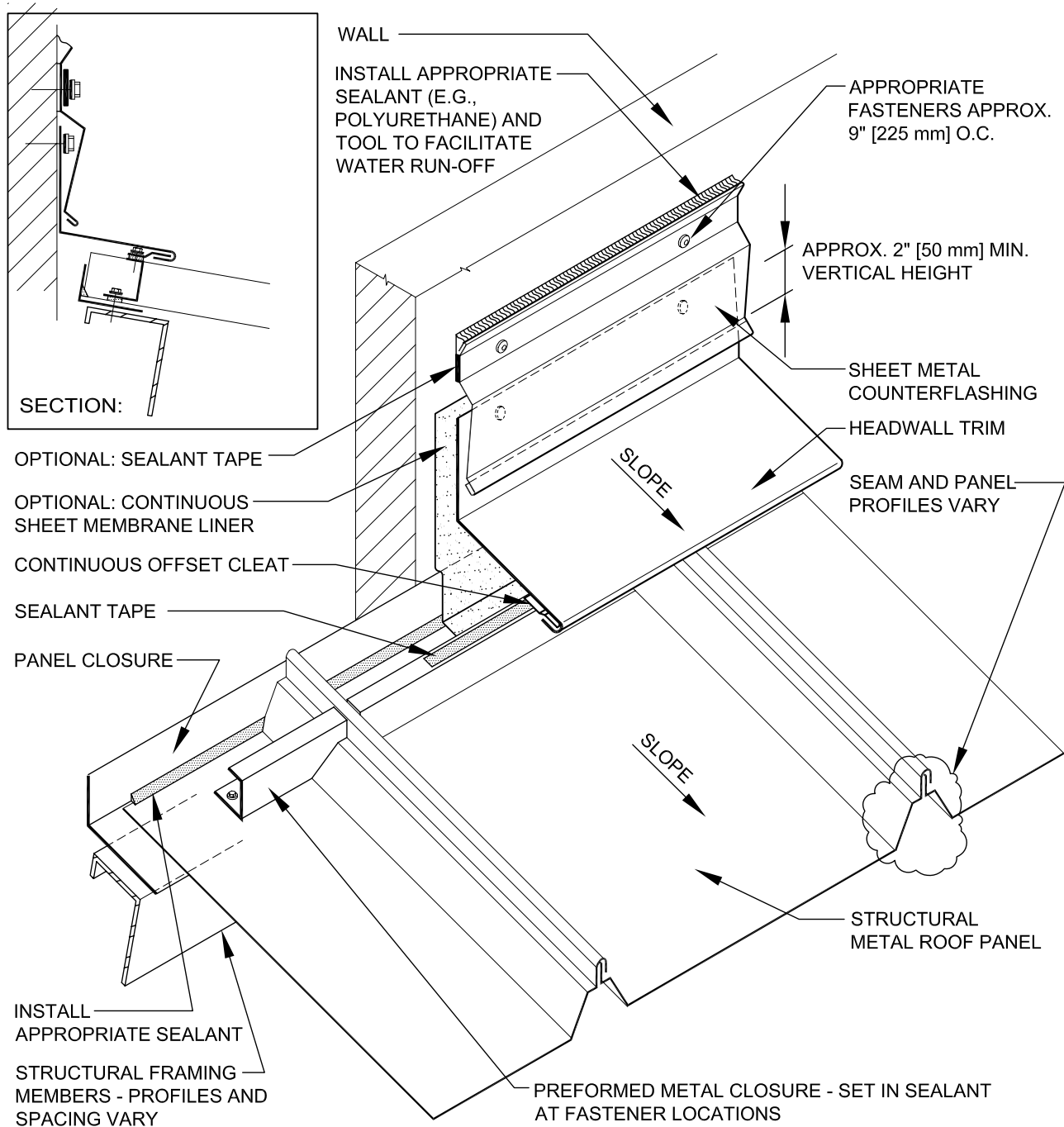


**ROOF-TO-WALL (HEADWALL) TRANSITION**

2006

NOT DRAWN TO SCALE

**S-MTL-10**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANELS ALONG THE HEAD WALL.
4. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR COUNTERFLASHING OPTIONS.
5. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

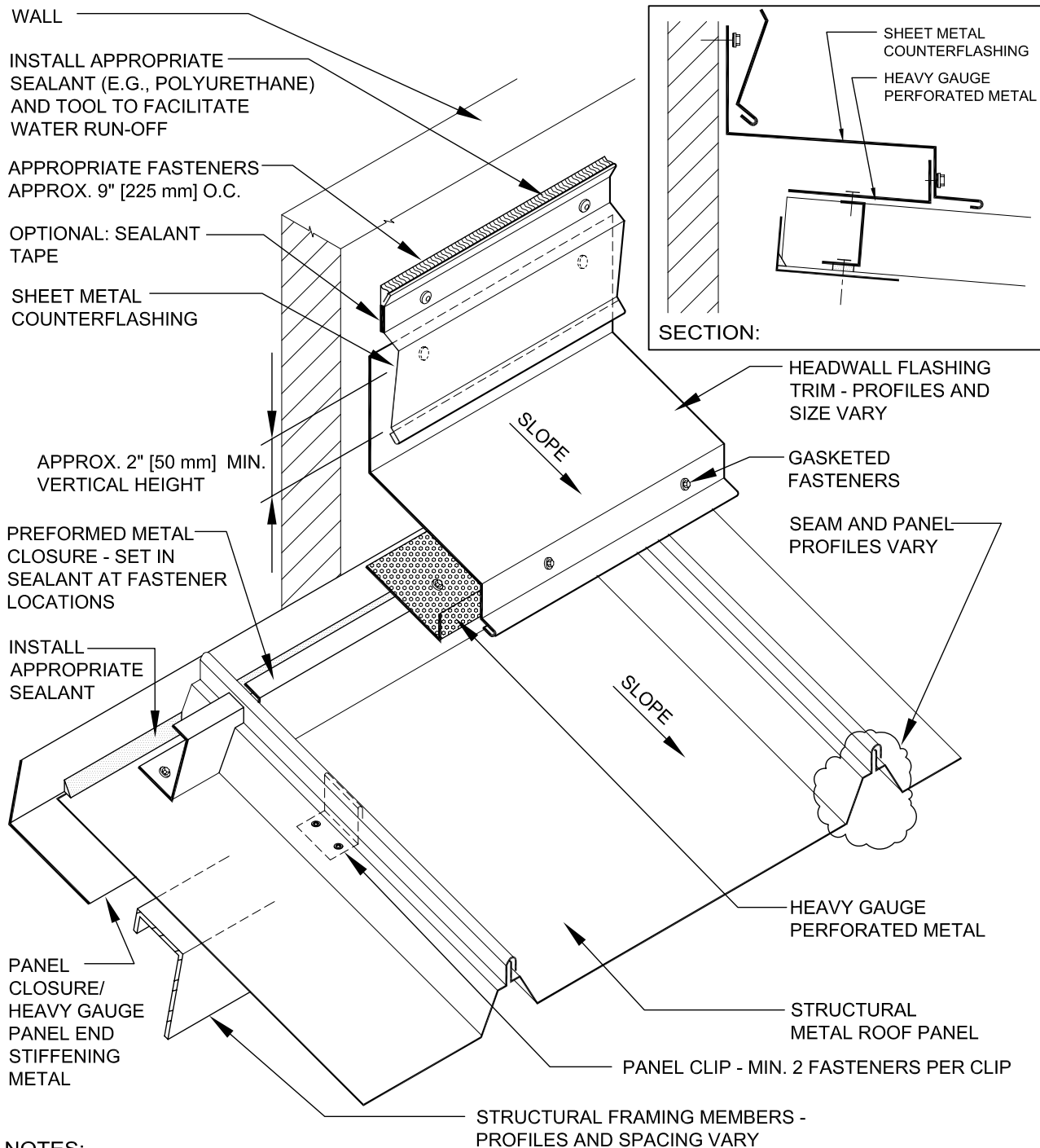


**ROOF-TO-WALL (HEADWALL) TRANSITION**

2006

NOT DRAWN TO SCALE

**S-MTL-10A**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR COUNTERFLASHING OPTIONS.
4. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANELS ALONG THE HEAD WALL.
5. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

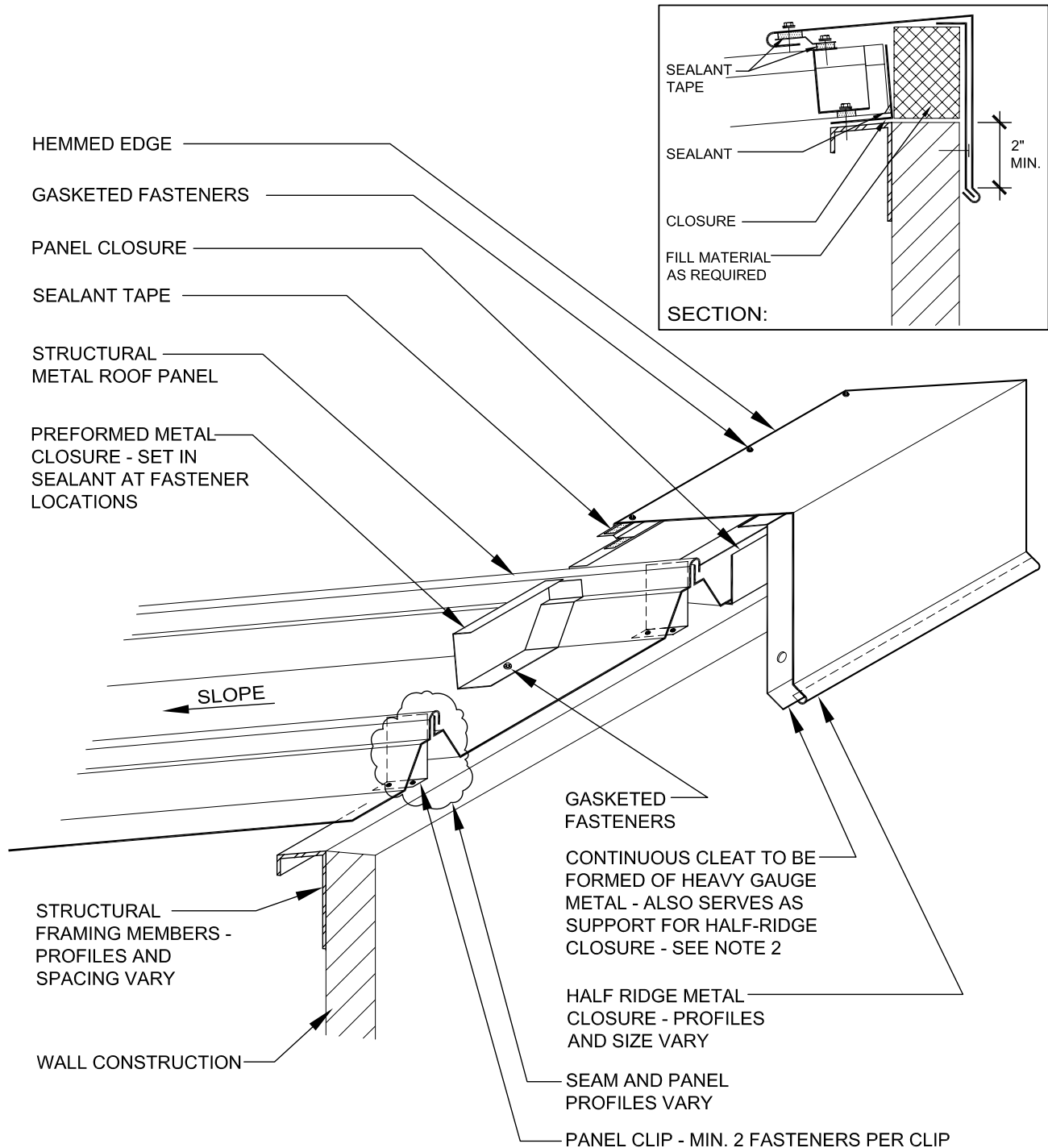


**VENTED ROOF-TO-WALL (HEADWALL) TRANSITION**

2006

NOT DRAWN TO SCALE

S-MTL-11



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS AND CLEAT RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. WHEN THE "C" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE HALF-RIDGE.
5. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

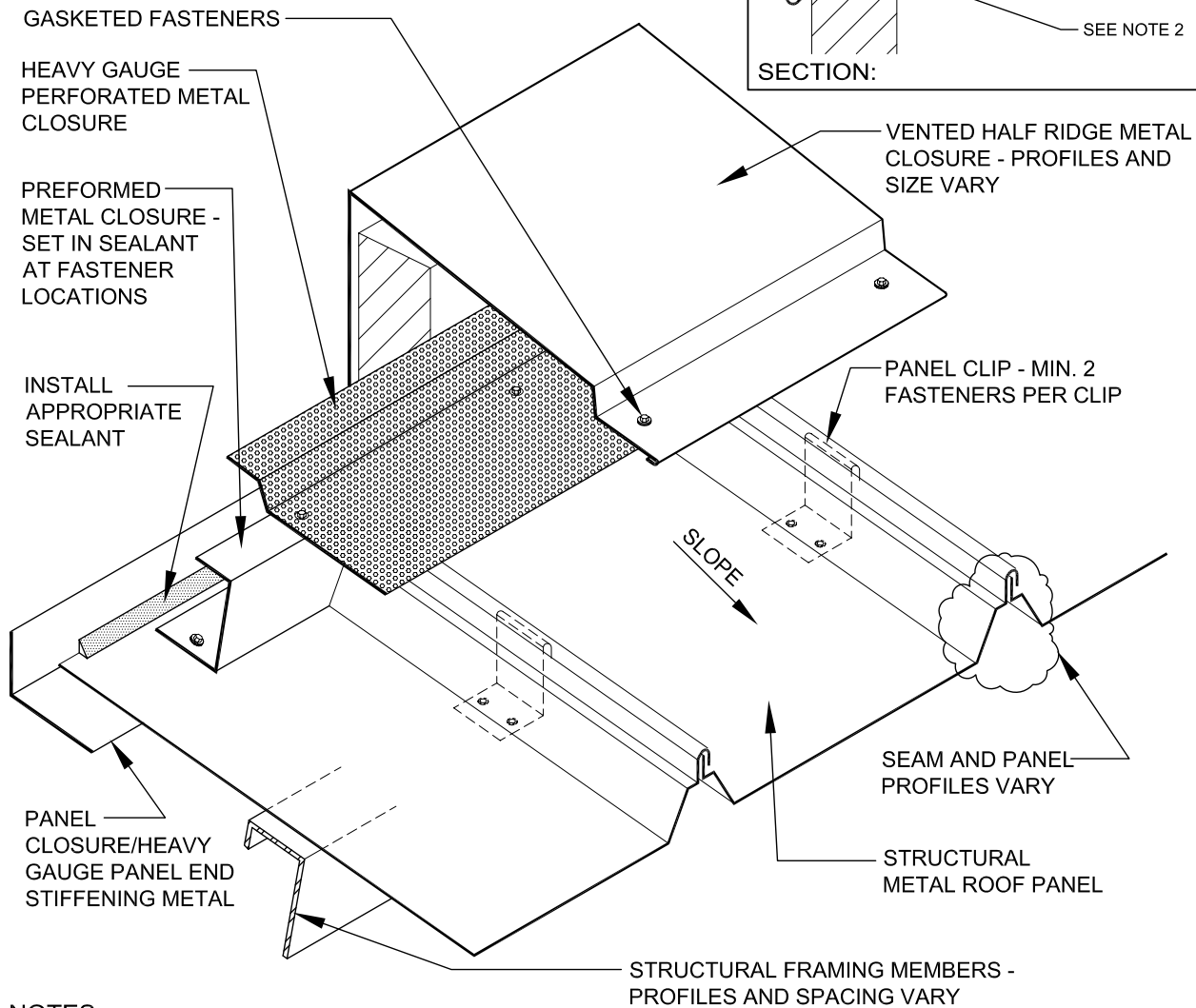
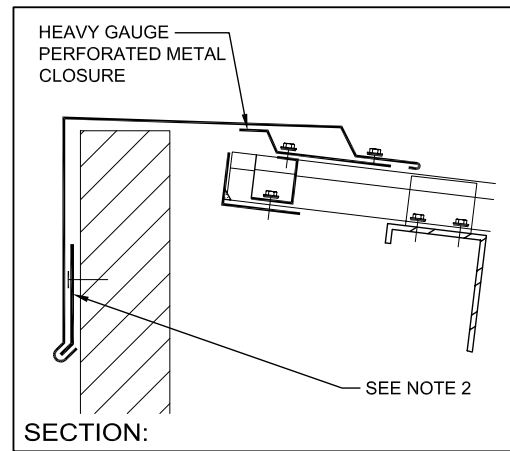
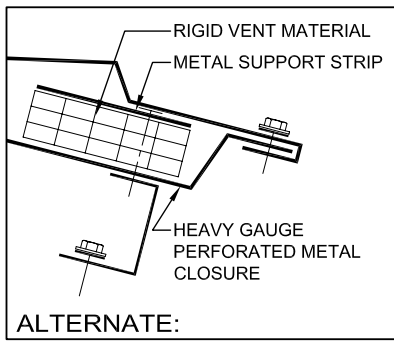


**HALF-RIDGE PERIMETER EDGE METAL FLASHING**

2006

NOT DRAWN TO SCALE

**S-MTL-12**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS AND CLEAT RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. WHEN "C" CLOSURE IS FASTENED THROUGH STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE HALF RIDGE.
5. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

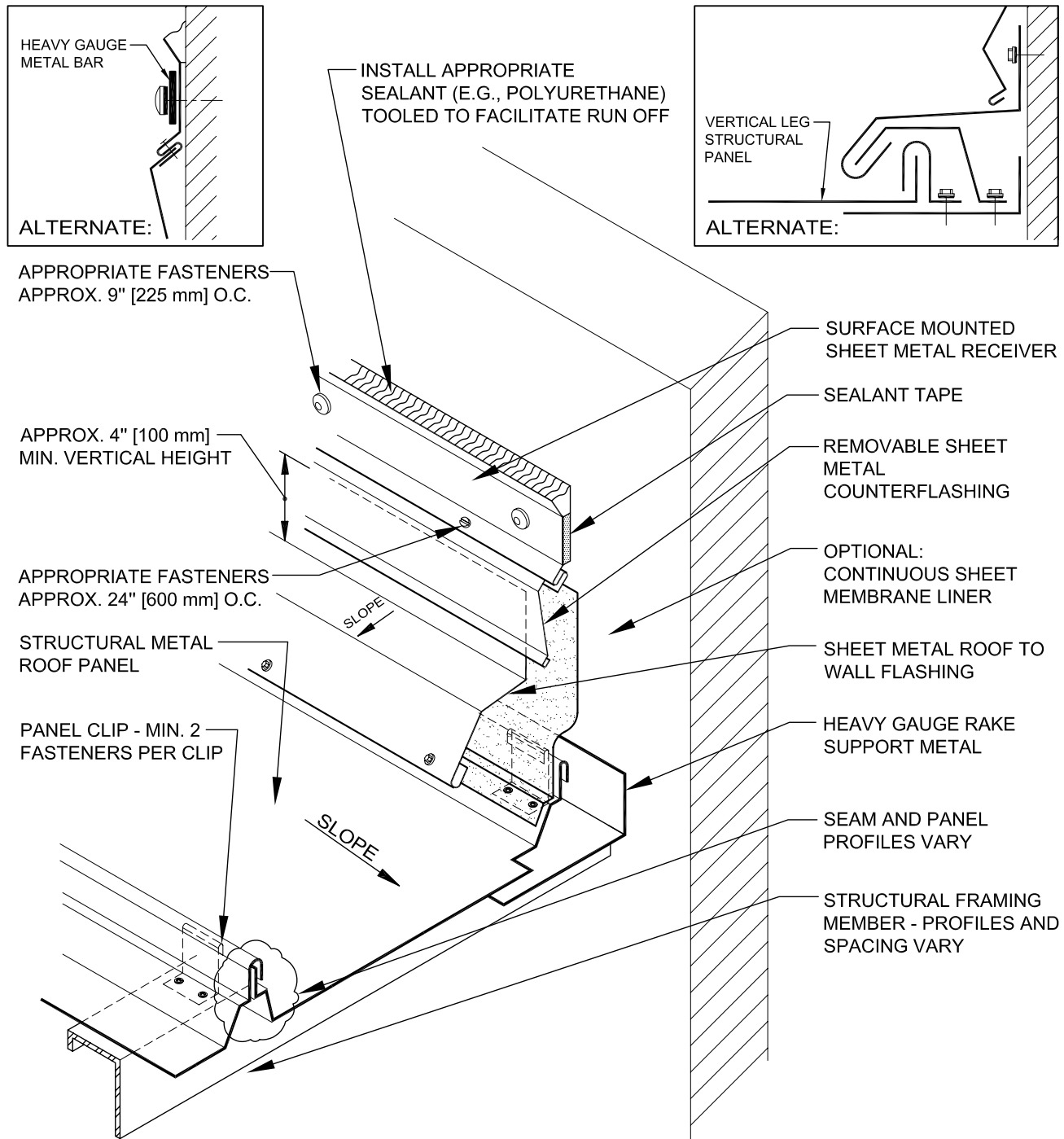


**VENTED HALF-RIDGE PERIMETER EDGE METAL FLASHING**

2006

NOT DRAWN TO SCALE

S-MTL-13



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR ADDITIONAL COUNTERFLASHING OPTIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

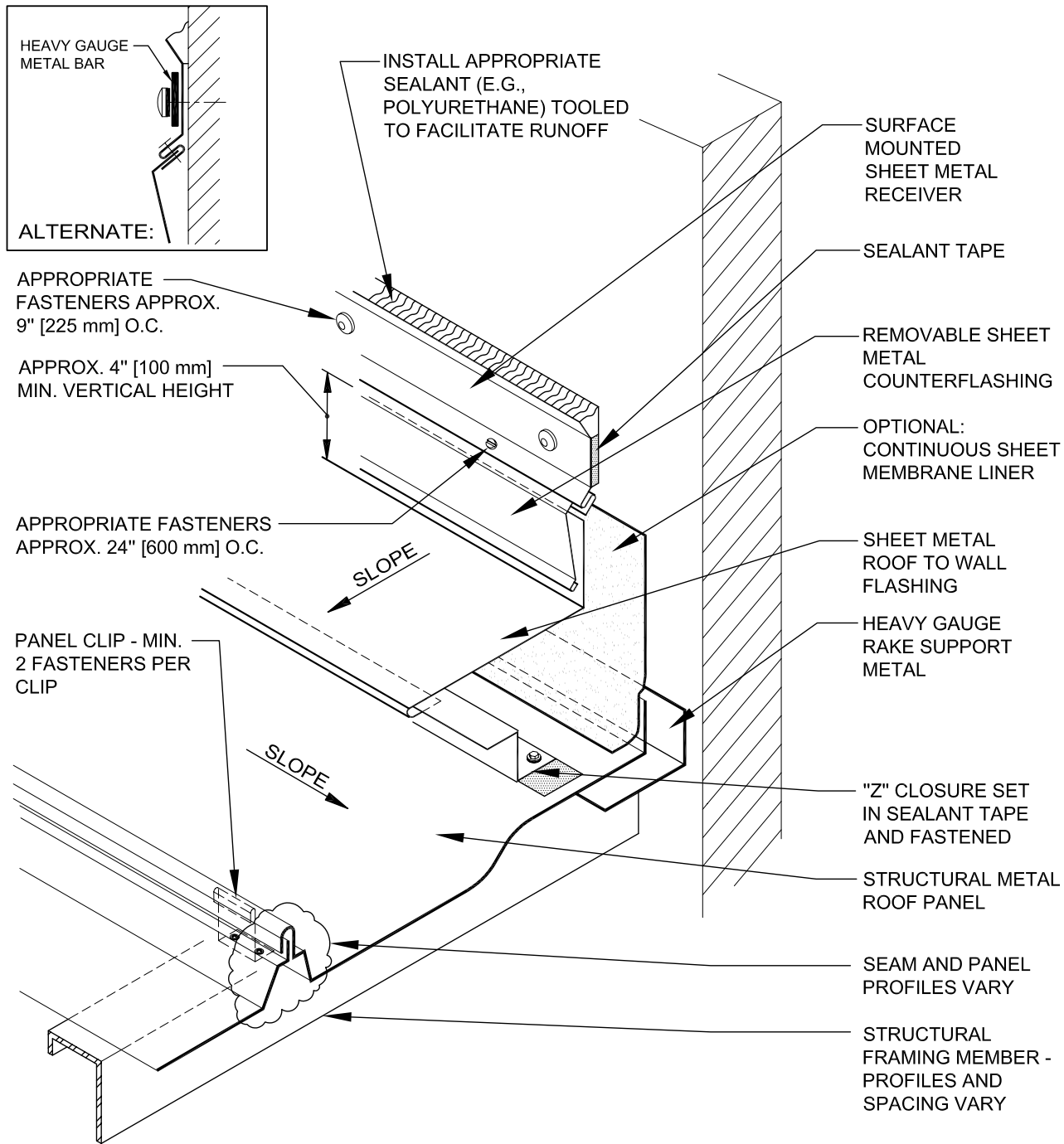


**ROOF-TO-WALL (SIDEWALL) TRANSITION - STARTER PANEL**

2006

NOT DRAWN TO SCALE

**S-MTL-14**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF PANEL NOT SHOWN FOR CLARITY.
3. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE SIDEWALL.
4. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE ROOFING MANUAL FOR ADDITIONAL COUNTERFLASHING OPTIONS.
5. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

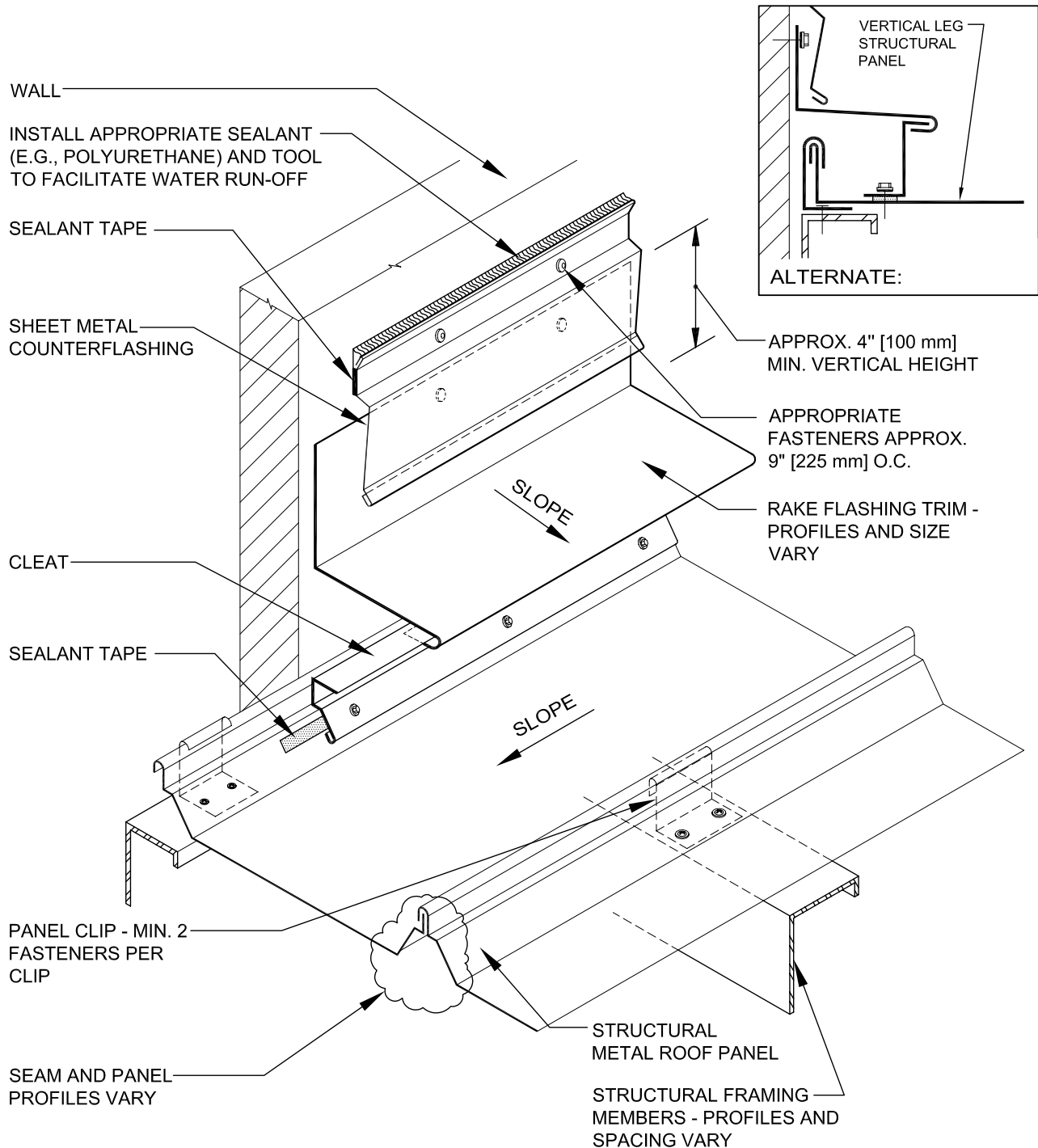


**ROOF-TO-WALL (SIDEWALL) TRANSITION - END PANEL**

**2006**

NOT DRAWN TO SCALE

**S-MTL-14A**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR COUNTERFLASHING OPTIONS.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO - SEE ALTERNATE.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

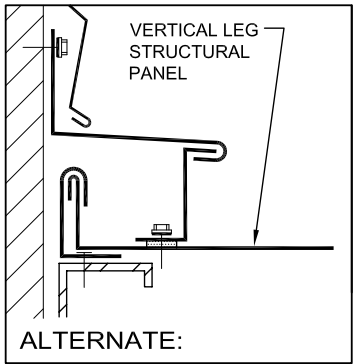
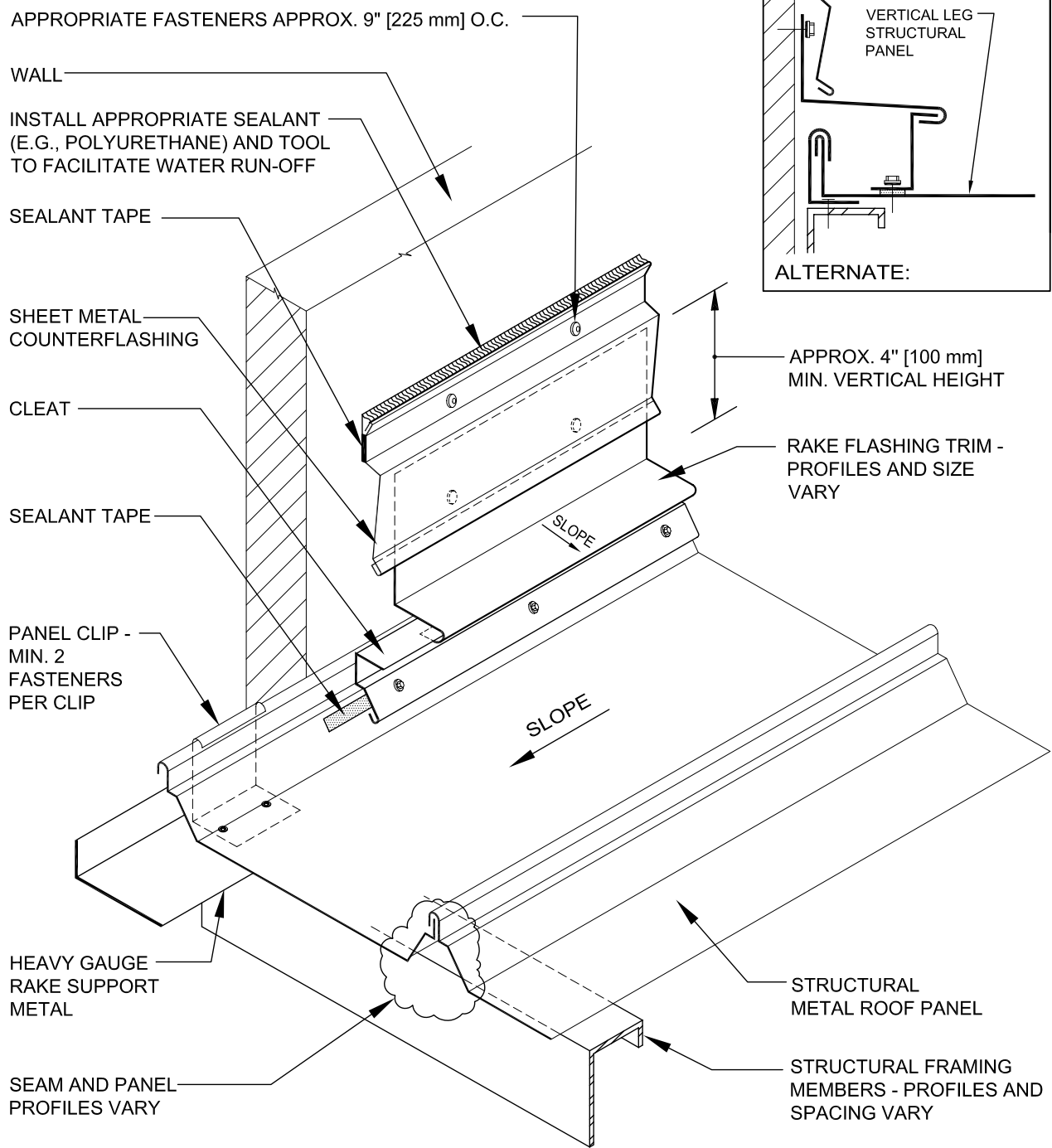


**ROOF-TO-WALL (SIDEWALL) TRANSITION -  
STARTER PANEL**

2006

NOT DRAWN TO SCALE

**S-MTL-14B**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
3. REFER TO SM-13, 14, 15 IN THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR COUNTERFLASHING OPTIONS.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO - SEE ALTERNATE.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

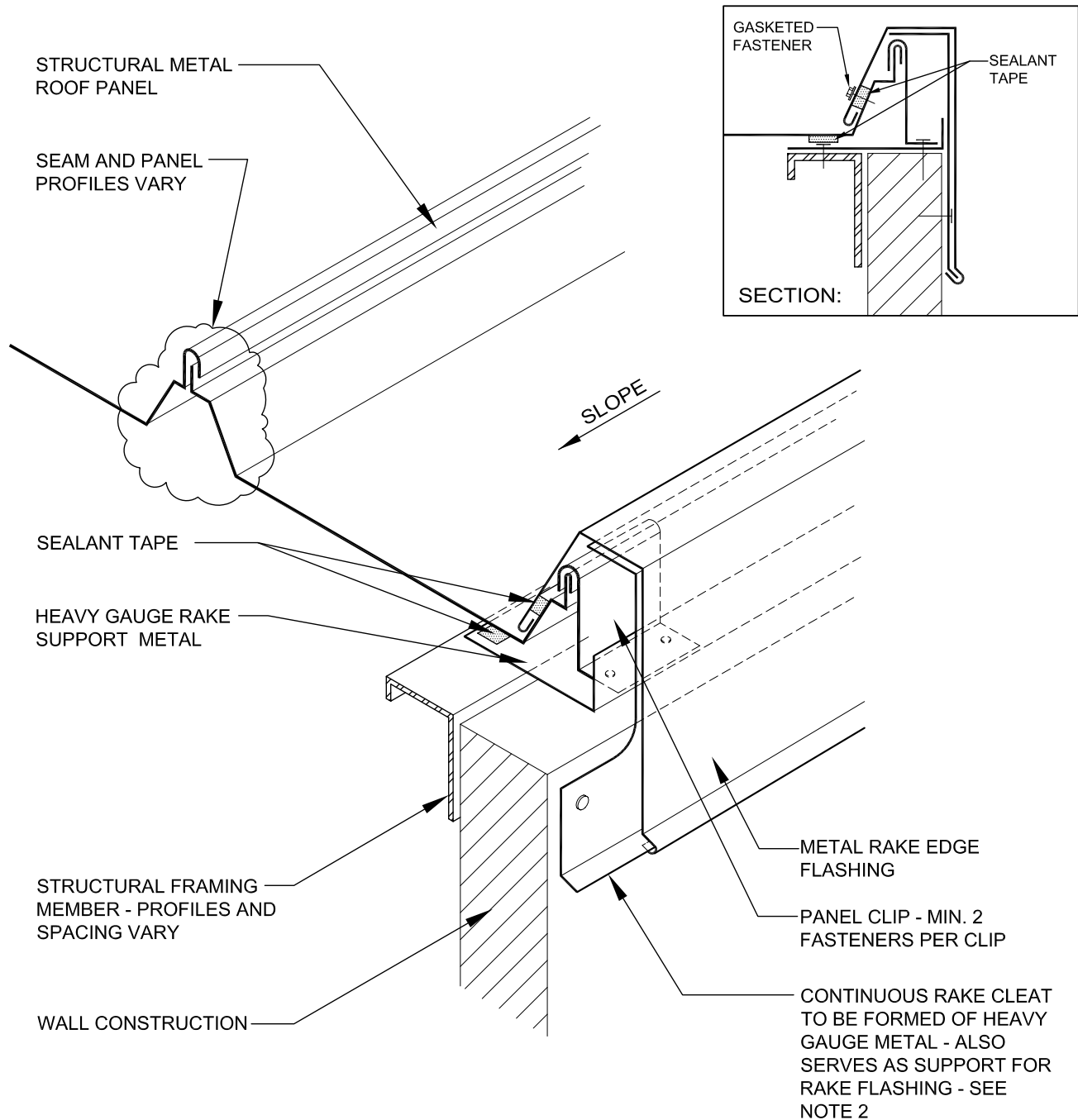


**ROOF-TO-WALL (SIDEWALL) TRANSITION -  
STARTER PANEL**

2006

NOT DRAWN TO SCALE

**S-MTL-14C**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS AND CLEAT RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

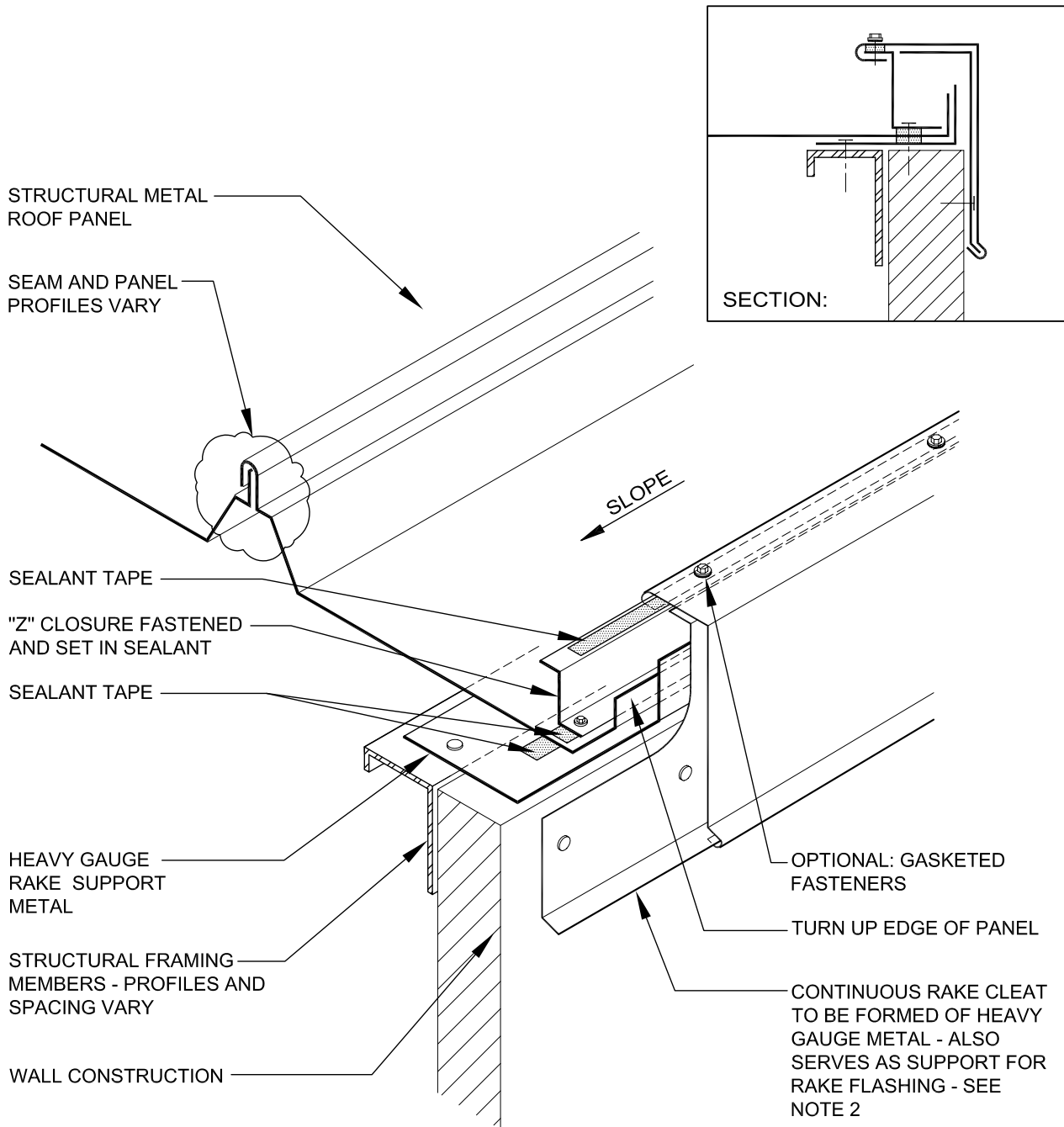


**RAKE EDGE FLASHING - STARTER PANEL**

2006

NOT DRAWN TO SCALE

**S-MTL-15**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. REFER TO METAL TABLE 1 FOR PERIMETER EDGE METAL THICKNESS AND CLEAT RECOMMENDATIONS.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE RAKE EDGE.
5. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
6. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

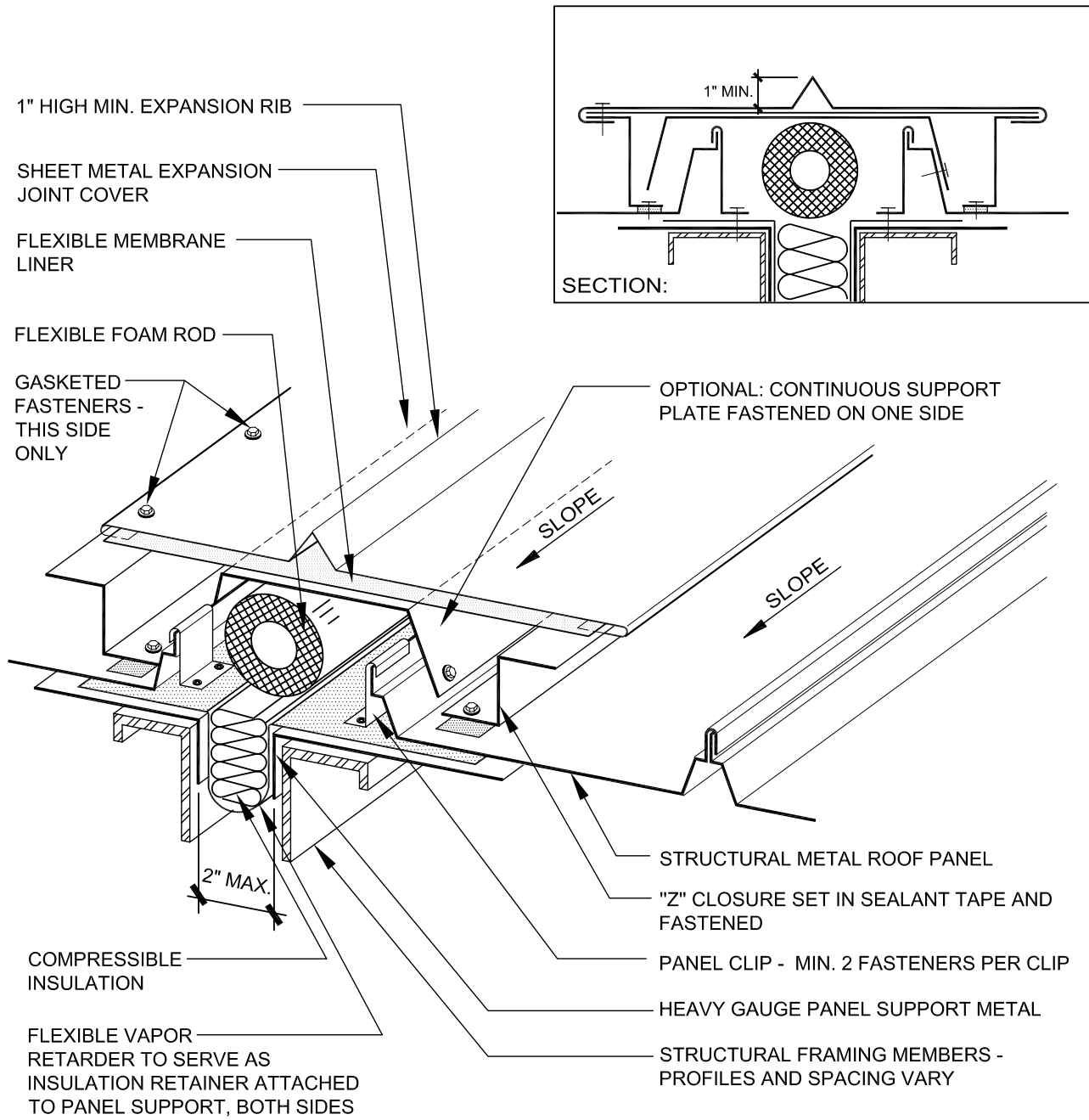


**RAKE EDGE FLASHING - END PANEL**

2006

NOT DRAWN TO SCALE

**S-MTL-15A**



**NOTES:**

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE EXPANSION JOINT.
5. THIS DETAIL WILL WORK FOR A 2" MAX. EXPANSION JOINT OPENING WITH 1" +/- MOVEMENT.
6. THE FLEXIBLE FOAM ROD SHOULD HAVE A MINIMUM DIAMETER 1-1/2 TIMES THE FRAMED OPENING.
7. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

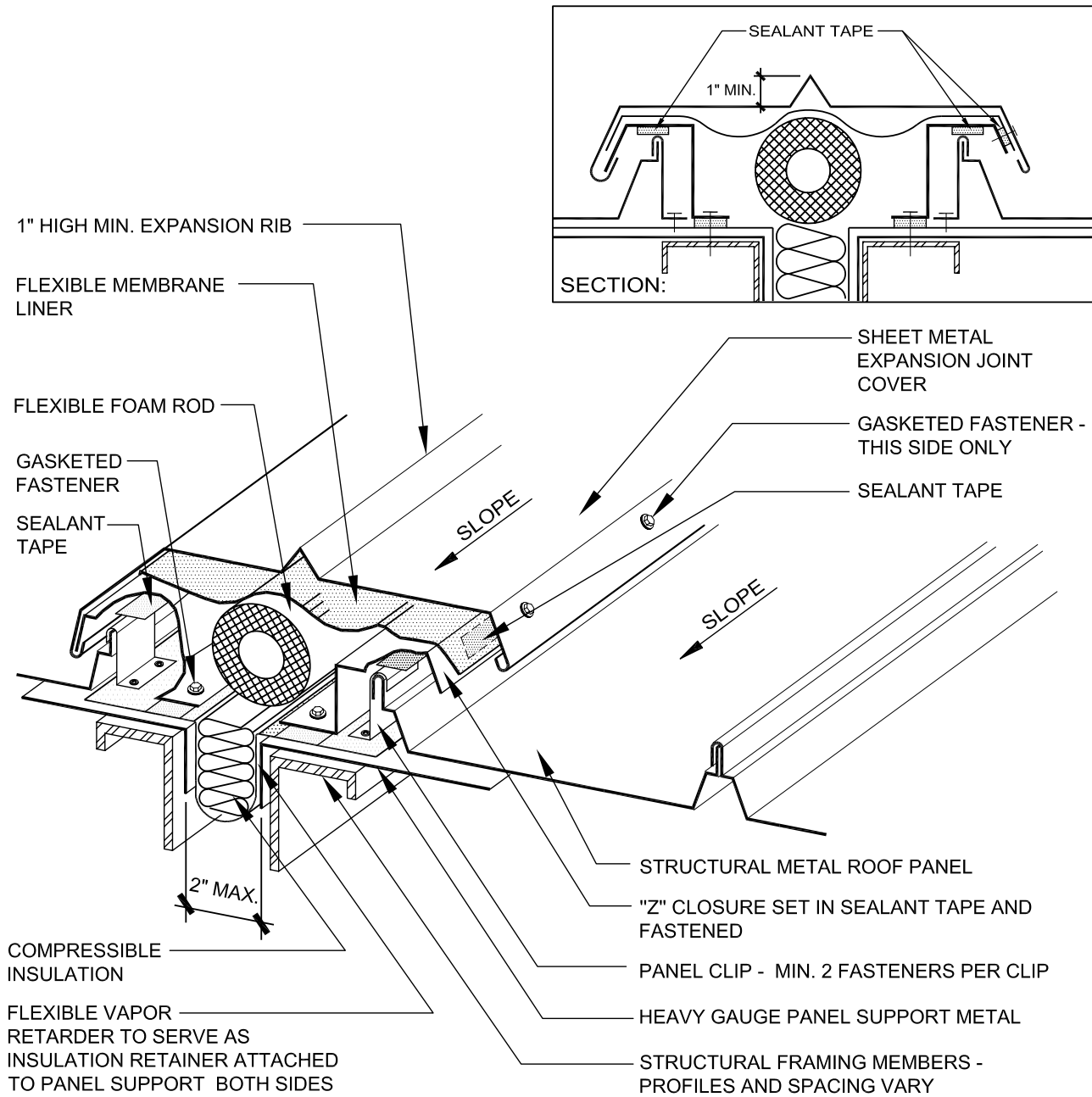


**EXPANSION JOINT - WIDE CAP**

2006

NOT DRAWN TO SCALE

**S-MTL-16**



NOTES:

1. SPECIFIC FASTENING AND STRUCTURAL REQUIREMENTS ARE NOT INDICATED, AS THEY VARY FROM SYSTEM TO SYSTEM DEPENDING UPON PANEL MANUFACTURER'S REQUIREMENTS, WIND ZONE, LOCAL CODE AND WALL CONSTRUCTION.
2. THIS DETAIL CAN BE INSTALLED WITH VERTICAL LEG STRUCTURAL METAL PANELS ALSO.
3. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
4. WHEN THE "Z" CLOSURE IS FASTENED THROUGH THE STRUCTURAL FRAMING, THIS FIXES THE PANEL ALONG THE EXPANSION JOINT.
5. THIS DETAIL WILL WORK FOR A 2" MAX. EXPANSION JOINT OPENING WITH 1" +/- MOVEMENT.
6. THE FLEXIBLE FOAM ROD SHOULD HAVE A MINIMUM DIAMETER 1-1/2 TIMES THE FRAMED OPENING.
7. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

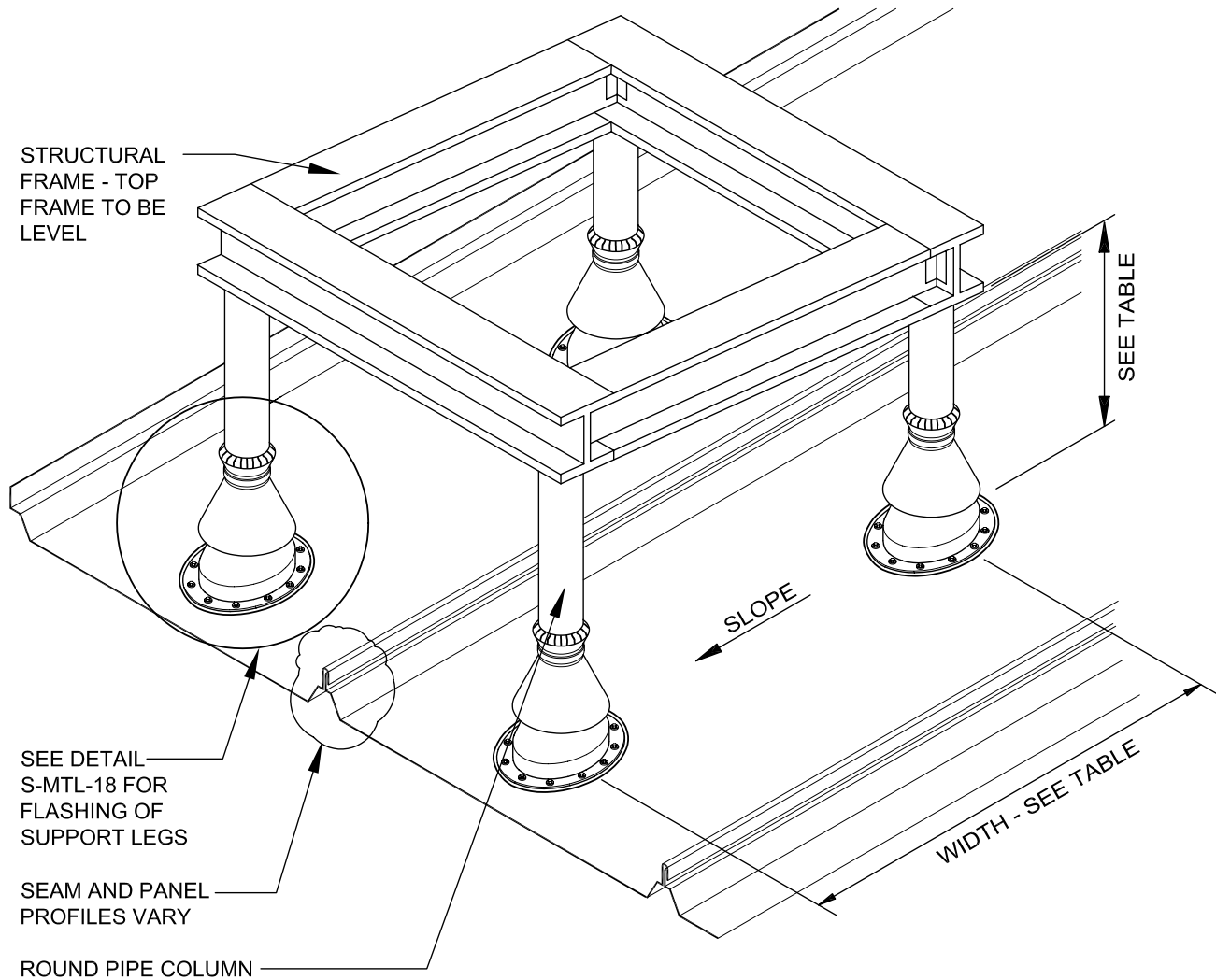


**EXPANSION JOINT - NARROW CAP**

2006

NOT DRAWN TO SCALE

**S-MTL-16A**



WIDTH OF EQUIPMENT	HEIGHT OF LEGS
UP TO 24" [UP TO 610 mm]	14" [350 mm]
25" TO 36" [635 TO 915 mm]	18" [450 mm]
37" TO 48" [940 mm TO 1.2 m]	24" [610 mm]
49" TO 60" [1.25 m TO 1.5 m]	30" [750 mm]
61" AND WIDER [1.5 m AND WIDER]	48" [1.2 m]

1. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
2. NRCA RECOMMENDS PENETRATIONS SHOULD NOT INTERFERE WITH PANEL SEAMS OR OCCUR AT TRANSVERSE SEAMS.
3. WHEN FIELD PANELS OVERLAP AT THE PENETRATION, ATTACHMENT OF THE OVERLAPPING PANELS TO EACH OTHER IS NECESSARY.
4. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

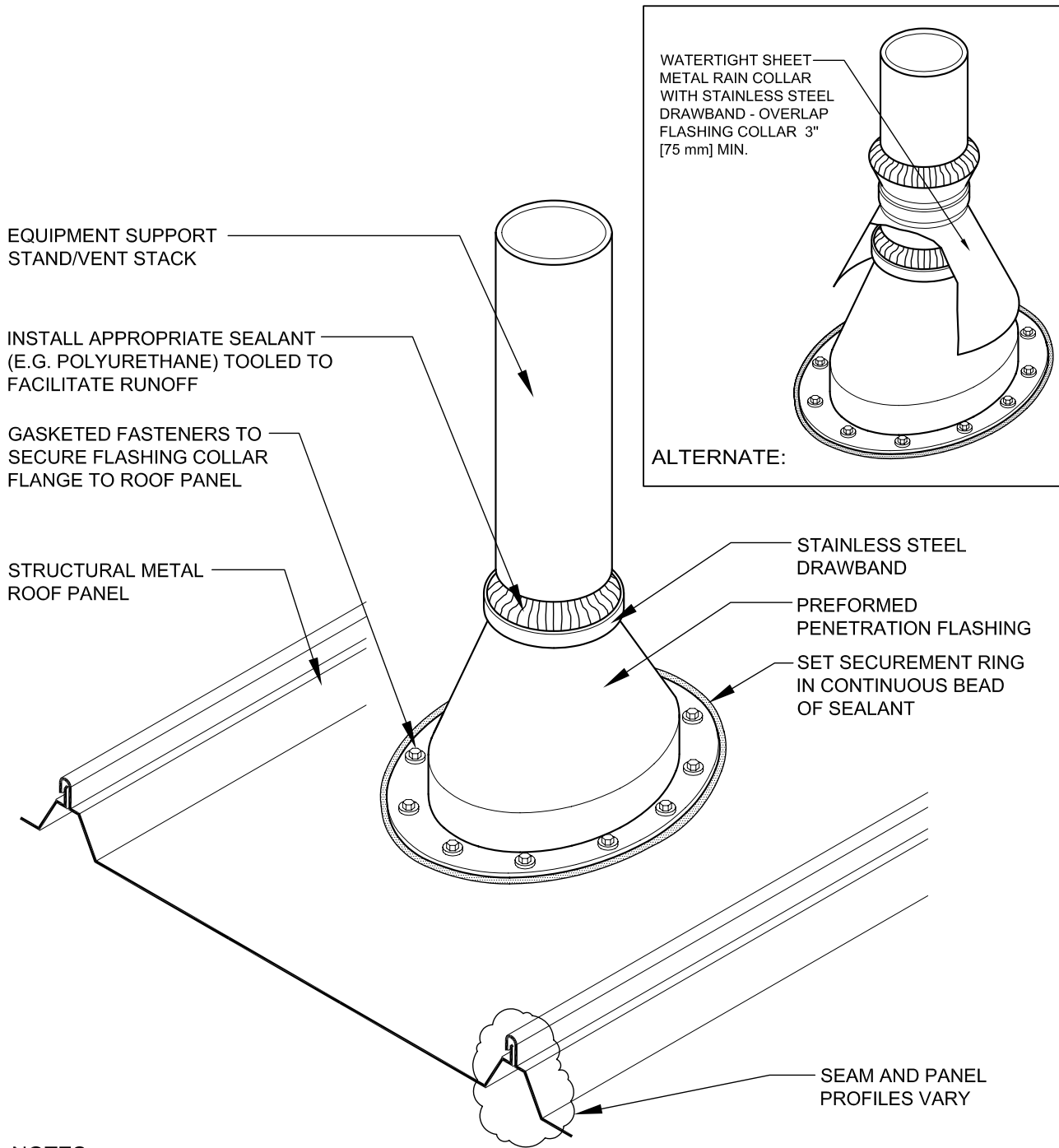


**EQUIPMENT SUPPORT STAND**

2006

NOT DRAWN TO SCALE

**S-MTL-17**



**NOTES:**

1. NRCA RECOMMENDS PENETRATIONS SHOULD NOT INTERFERE WITH PANEL SEAMS OR OCCUR AT TRANSVERSE SEAMS. SEE DETAIL 18A.
2. IF FIELD PANELS OVERLAP AT THE PENETRATION, ATTACHMENT OF THE DOWNSLOPE PANEL, ALONG ITS UPSLOPE END, MAY BE NECESSARY.
3. VENT STACKS AND OTHER PIPES SHOULD HAVE ADEQUATE CLEARANCE ON ALL SIDES FROM WALLS, AND OTHER PROJECTIONS TO FACILITATE PROPER FLASHING AND PANEL DRAINAGE.
4. FOR HOT PIPES, SPECIFIC HIGH-TEMPERATURE BOOTS SHOULD BE USED.
5. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

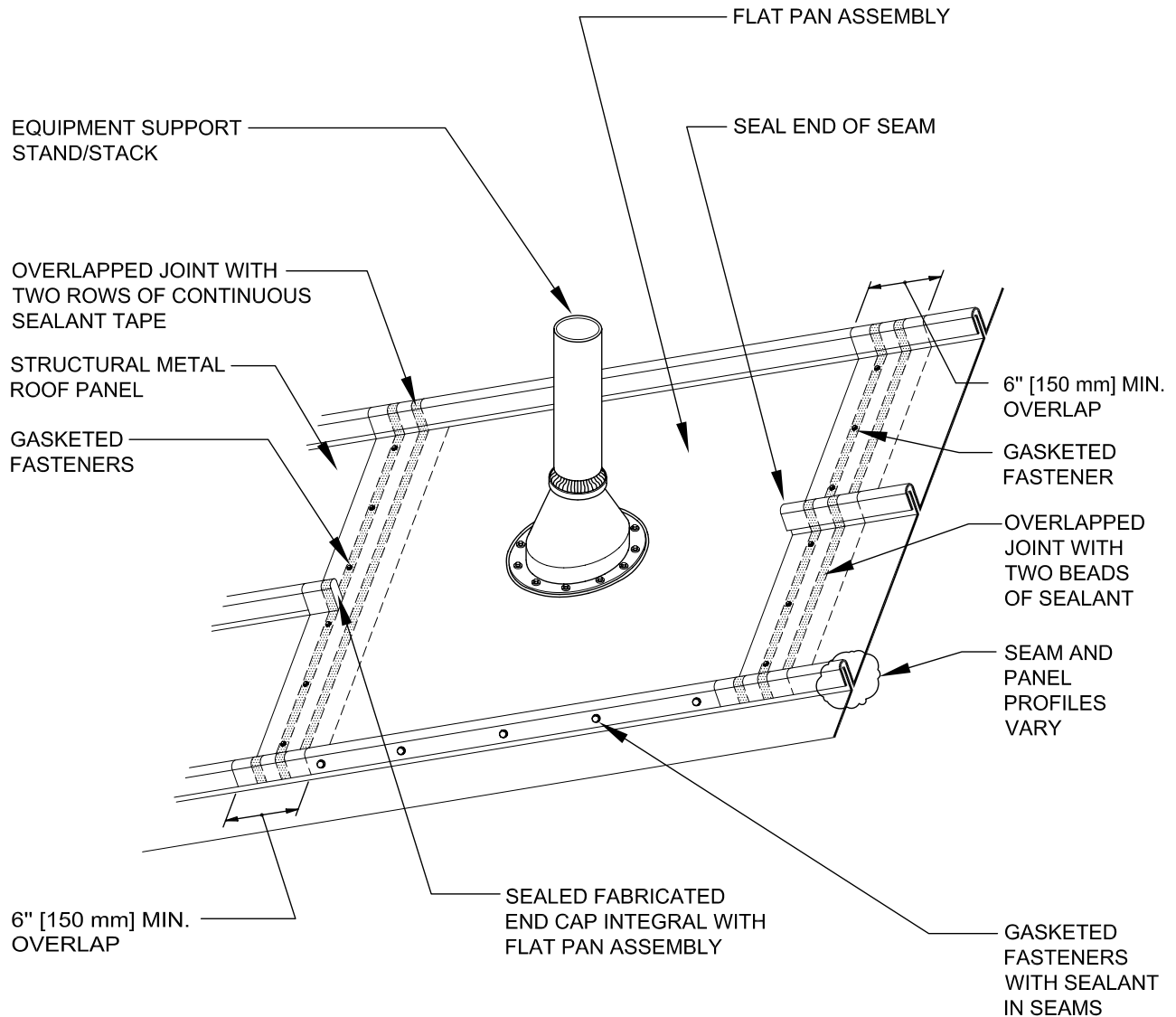


**EQUIPMENT SUPPORT STAND/VENT STACK WITH PREFORMED FLASHING**

2006

NOT DRAWN TO SCALE

**S-MTL-18**



**NOTES:**

1. PROPER STRUCTURAL SUPPORT IS REQUIRED FOR FLAT PAN ASSEMBLY.
2. WHERE PENETRATIONS INTERSECT SEAMS, THIS DETAIL IS PREFERRED RATHER THAN INSTALLING PREFORMED BOOT THRU SEAM.
3. IF FIELD PANELS OVERLAP AT THE PENETRATION, ATTACHMENT OF THE DOWNSLOPE PANEL, ALONG ITS UPSLOPE END, MAY BE NECESSARY.
4. VENT STACKS AND OTHER PIPES SHOULD HAVE ADEQUATE CLEARANCE ON ALL SIDES FROM WALLS, AND OTHER PROJECTIONS TO FACILITATE PROPER FLASHING AND PROPER DRAINAGE.
5. FOR HOT PIPES, SPECIFIC HIGH-TEMPERATURE BOOTS SHOULD BE USED.
6. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM NOT SHOWN FOR CLARITY.
7. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

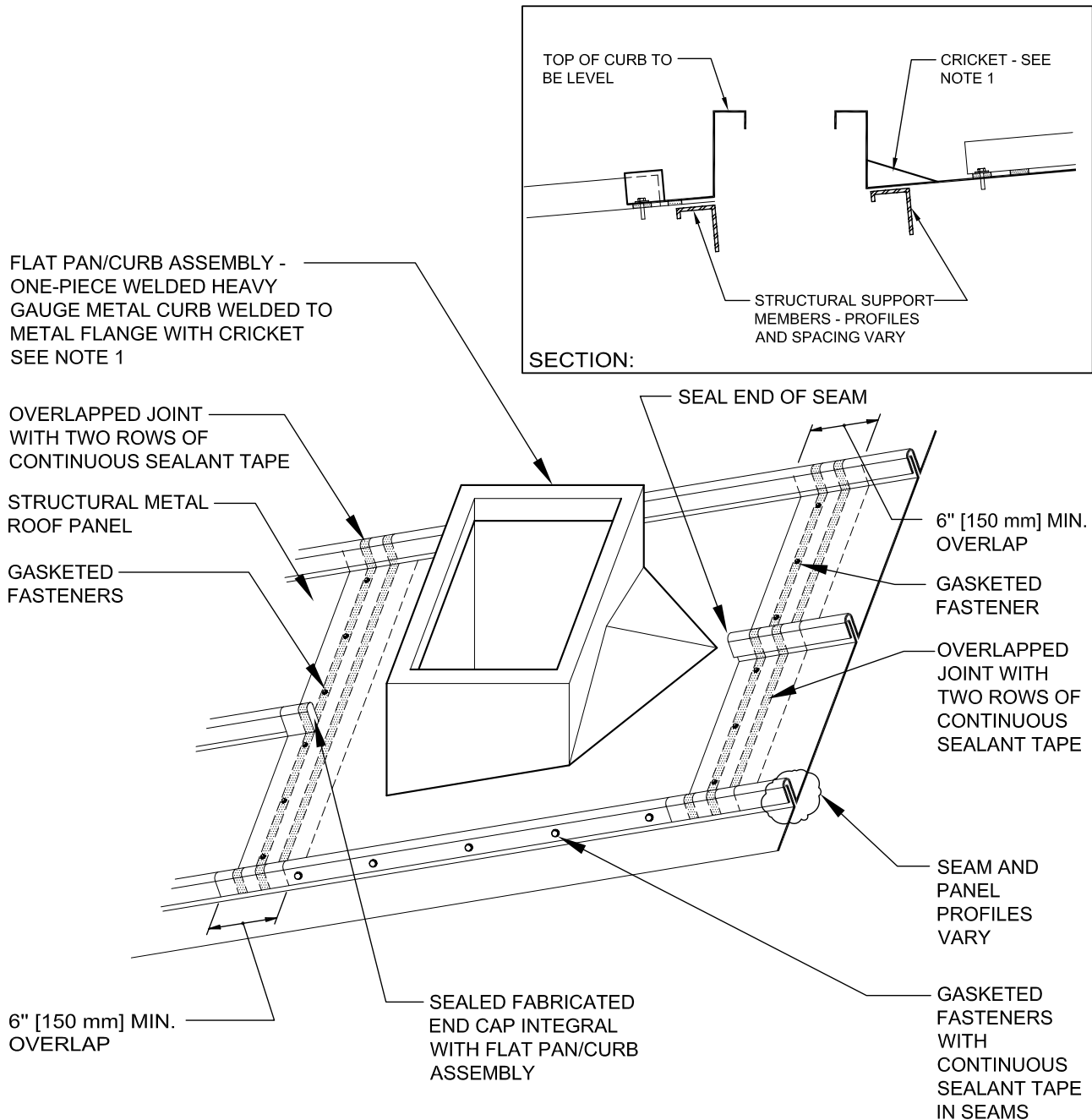


**EQUIPMENT SUPPORT STAND/VENT STACK WITH PREFORMED FLASHING AT SEAM LOCATION**

2006

NOT DRAWN TO SCALE

**S-MTL-18A**



**NOTES:**

1. NRCA SUGGESTS THAT DESIGNERS CONSIDER SPECIFYING CRICKETS WHEN THE RAISED CURB IS MORE THAN 24 INCHES [600 mm] WIDE. WATER DIVERTERS MAY BE USED IN LIEU OF CRICKETS WHEN THE RAISED CURB IS LESS THAN 24 INCHES [600 mm] WIDE.
2. PROPER STRUCTURAL SUPPORT IS REQUIRED UNDER ALL SIDES OF THE RAISED CURB.
3. THIS DETAIL FIXES THE RAISED CURB TO THE STRUCTURAL METAL PANELS.
4. CURB MOUNTED EQUIPMENT SHOULD BE WEATHERPROOF AND HAVE A WEATHERPROOF INTERLOCK OR SUFFICIENT OVERLAP WITH THE CURB.
5. PREMANUFACTURED CURBS ARE AVAILABLE.
6. INSULATION AND VAPOR RETARDER FOR ROOF SYSTEM OR CURB NOT SHOWN FOR CLARITY.
7. REFER TO INTRODUCTION TO METAL DETAILS FOR ADDITIONAL INFORMATION.

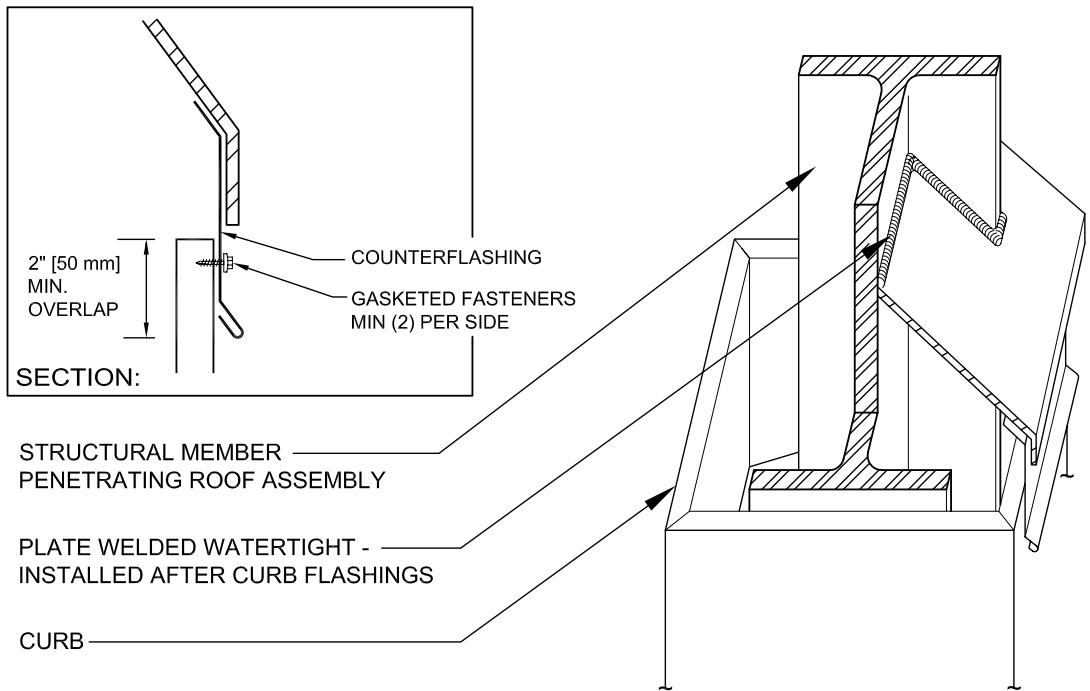


**RAISED CURB FOR ROOFTOP UNITS**

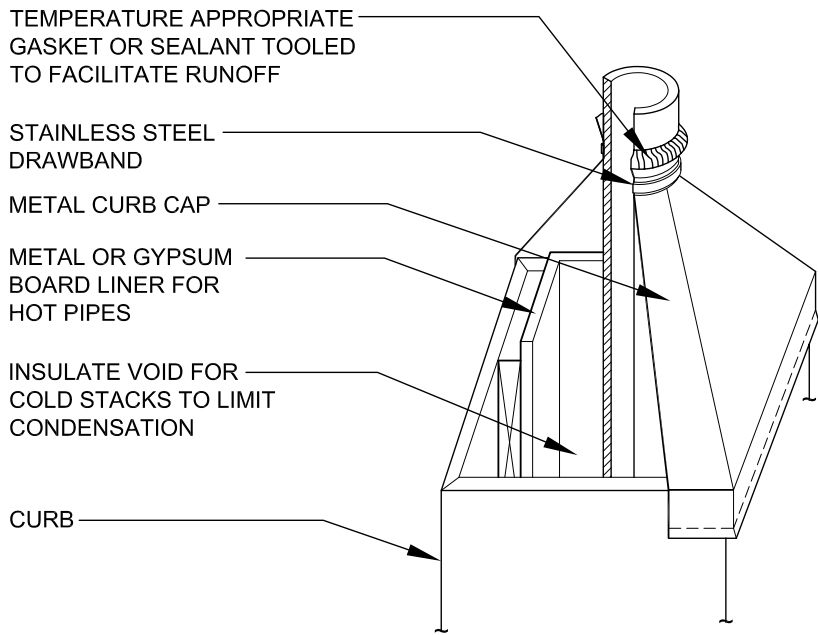
2006

NOT DRAWN TO SCALE

S-MTL-19



1 WELDED COUNTERFLASHING FOR STRUCTURAL MEMBER THROUGH ROOF



2 ISOLATED STACK FLASHING FOR HOT OR COLD PIPE PENETRATIONS



COUNTERFLASHING OPTIONS FOR RAISED CURBS

2006

NOT DRAWN TO SCALE

S-MTL-20

RECOMMENDED MINIMUM GAUGES FOR FASCIA AND CLEAT<sup>①</sup>

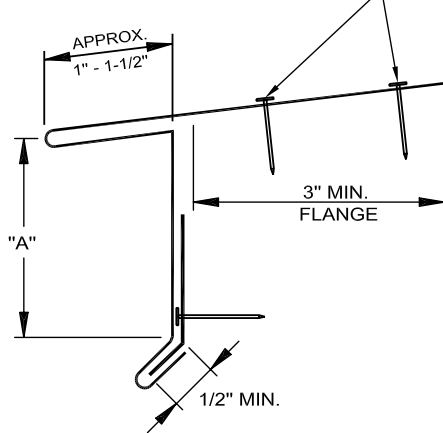
EXPOSED FACE WITHOUT BRAKES "A" DIMENSION	ALUMINUM ALLOY (3003)	COLD ROLLED COPPER	GALVANIZED OR COATED (G90) STEEL	STAINLESS STEEL (302 AND 304)	CLEAT <sup>②</sup>
UP TO 1.5" FACE	.032"	16 oz.	26 ga.	26 ga.	NOT REQUIRED
1.5" TO 3" FACE	.040"	20 oz.	24 ga.	24 ga.	NOT REQUIRED
1.5" TO 3" FACE	.032"	16 oz.	26 ga.	26 ga.	SAME GAUGE AS FASCIA METAL
3" TO 6" FACE	.040"	16 oz.	24 ga.	24 ga.	SAME GAUGE AS FASCIA METAL
6" TO 8" FACE	.050"	20 oz.	24 ga.	24 ga.	ONE GAUGE HEAVIER THAN FASCIA METAL
8" TO 15" FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ONE GAUGE HEAVIER THAN FASCIA METAL

RECOMMENDED PROFILES AND FASTENING FOR FASCIA AND CLEAT<sup>①</sup>

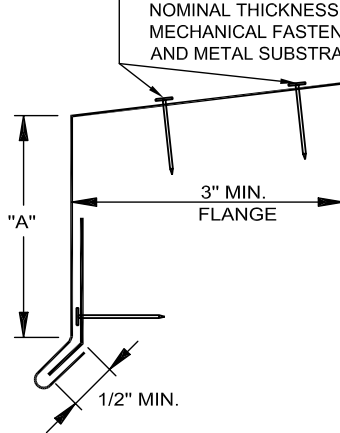
FASTEN AT APPROX. 3" TO 6" O.C. STAGGERED, WITH CORROSION-RESISTANT NAILS. NAILS SHALL BE BARBED, ANNULAR RING OR SCREW SHANK. LENGTH TO ACHIEVE APPROX. 1 1/4" PENETRATION INTO 2" NOMINAL THICKNESS WOOD NAILER.

OR

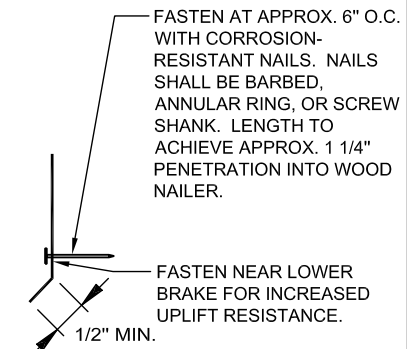
FASTEN AT APPROX. 6" TO 12" O.C. STAGGERED, WITH CORROSION RESISTANT MECHANICAL FASTENERS. LENGTH TO ACHIEVE APPROX. 3/4" PENETRATION THROUGH METAL SUBSTRATE, APPROXIMATELY 1" PENETRATION INTO 2" NOMINAL THICKNESS WOOD NAILER, OR FULL PENETRATION THROUGH WOOD SUBSTRATE. WHERE LESS THAN 2" NOMINAL THICKNESS WOOD EXISTS OVER METAL SUBSTRATE, MECHANICAL FASTENER TO ACHIEVE 3/4" PENETRATION INTO WOOD AND METAL SUBSTRATE.



"T" TYPE PROFILE



"L" TYPE PROFILE



CLEAT<sup>②</sup>

NOTES:

1. CONSIDERATION MUST BE GIVEN TO WIND ZONE AND LOCAL CONDITIONS FOR THE SELECTION OF METAL GAUGE, PROFILE, AND FASTENING SCHEDULE. SEVERE CONDITIONS OR CODE AND REGULATORY BODIES MAY REQUIRE MORE CONSERVATIVE DESIGNS. WHEN USING THE ABOVE TABLE, ADDITIONAL ITEMS SHOULD BE CONSIDERED, SUCH AS FASTENING PATTERN.
2. ALL CLEATS SHALL BE CONTINUOUS WITH PIECES NOT TO EXCEED 12 FEET, ALLOW A 1/4" GAP BETWEEN PIECES. JOINTS IN CLEAT SHOULD NOT COINCIDE WITH JOINTS IN FASCIA METAL.
3. WHEN NON-CCA PRESERVATIVE TREATED WOOD IS USED, CORROSION OF FASTENERS MAY OCCUR. SEE NRCA SPECIAL REPORT, "USE OF TREATED WOOD IN ROOF ASSEMBLIES," DATED FEBRUARY 2005.



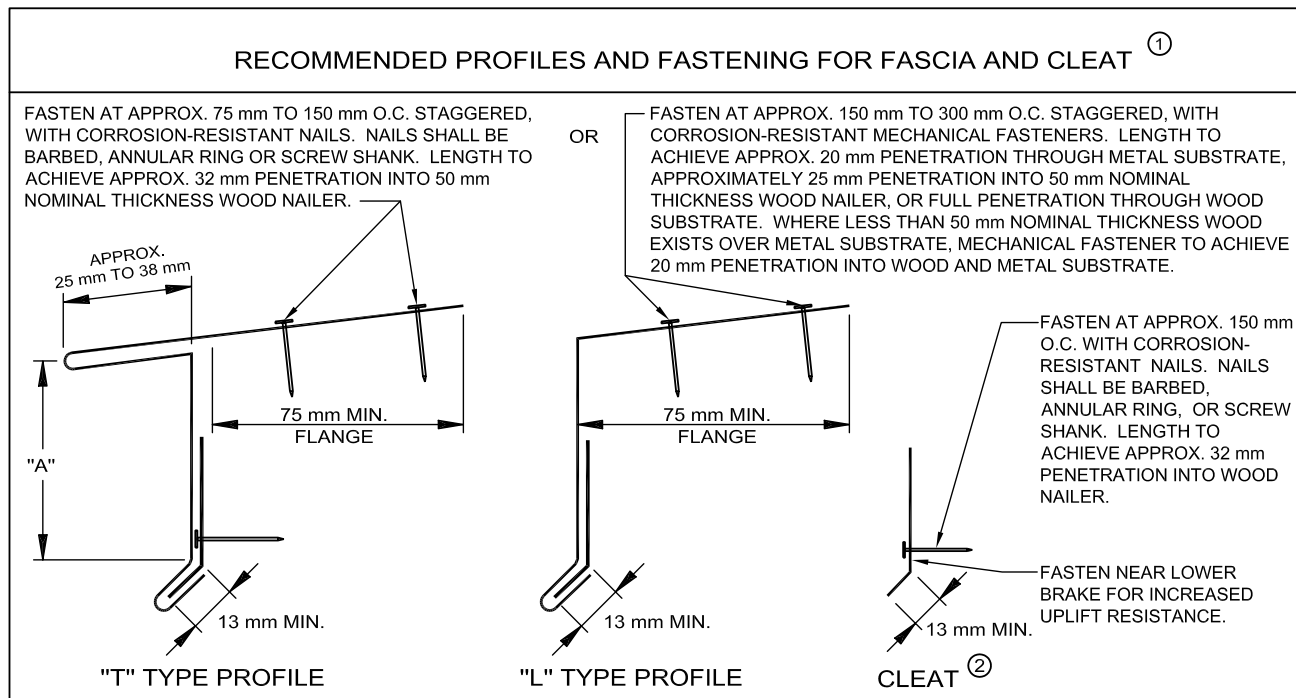
GUIDE FOR SHEET METAL TRIM AND FASCIA EDGES FOR METAL ROOF SYSTEMS

2006

NOT DRAWN TO SCALE

METAL - TABLE 1

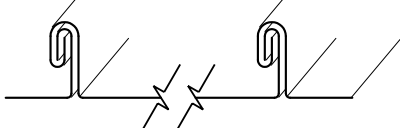
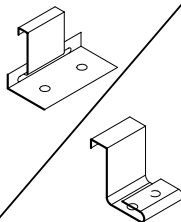
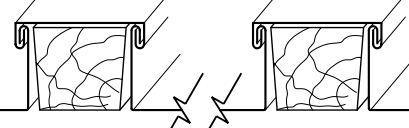
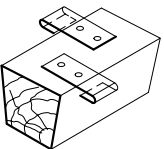
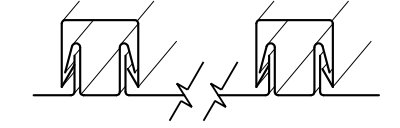
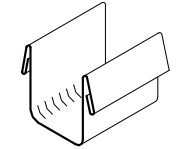
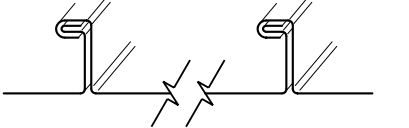
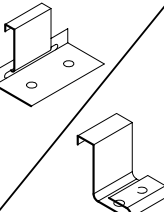
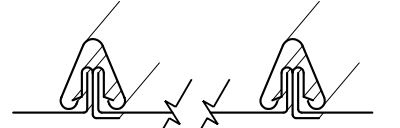
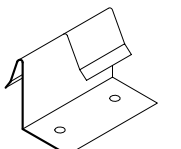
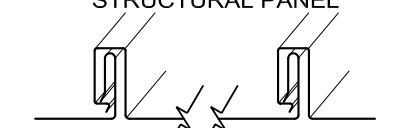
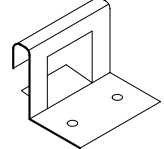
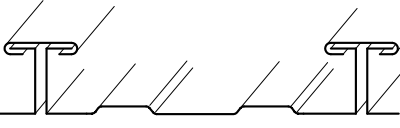
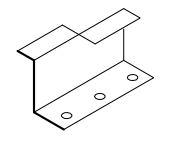
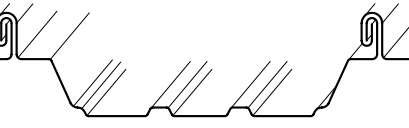
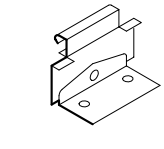
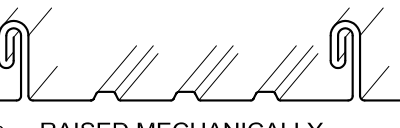
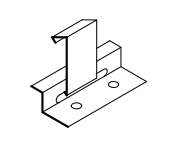
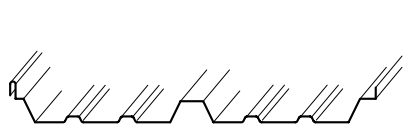
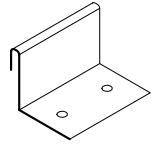
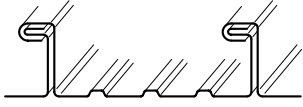
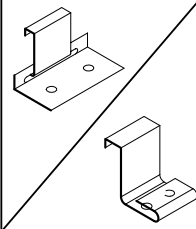
RECOMMENDED MINIMUM GAUGES FOR FASCIA AND CLEAT <sup>①</sup>					
EXPOSED FACE WITHOUT BRAKES "A" DIMENSION	ALUMINUM ALLOY (3003)	COLD ROLLED COPPER	GALVANIZED OR COATED (G90) STEEL	STAINLESS STEEL (302 AND 304)	CLEAT <sup>②</sup>
UP TO 38 mm FACE	.81 mm	4.87 kg/m <sup>2</sup>	.48 mm	.48 mm	NOT REQUIRED
38 mm TO 75 mm FACE	1.02 mm	6.10 kg/m <sup>2</sup>	.64 mm	.64 mm	NOT REQUIRED
38 mm TO 75 mm FACE	.81 mm	4.87 kg/m <sup>2</sup>	.48 mm	.48 mm	SAME GAUGE AS FASCIA METAL
75 mm TO 150 mm FACE	1.02 mm	4.87 kg/m <sup>2</sup>	.64 mm	.64 mm	SAME GAUGE AS FASCIA METAL
150 mm TO 200 mm FACE	1.27 mm	6.10 kg/m <sup>2</sup>	.64 mm	.64 mm	ONE GAUGE HEAVIER THAN FASCIA METAL
200 mm TO 375 mm FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ADD BRAKES TO STIFFEN OR USE TWO-PIECE FACE	ONE GAUGE HEAVIER THAN FASCIA METAL



**NOTES:**

1. CONSIDERATION MUST BE GIVEN TO WIND ZONE AND LOCAL CONDITIONS FOR THE SELECTION OF METAL GAUGE, PROFILE, AND FASTENING SCHEDULE. SEVERE CONDITIONS OR CODE AND REGULATORY BODIES MAY REQUIRE MORE CONSERVATIVE DESIGNS. WHEN USING THE ABOVE TABLE, ADDITIONAL ITEMS SHOULD BE CONSIDERED, SUCH AS FASTENING PATTERN.
2. ALL CLEATS SHALL BE CONTINUOUS WITH PIECES NOT TO EXCEED 12 FEET, ALLOW A 1/4" GAP BETWEEN PIECES. JOINTS IN CLEAT SHOULD NOT COINCIDE WITH JOINTS IN FASCIA METAL.
3. WHEN NON-CCA PRESERVATIVE TREATED WOOD IS USED, CORROSION OF FASTENERS MAY OCCUR. SEE NRCA SPECIAL REPORT, "USE OF TREATED WOOD IN ROOF ASSEMBLIES," DATED FEBRUARY 2005.

 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>GUIDE FOR SHEET METAL TRIM AND FASCIA EDGES FOR METAL ROOF SYSTEMS</b></p>	<p><b>2006</b>    <i>NOT DRAWN TO SCALE</i>    <b>METAL - TABLE 1 (METRIC)</b></p>
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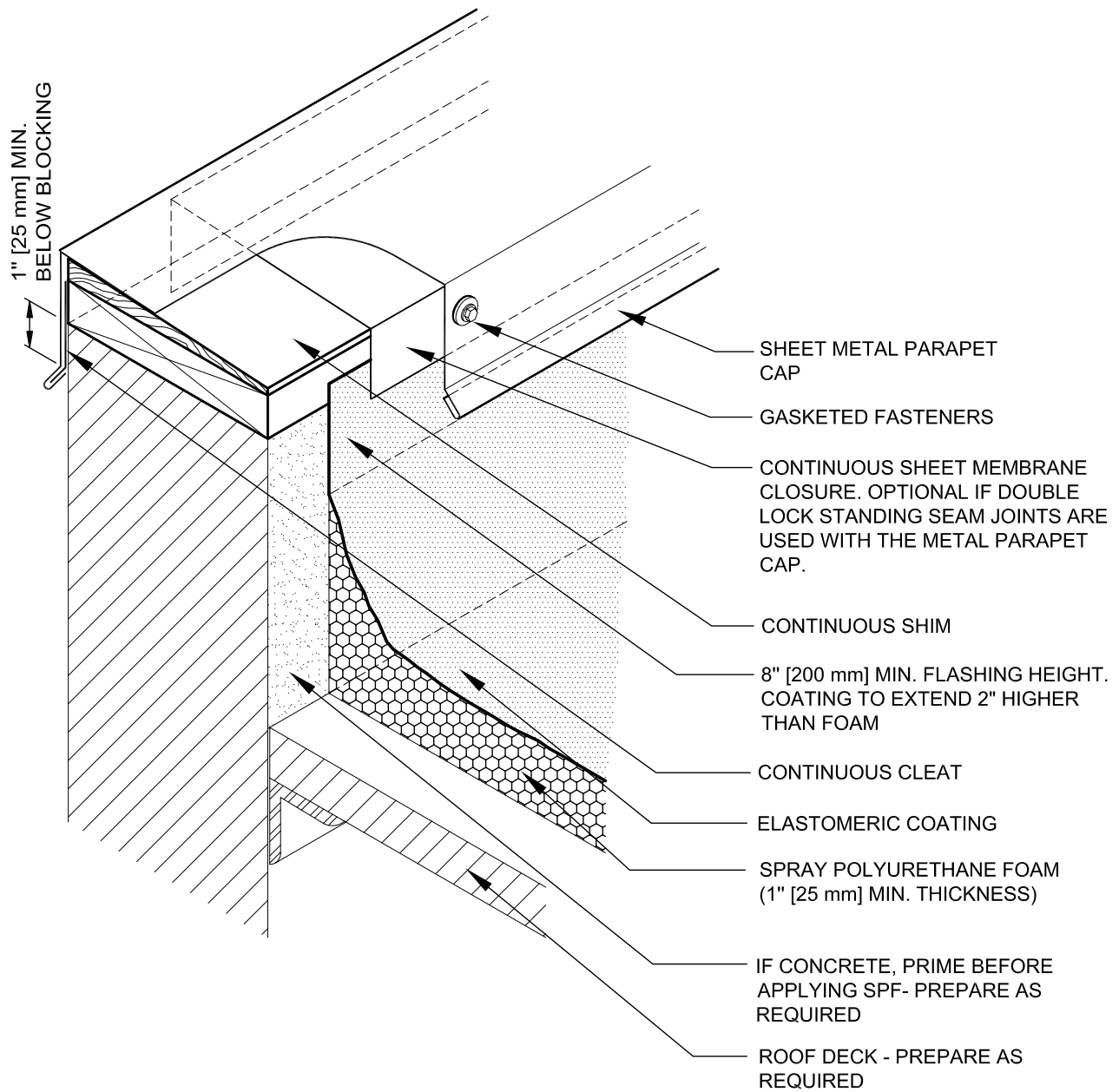
SOME COMMON ARCHITECTURAL AND STRUCTURAL METAL ROOFING PANEL PROFILES AND CLIPS			
<p>ARCHITECTURAL PANEL</p>  <p>1. DOUBLE-LOCK STANDING SEAM</p>		<p>ARCHITECTURAL PANEL</p>  <p>2. TRADITIONAL BATTEN</p>	
<p>ARCHITECTURAL PANEL</p>  <p>3. SNAP-ON BATTEN CAP WITH CLIP</p>		<p>ARCHITECTURAL PANEL</p>  <p>4. MECHANICALLY-SEAMED SINGLE LOCK</p>	
<p>ARCHITECTURAL PANEL</p>  <p>5. SNAP-CAP SEAM</p>		<p>ARCHITECTURAL PANEL STRUCTURAL PANEL</p>  <p>6. SNAP-LOCK SEAM</p>	
<p>ARCHITECTURAL PANEL STRUCTURAL PANEL</p>  <p>7. T-SEAM</p>		<p>ARCHITECTURAL PANEL STRUCTURAL PANEL</p>  <p>8. TRAPEZOIDAL SEAM</p>	
<p>STRUCTURAL PANEL</p>  <p>9. RAISED MECHANICALLY-SEAMED PANEL</p>		<p>STRUCTURAL PANEL</p>  <p>10. INTERMEDIATE RIB</p>	
<p>STRUCTURAL PANEL</p>  <p>11. MECHANICALLY-SEAMED SINGLE LOCK</p>			



SOME EXAMPLES OF SEAM AND CLIP PROFILES

2006

NOT DRAWN TO SCALE METAL - TABLE 2



NOTES:

1. THIS DETAIL SHOULD BE USED ONLY WHEN THE DECK IS SUPPORTED BY THE WALL.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

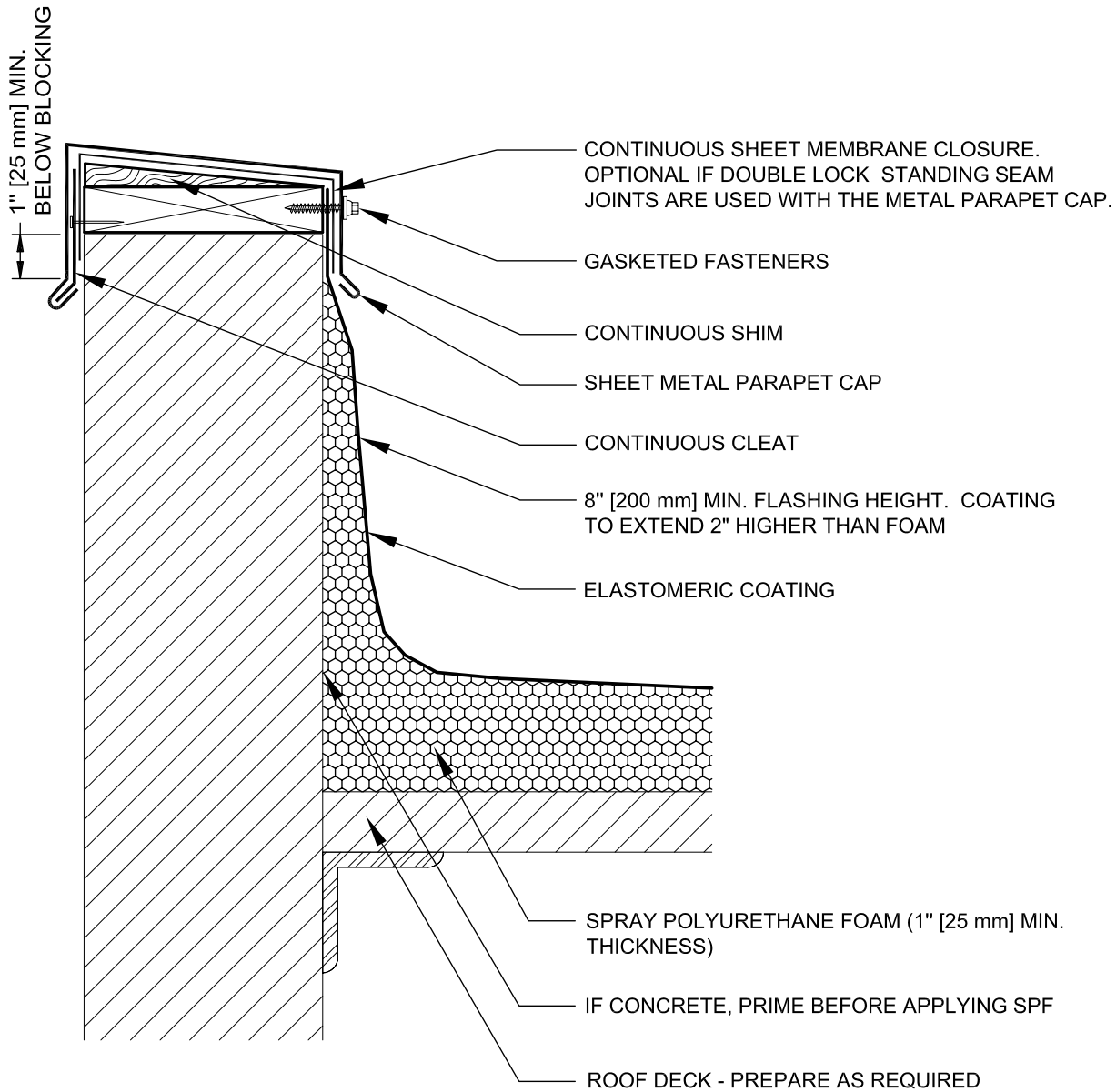


**METAL PARAPET CAP (COPING)**

2006

NOT DRAWN TO SCALE

**SPF-1**



**NOTES:**

1. THIS DETAIL SHOULD BE USED ONLY WHEN THE DECK IS SUPPORTED BY THE WALL.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

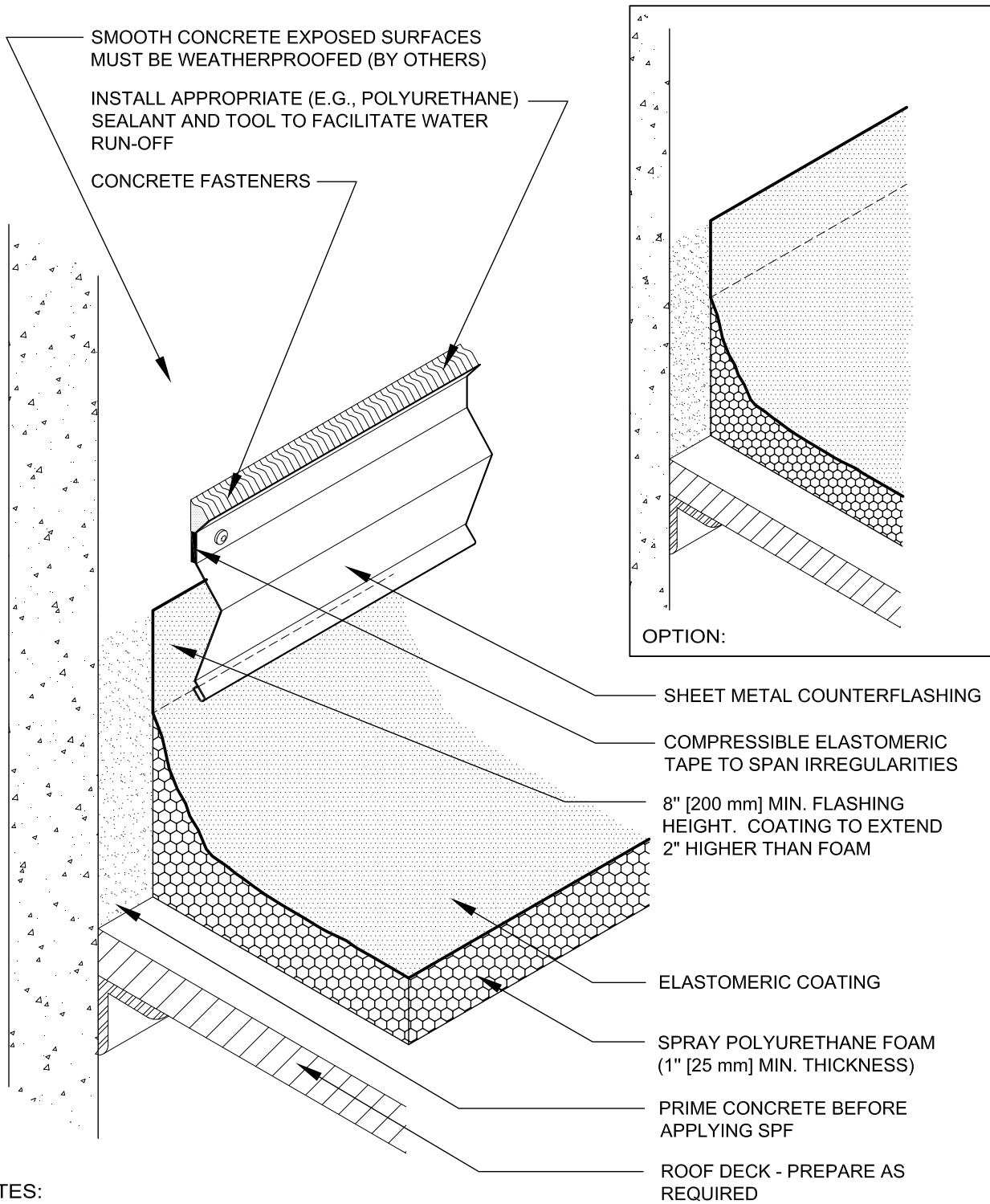


**METAL PARAPET CAP (COPING)**

**2006**

NOT DRAWN TO SCALE

**SPF-1S**



NOTES:

1. THIS DETAIL SHOULD BE USED ONLY WHERE THE DECK IS SUPPORTED BY THE WALL.
2. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

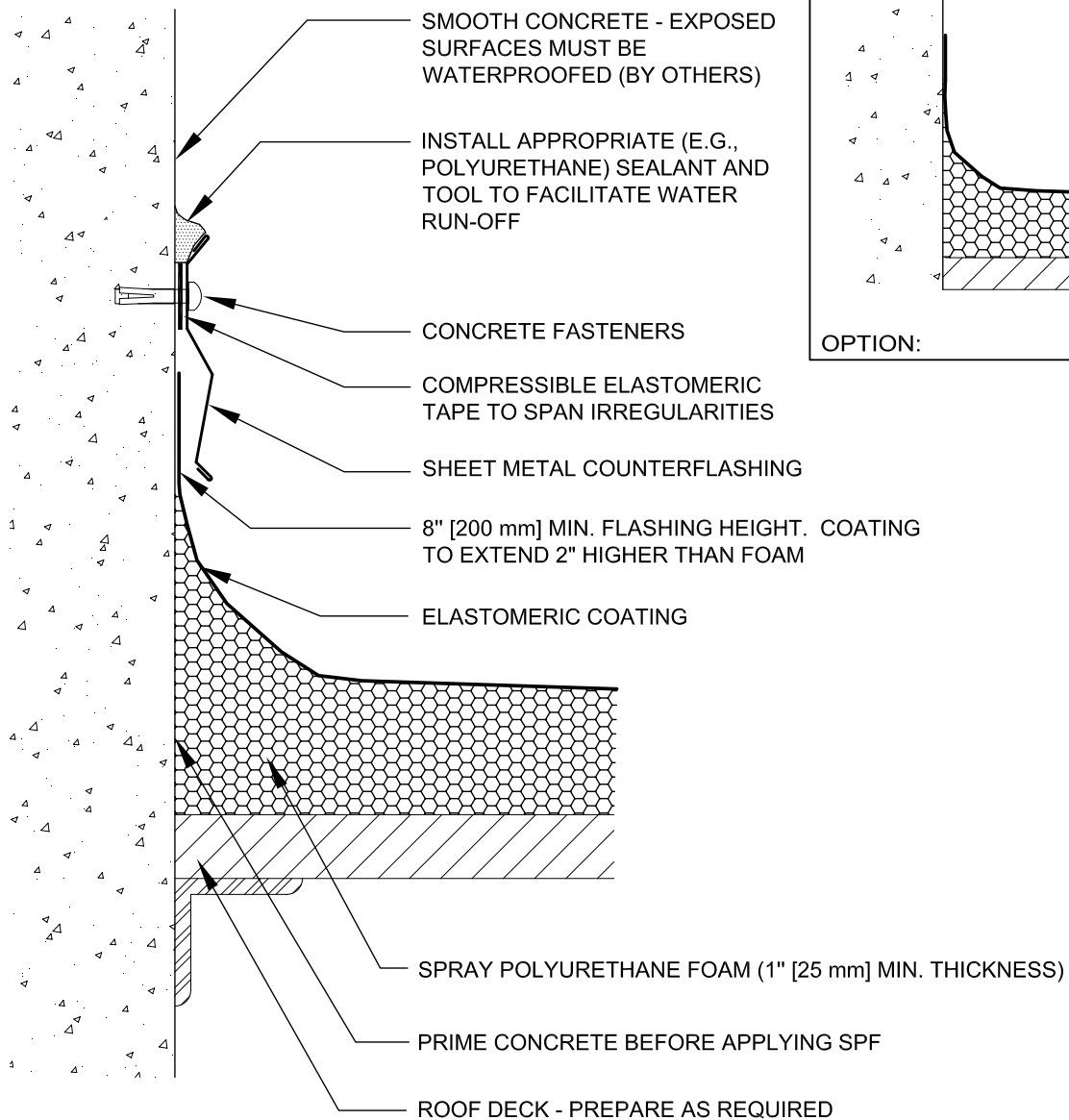


**BASE FLASHING FOR WALL-SUPPORTED DECK**

2006

NOT DRAWN TO SCALE

**SPF-4**



NOTES:

1. THIS DETAIL SHOULD BE USED ONLY WHERE THE DECK IS SUPPORTED BY THE WALL.
2. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

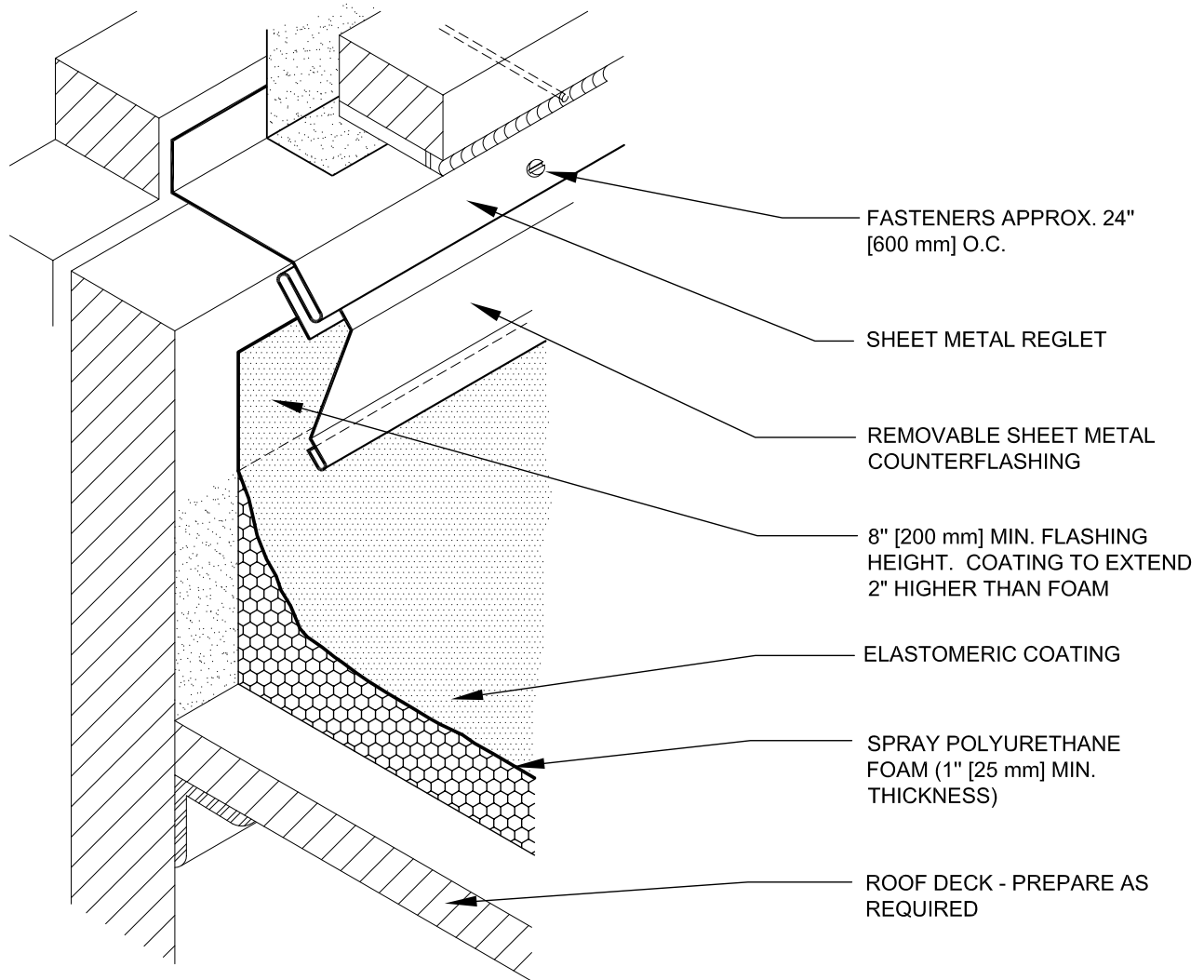


**BASE FLASHING FOR WALL-SUPPORTED DECK**

2006

NOT DRAWN TO SCALE

**SPF-4S**



**NOTES:**

1. THIS DETAIL SHOULD BE USED ONLY WHERE THE DECK IS SUPPORTED BY THE WALL.
2. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

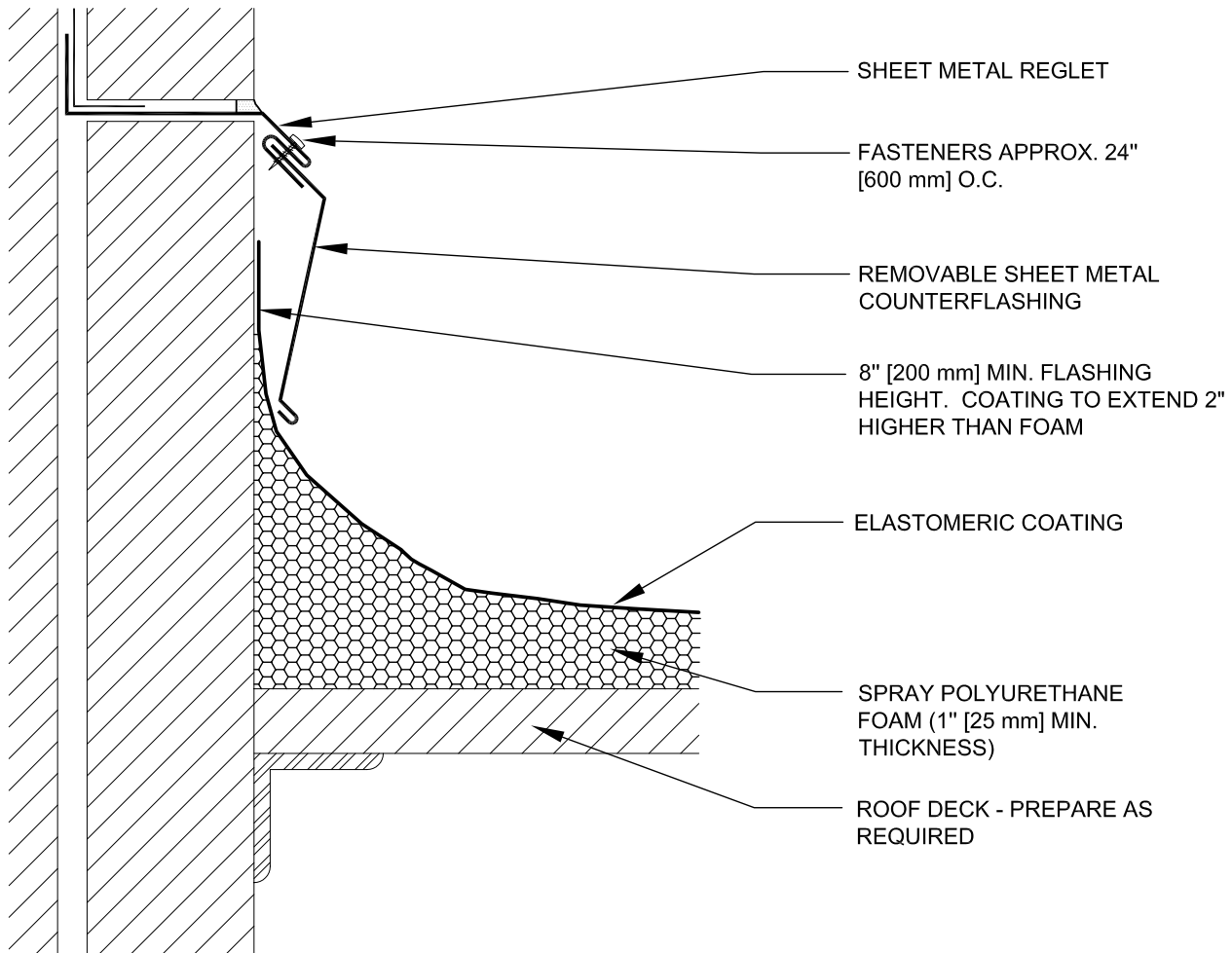


**BASE FLASHING AT THROUGH-WALL FLASHING  
FOR WALL-SUPPORTED DECK**

**2006**

NOT DRAWN TO SCALE

**SPF-5**



NOTES:

1. THIS DETAIL SHOULD BE USED ONLY WHERE THE DECK IS SUPPORTED BY THE WALL.
2. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

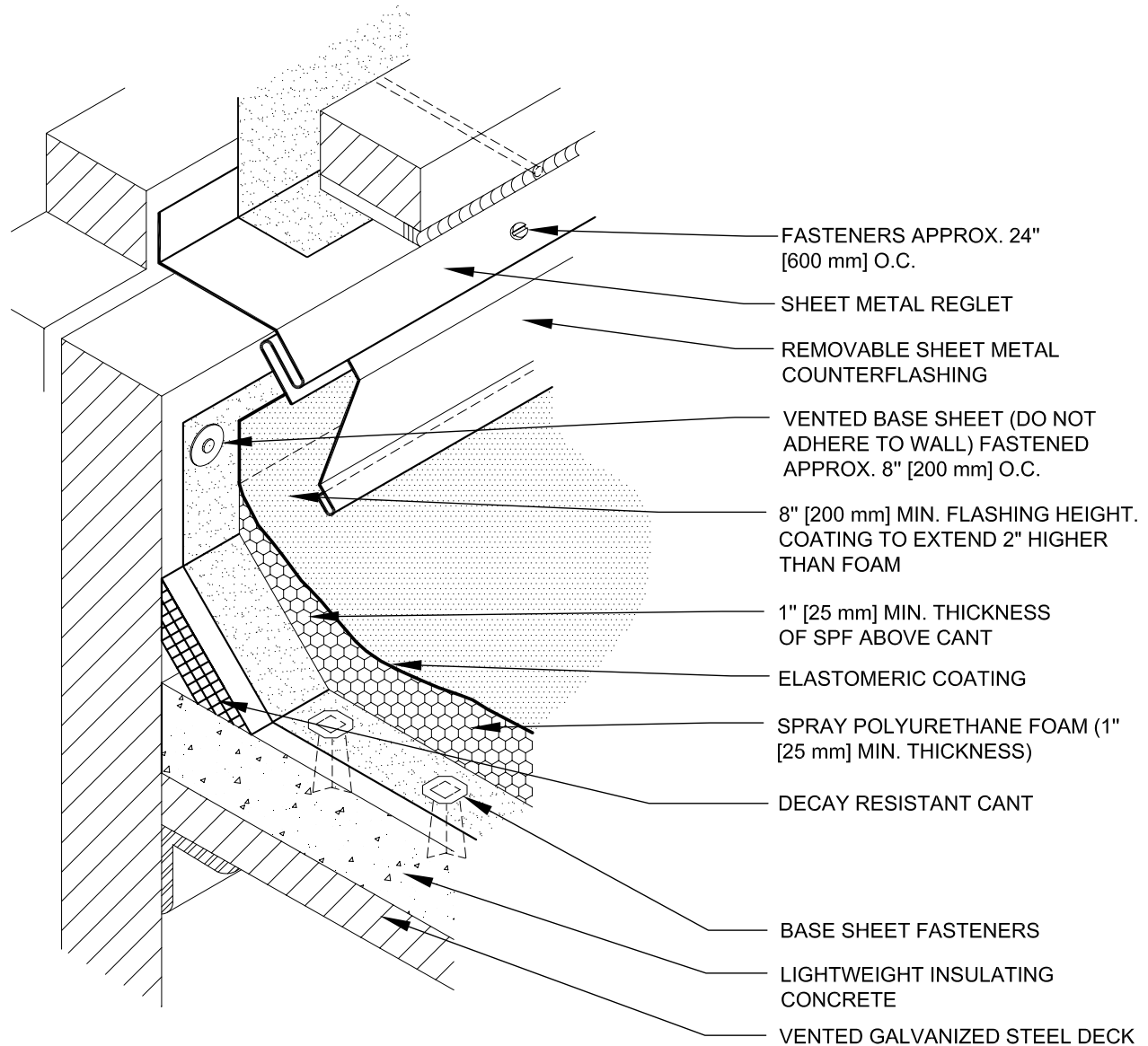


**BASE FLASHING AT THROUGH-WALL FLASHING  
FOR WALL-SUPPORTED DECK**

2006

NOT DRAWN TO SCALE

SPF-5S



**NOTES:**

1. THIS DETAIL TO BE USED OVER WET-FILL DECKS (E.G., LIGHTWEIGHT INSULATING CONCRETE, POURED GYPSUM) OR WHEN REROOFING OVER EXISTING WET-FILL DECKS.
2. THIS DETAIL SHOULD BE USED ONLY WHERE THE DECK IS SUPPORTED BY THE WALL.
3. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
4. WOOD BLOCKING SHOULD BE SLOTTED FOR VENTING OF WET-FILL DECKS WHERE APPLICABLE.
5. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
6. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

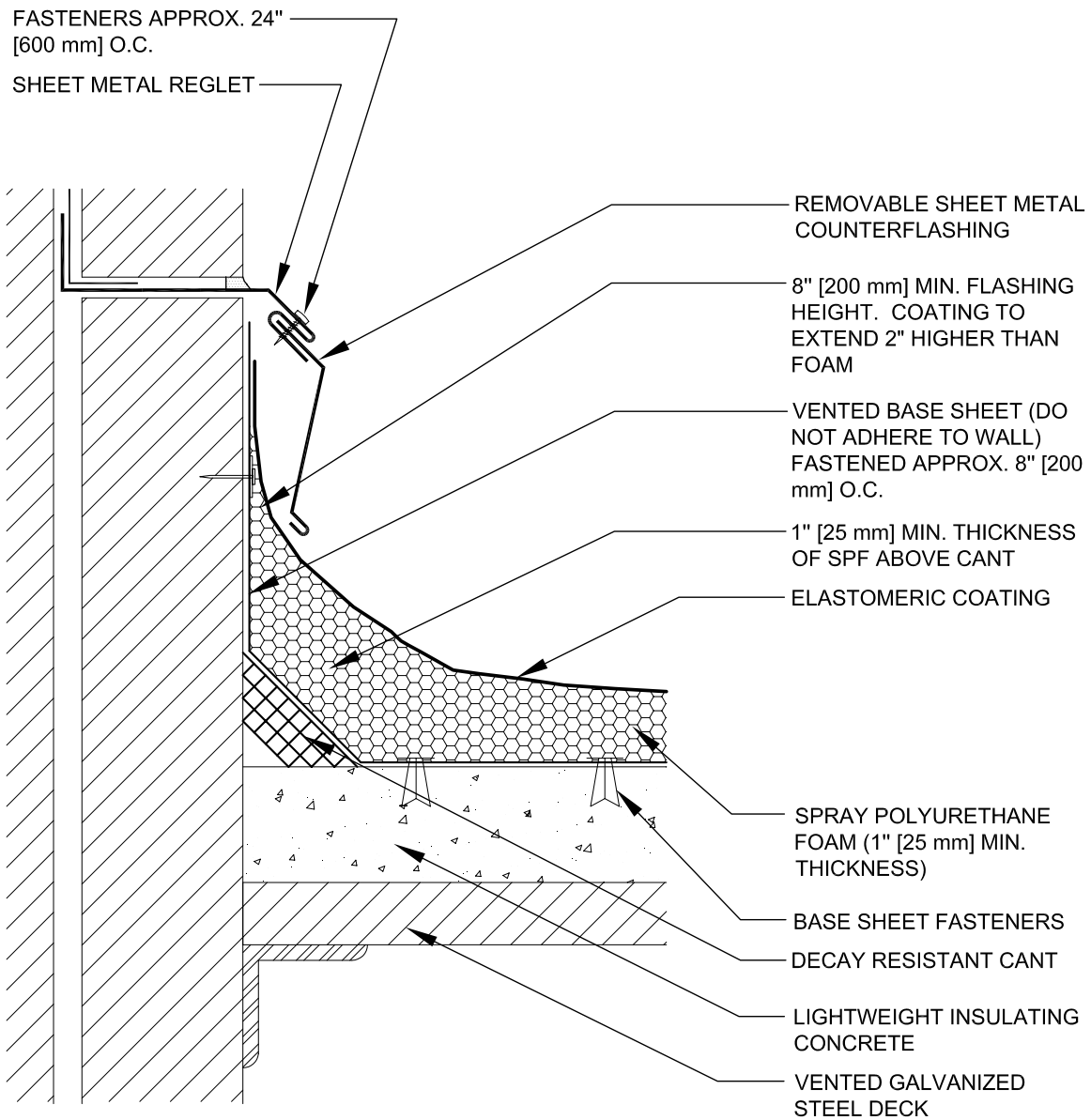


**BASE FLASHING AT THROUGH-WALL FLASHING FOR VENTED BASE SHEET**

2006

NOT DRAWN TO SCALE

SPF-5A



**NOTES:**

1. THIS DETAIL TO BE USED OVER WET-FILL DECKS (E.G., LIGHTWEIGHT INSULATING CONCRETE, POURED GYPSUM) OR WHEN REROOFING OVER EXISTING WET-FILL DECKS.
2. THIS DETAIL SHOULD BE USED ONLY WHERE THE DECK IS SUPPORTED BY THE WALL.
3. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
4. WOOD BLOCKING SHOULD BE SLOTTED FOR VENTING OF WET-FILL DECKS WHERE APPLICABLE.
5. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
6. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

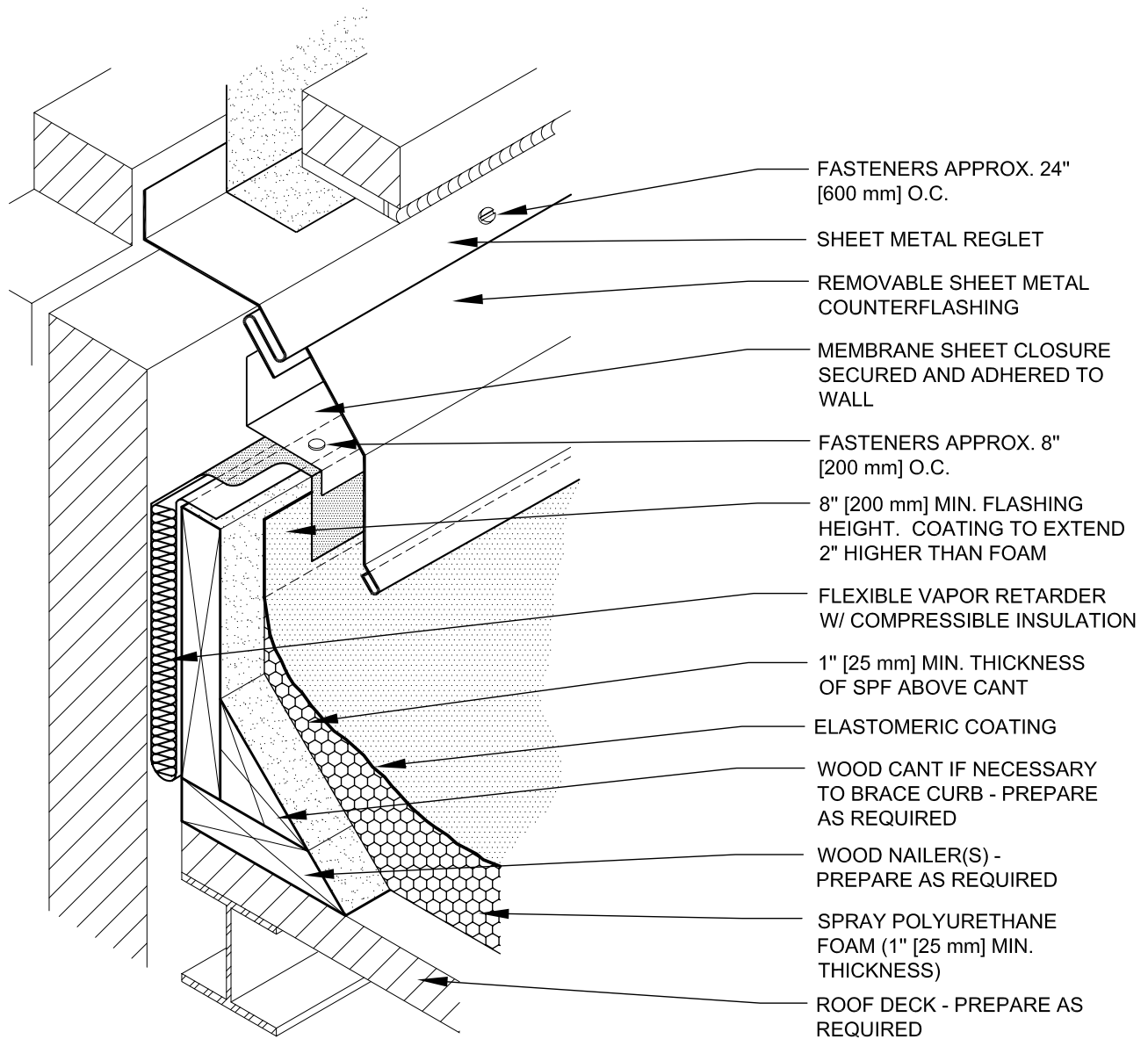


**BASE FLASHING AT THROUGH-WALL FLASHING  
FOR VENTED BASE SHEET**

**2006**

NOT DRAWN TO SCALE

**SPF-5AS**



**NOTES:**

1. THIS DETAIL SHOULD BE USED WHERE THERE IS ANY POSSIBILITY THAT DIFFERENTIAL MOVEMENT WILL OCCUR BETWEEN THE DECK AND A VERTICAL SURFACE, SUCH AS AT A PENTHOUSE WALL. THE WOOD MEMBERS SHOULD NOT BE FASTENED TO THE WALL.
2. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
3. THIS DETAIL MAY NOT BE APPLICABLE FOR USE WITH LIGHTWEIGHT FILLS.
4. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
5. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

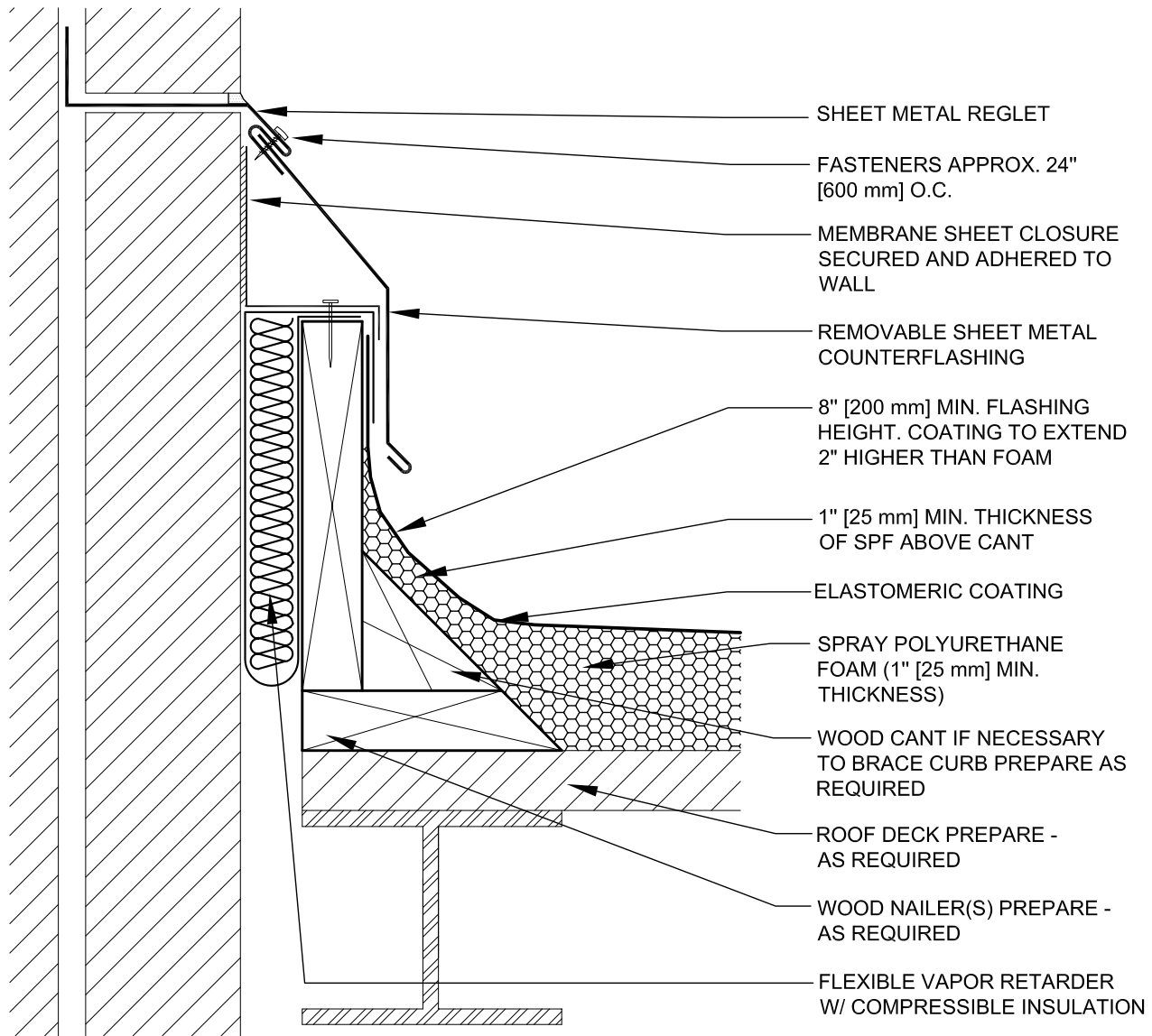


**BASE FLASHING AT THROUGH-WALL FLASHING FOR NON-WALL-SUPPORTED DECK**

2006

NOT DRAWN TO SCALE

**SPF-6**



**NOTES:**

1. THIS DETAIL SHOULD BE USED WHERE THERE IS ANY POSSIBILITY THAT DIFFERENTIAL MOVEMENT WILL OCCUR BETWEEN THE DECK AND A VERTICAL SURFACE, SUCH AS AT A PENTHOUSE WALL. THE WOOD MEMBERS SHOULD NOT BE FASTENED TO THE WALL.
2. REFER TO SPF-TABLE 2 FOR ALTERNATE SHEET METAL COUNTERFLASHING TERMINATIONS.
3. THIS DETAIL MAY NOT BE APPLICABLE FOR USE WITH LIGHTWEIGHT FILLS.
4. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
5. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

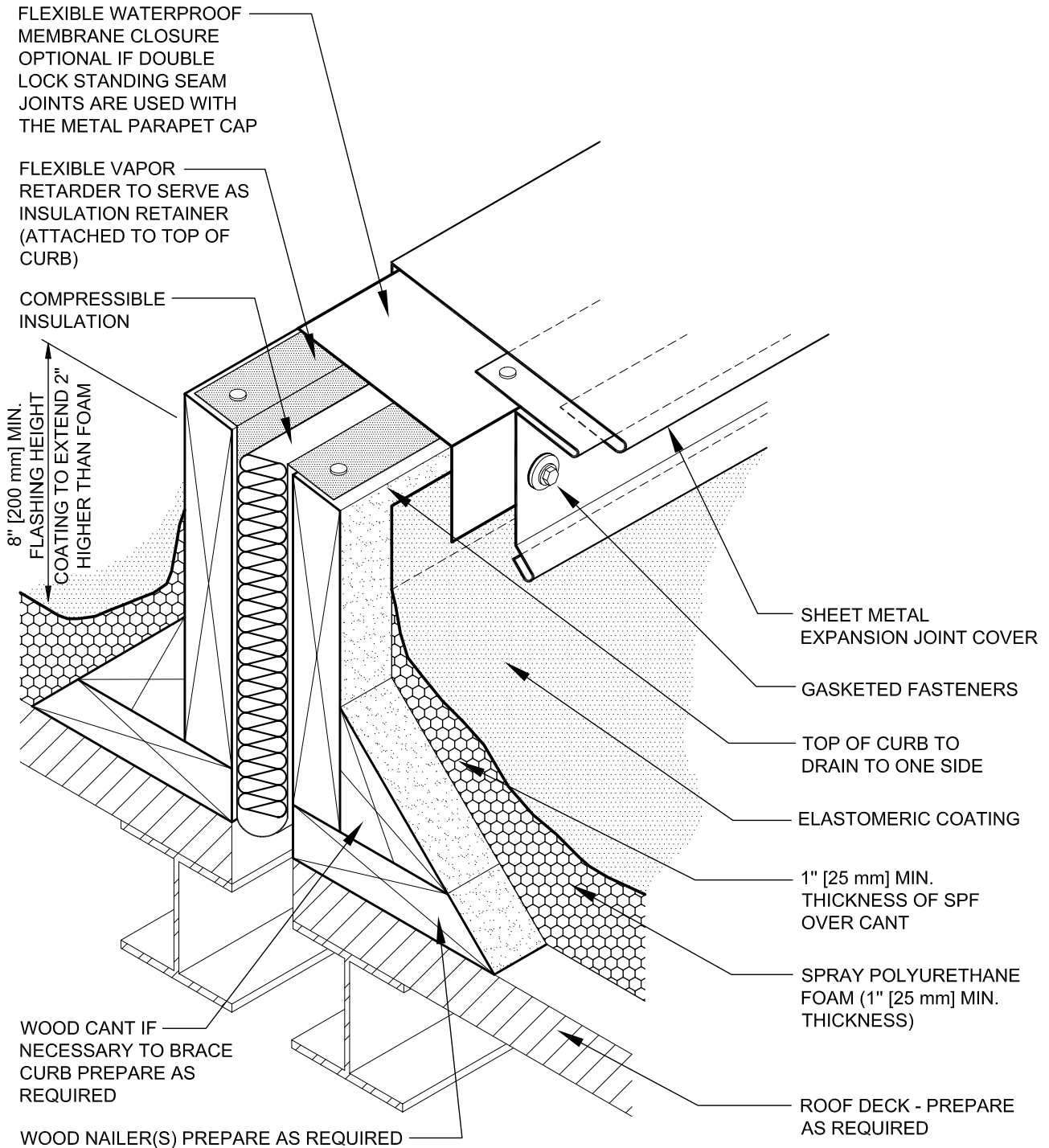


**BASE FLASHING AT THROUGH-WALL FLASHING FOR NON-WALL-SUPPORTED DECK**

2006

NOT DRAWN TO SCALE

**SPF-6S**



**NOTES:**

1. THIS DETAIL ALLOWS FOR BUILDING MOVEMENT IN MULTIPLE DIRECTIONS.
2. FLASHING REQUIREMENTS TYPICAL FOR BOTH SIDES OF EXPANSION JOINT.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

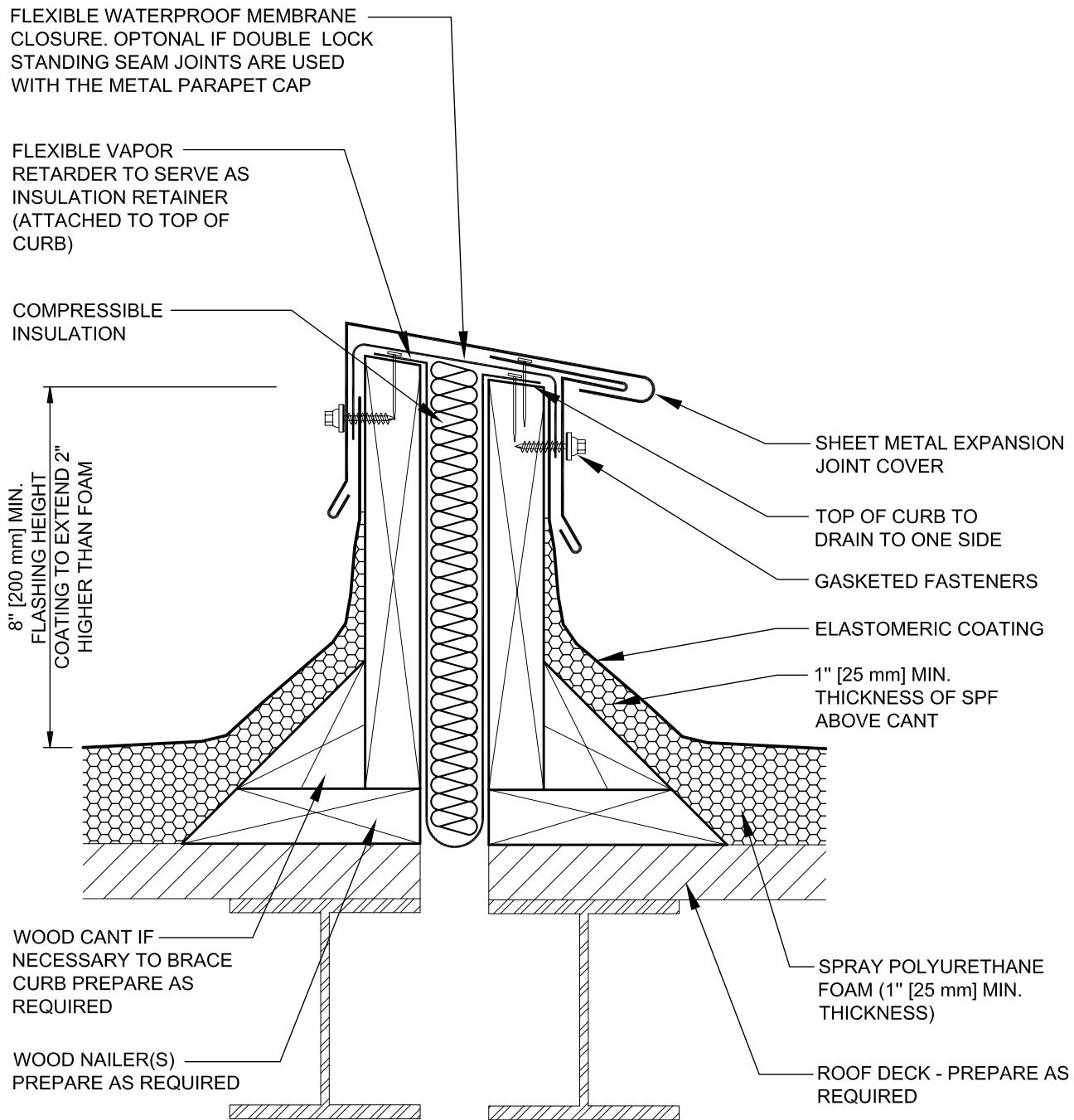


**EXPANSION JOINT WITH METAL COVER**

2006

NOT DRAWN TO SCALE

**SPF-7**



**NOTES:**

1. THIS DETAIL ALLOWS FOR BUILDING MOVEMENT IN MULTIPLE DIRECTIONS.
2. FLASHING REQUIREMENTS TYPICAL FOR BOTH SIDES OF EXPANSION JOINT.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

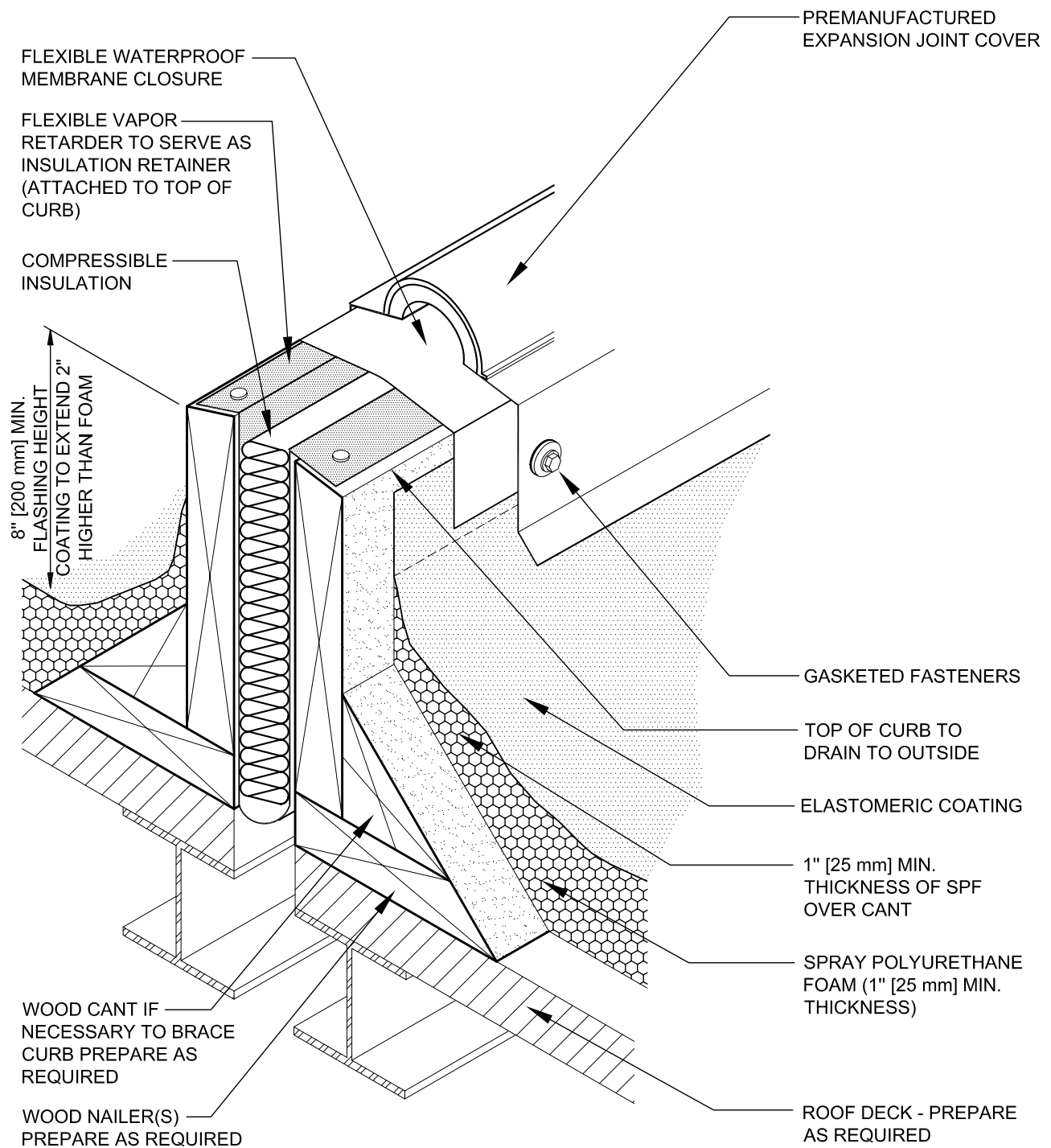


**EXPANSION JOINT WITH METAL COVER**

2006

NOT DRAWN TO SCALE

SPF-7S



NOTES:

1. THIS DETAIL ALLOWS FOR BUILDING MOVEMENT IN MULTIPLE DIRECTIONS.
2. FLASHING REQUIREMENTS TYPICAL FOR BOTH SIDES OF EXPANSION JOINT.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

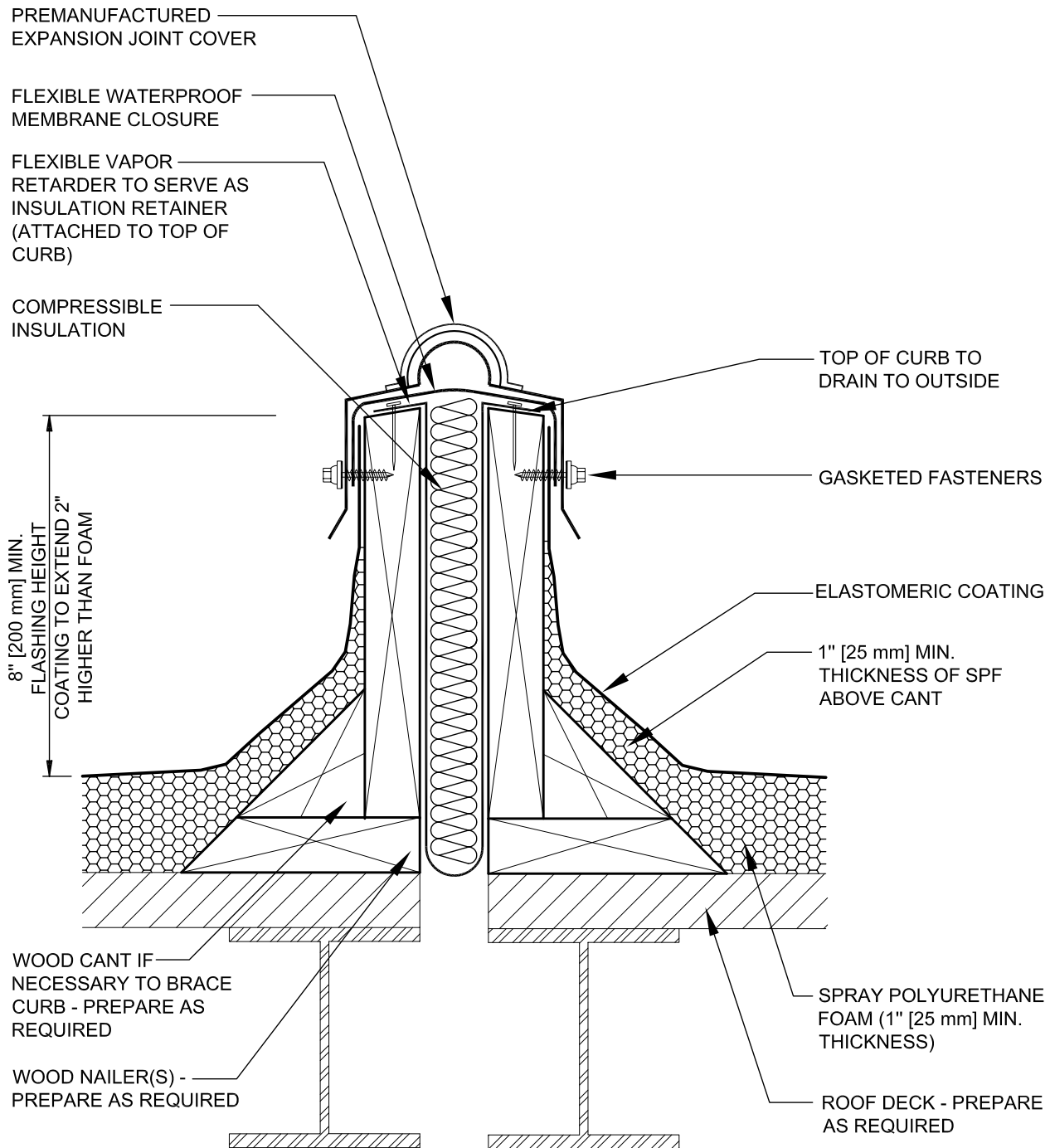


**EXPANSION JOINT WITH PREMANUFACTURED COVER**

2006

NOT DRAWN TO SCALE

**SPF-7A**



NOTES:

1. THIS DETAIL ALLOWS FOR BUILDING MOVEMENT IN MULTIPLE DIRECTIONS.
2. FLASHING REQUIREMENTS TYPICAL FOR BOTH SIDES OF EXPANSION JOINT.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

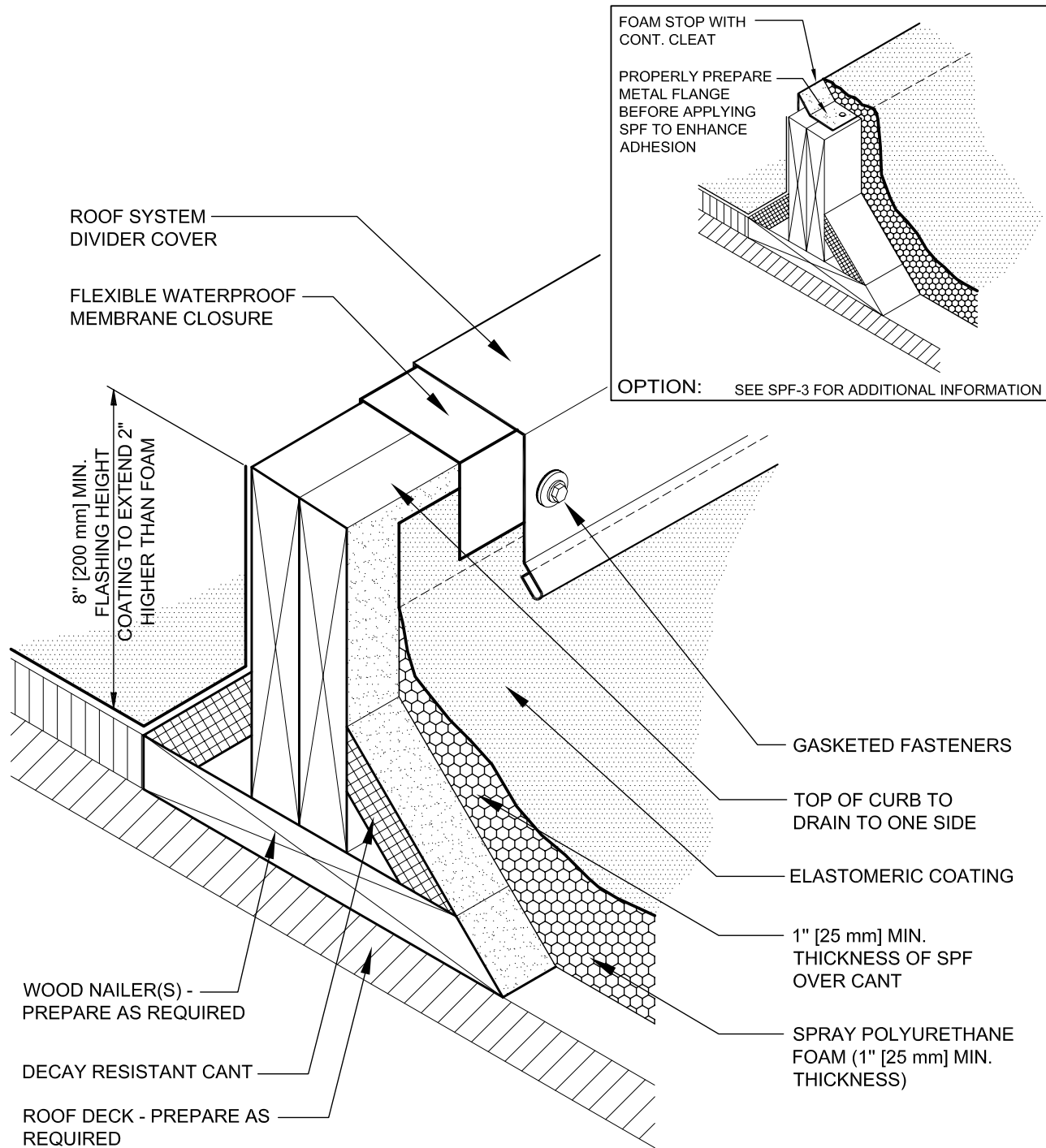


**EXPANSION JOINT WITH PREMANUFACTURED COVER**

2006

NOT DRAWN TO SCALE

SPF-7AS



NOTES:

1. A ROOF SYSTEM DIVIDER IS A RAISED DOUBLE WOOD MEMBER THAT IS PROPERLY ANCHORED TO THE ROOF DECK. ROOF SYSTEM DIVIDERS SHOULD NEVER RESTRICT THE FLOW OF WATER.
2. REFER TO APPROPRIATE SECTION OF LOW-SLOPE CONSTRUCTION DETAILS FOR FLASHING REQUIREMENTS.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

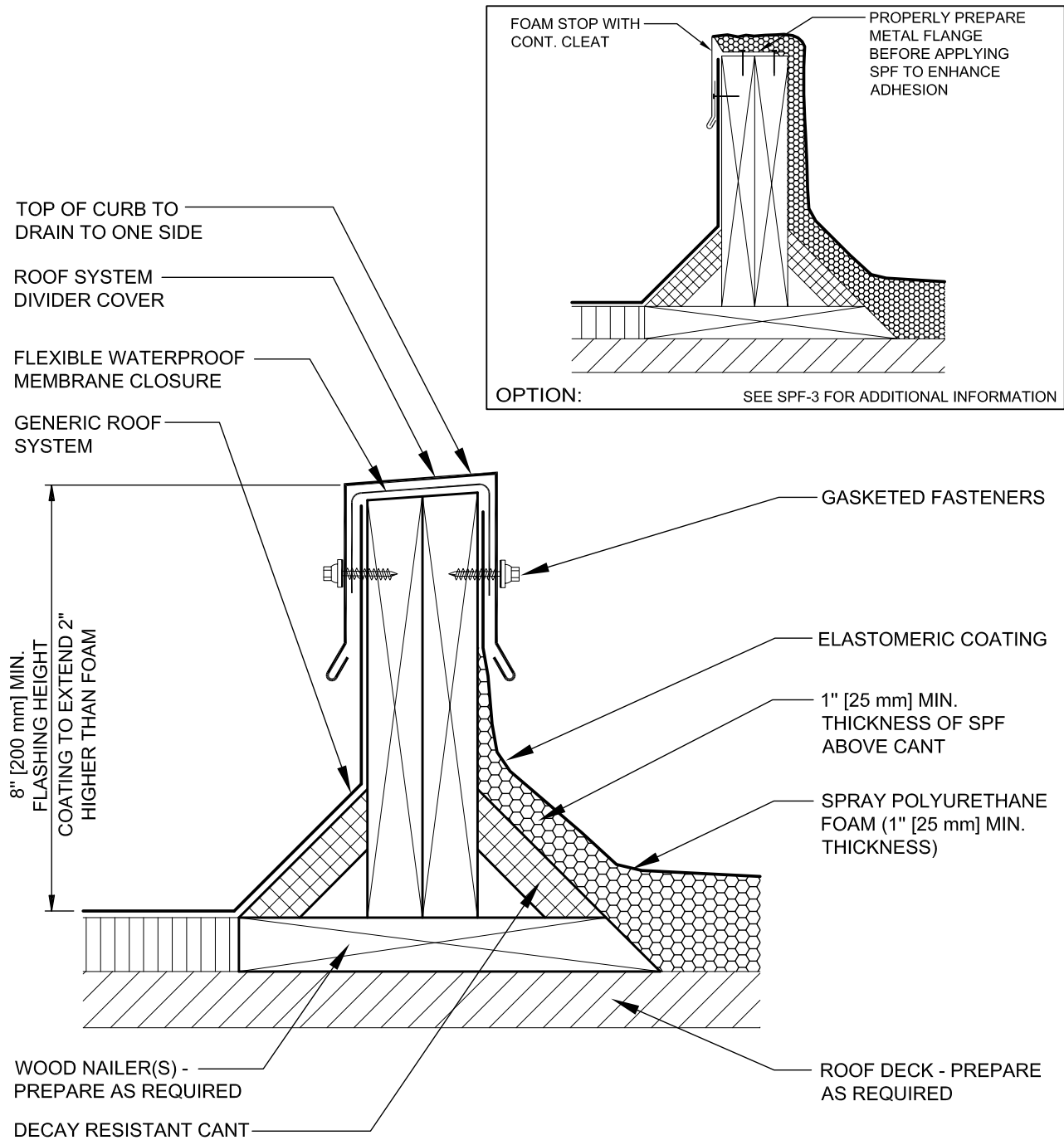


ROOF SYSTEM DIVIDER

2006

NOT DRAWN TO SCALE

SPF-8



**NOTES:**

1. A ROOF SYSTEM DIVIDER IS A RAISED DOUBLE WOOD MEMBER THAT IS PROPERLY ANCHORED TO THE ROOF DECK. ROOF SYSTEM DIVIDERS SHOULD NEVER RESTRICT THE FLOW OF WATER.
2. REFER TO APPROPRIATE SECTION OF LOW-SLOPE CONSTRUCTION DETAILS FOR FLASHING REQUIREMENTS.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



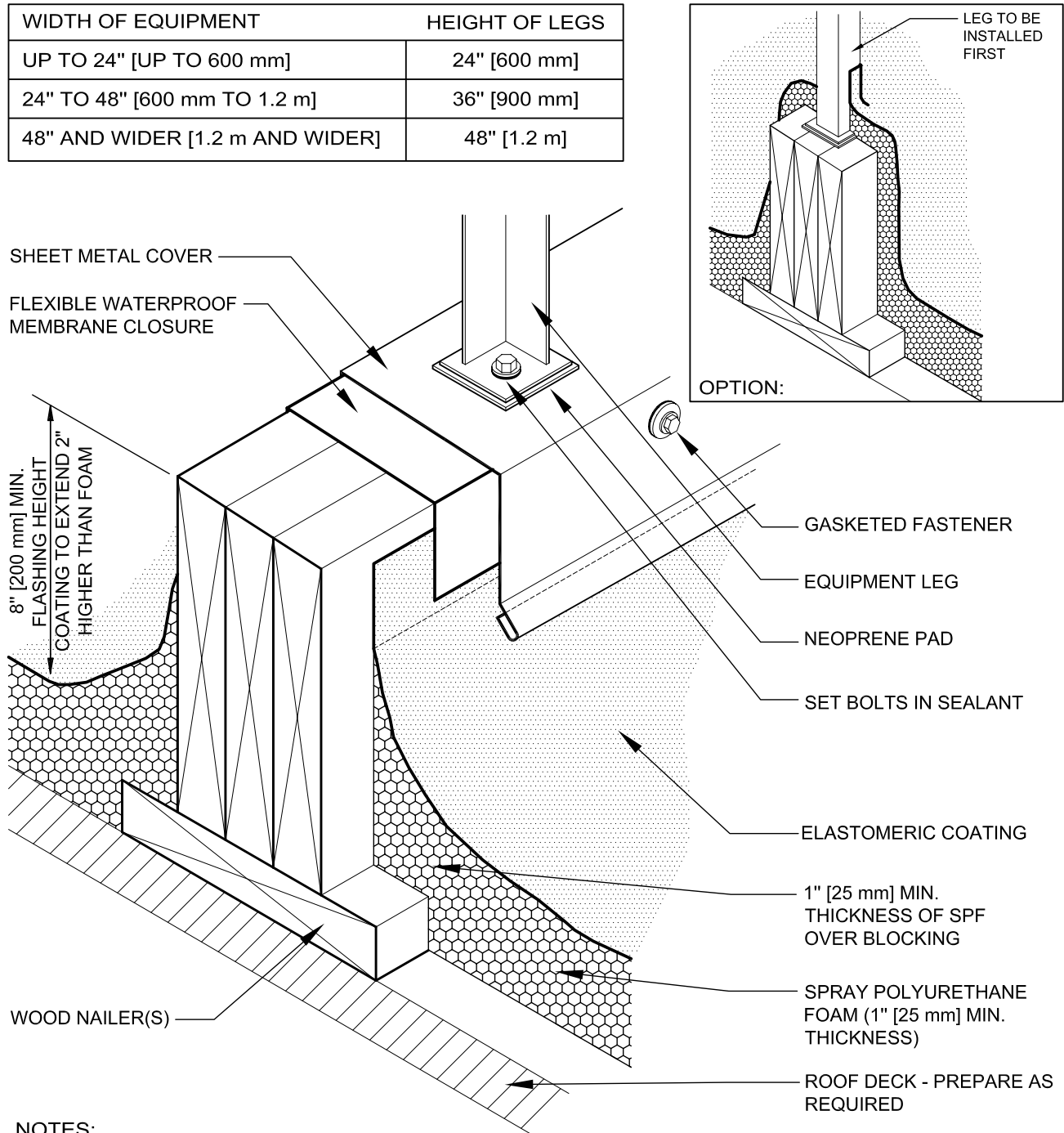
**ROOF SYSTEM DIVIDER**

2006

NOT DRAWN TO SCALE

**SPF-8S**

WIDTH OF EQUIPMENT	HEIGHT OF LEGS
UP TO 24" [UP TO 600 mm]	24" [600 mm]
24" TO 48" [600 mm TO 1.2 m]	36" [900 mm]
48" AND WIDER [1.2 m AND WIDER]	48" [1.2 m]



**NOTES:**

1. THIS DETAIL ALLOWS FOR ROOF SYSTEM MAINTENANCE AROUND THE SUPPORTED EQUIPMENT. THE CONTINUOUS SUPPORT IS PREFERRED IN LIGHTWEIGHT STRUCTURAL SYSTEMS BECAUSE THE EQUIPMENT WEIGHT CAN BE SPREAD ACROSS TWO OR MORE SUPPORTING MEMBERS. WHERE HEAVY STRUCTURAL SYSTEMS ARE USED OR WHERE THE LOAD CAN BE CONCENTRATED OVER A COLUMN, DETAIL SPF-10 MAY BE PREFERRED. A MINIMUM OF 2 FEET [600 mm] OF HORIZONTAL CLEARANCE MUST BE PROVIDED FOR REMOVAL AND REPLACEMENT OF ROOFING AND FLASHING BETWEEN PARALLEL SUPPORTS. REFER TO TABLE ABOVE FOR RECOMMENDATIONS ON VERTICAL CLEARANCE FROM ROOF SURFACE TO BOTTOM OF SUPPORTED EQUIPMENT.
2. FLASHING REQUIREMENTS TYPICAL FOR BOTH SIDES OF EQUIPMENT SUPPORT CURB.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



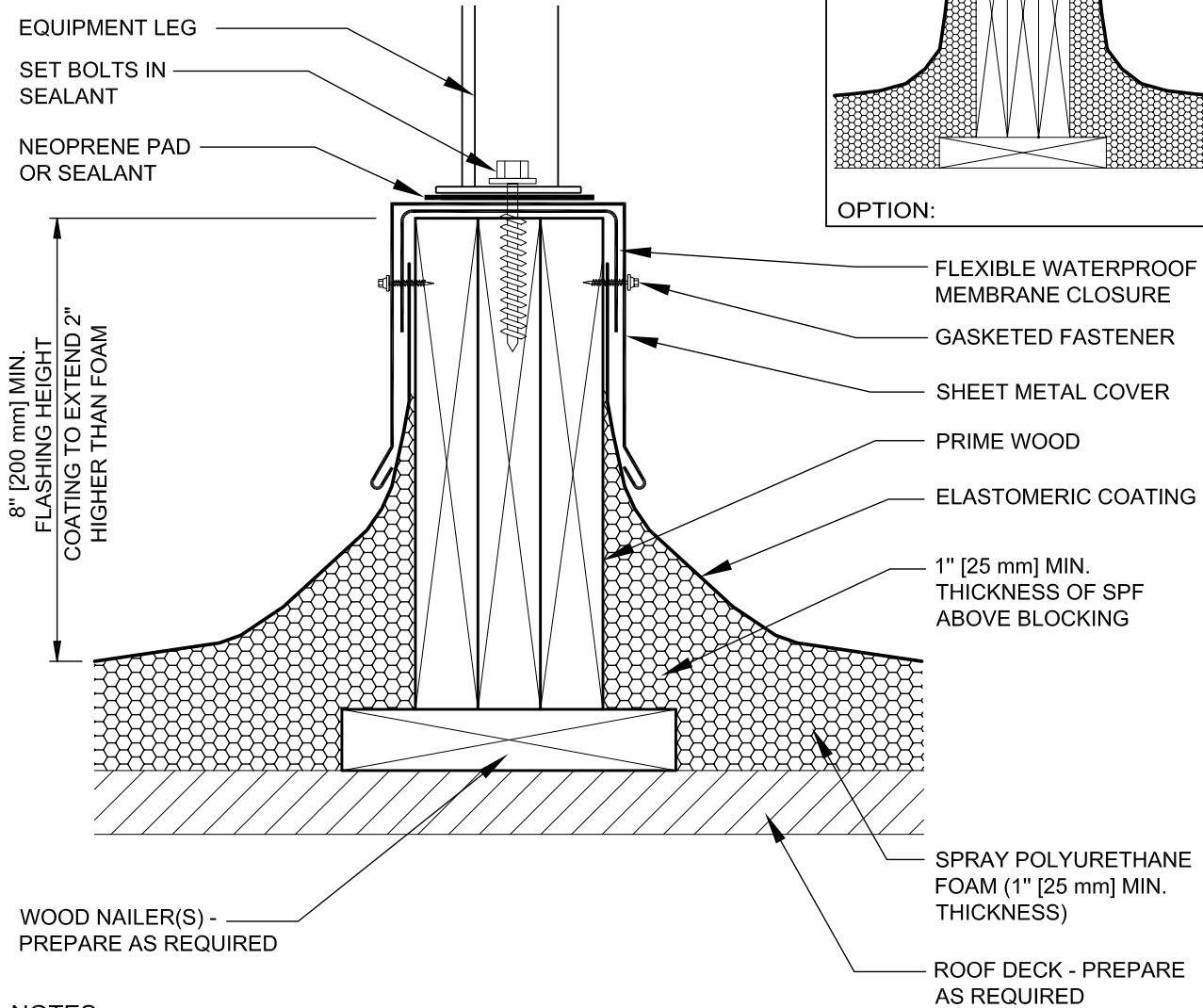
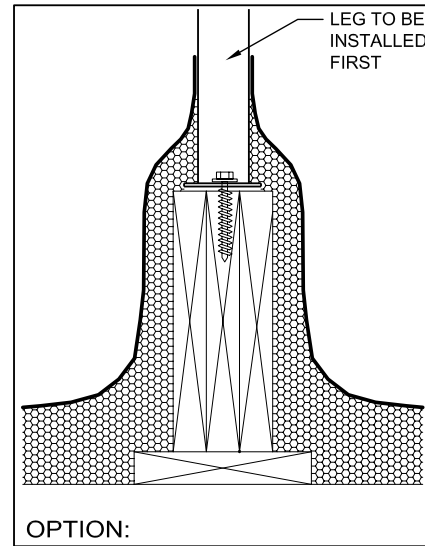
**EQUIPMENT SUPPORT CURB**

2006

NOT DRAWN TO SCALE

**SPF-9**

WIDTH OF EQUIPMENT	HEIGHT OF LEGS
UP TO 24" [UP TO 600 mm]	24" [600 mm]
24" TO 48" [600 mm TO 1.2 m]	36" [900 mm]
48" AND WIDER [1.2 m AND WIDER]	48" [1.2 m]



**NOTES:**

1. THIS DETAIL ALLOWS FOR ROOF SYSTEM MAINTENANCE AROUND THE SUPPORTED EQUIPMENT. THE CONTINUOUS SUPPORT IS PREFERRED IN LIGHTWEIGHT STRUCTURAL SYSTEMS BECAUSE THE EQUIPMENT WEIGHT CAN BE SPREAD ACROSS TWO OR MORE SUPPORTING MEMBERS. WHERE HEAVY STRUCTURAL SYSTEMS ARE USED OR WHERE THE LOAD CAN BE CONCENTRATED OVER A COLUMN, DETAIL SPF-10 MAY BE PREFERRED. A MINIMUM OF 2 FEET [600 mm] OF HORIZONTAL CLEARANCE MUST BE PROVIDED FOR REMOVAL AND REPLACEMENT OF ROOFING AND FLASHING BETWEEN PARALLEL SUPPORTS. REFER TO TABLE ABOVE FOR RECOMMENDATIONS ON VERTICAL CLEARANCE FROM ROOF SURFACE TO BOTTOM OF SUPPORTED EQUIPMENT.
2. FLASHING REQUIREMENTS TYPICAL FOR BOTH SIDES OF EQUIPMENT SUPPORT CURB.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

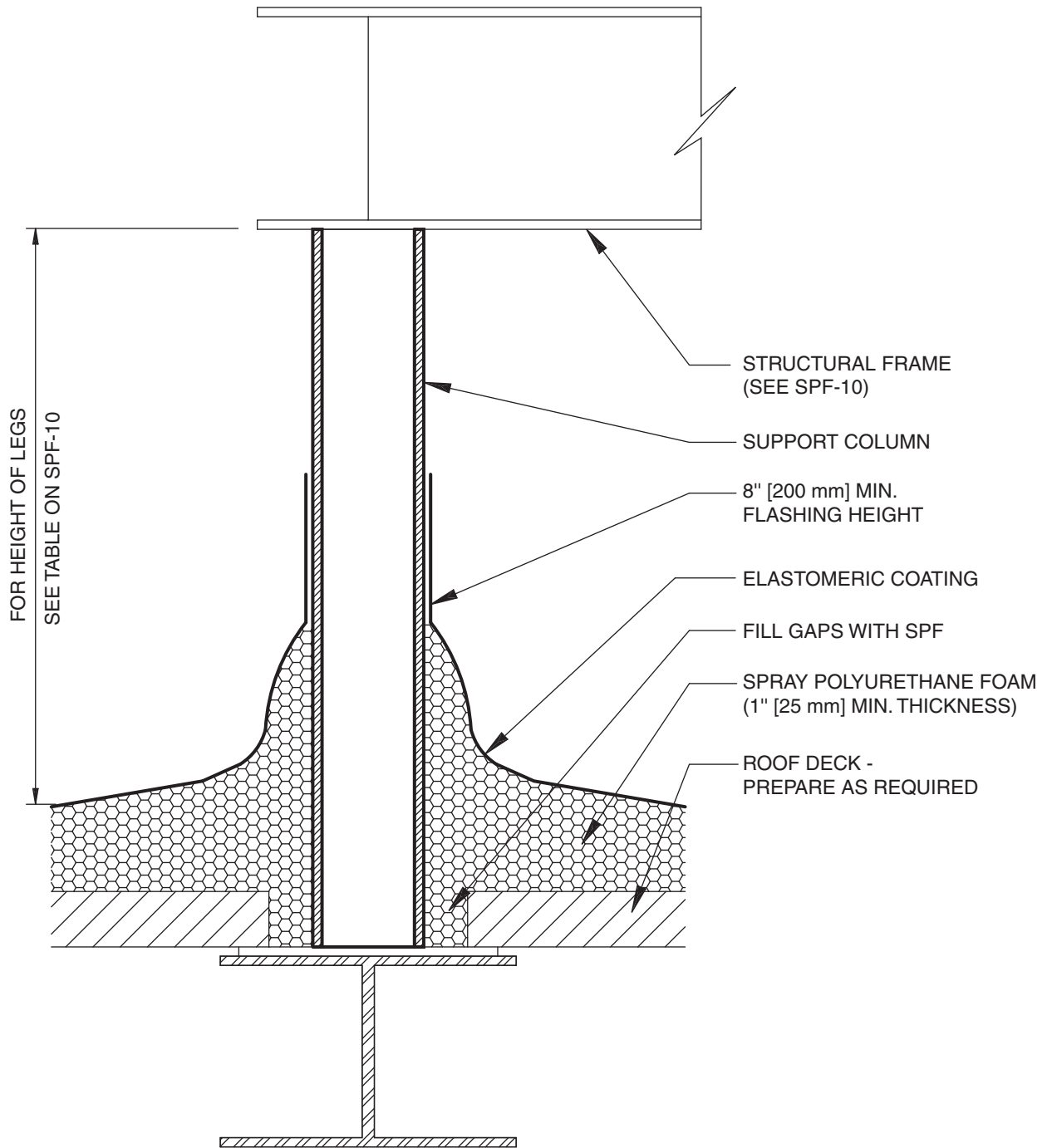


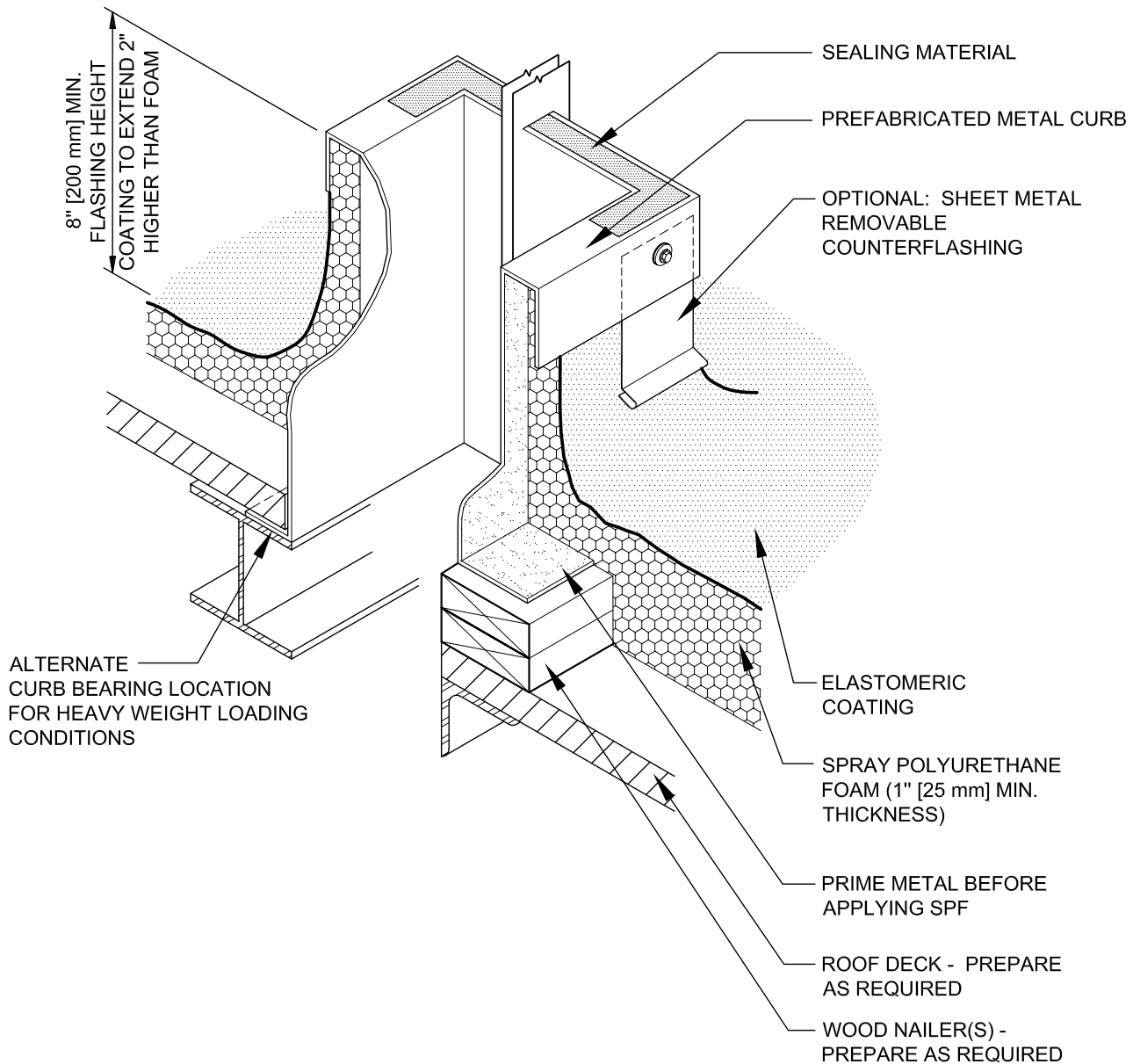
**EQUIPMENT SUPPORT CURB**

2006

NOT DRAWN TO SCALE

**SPF-9S**





NOTES:

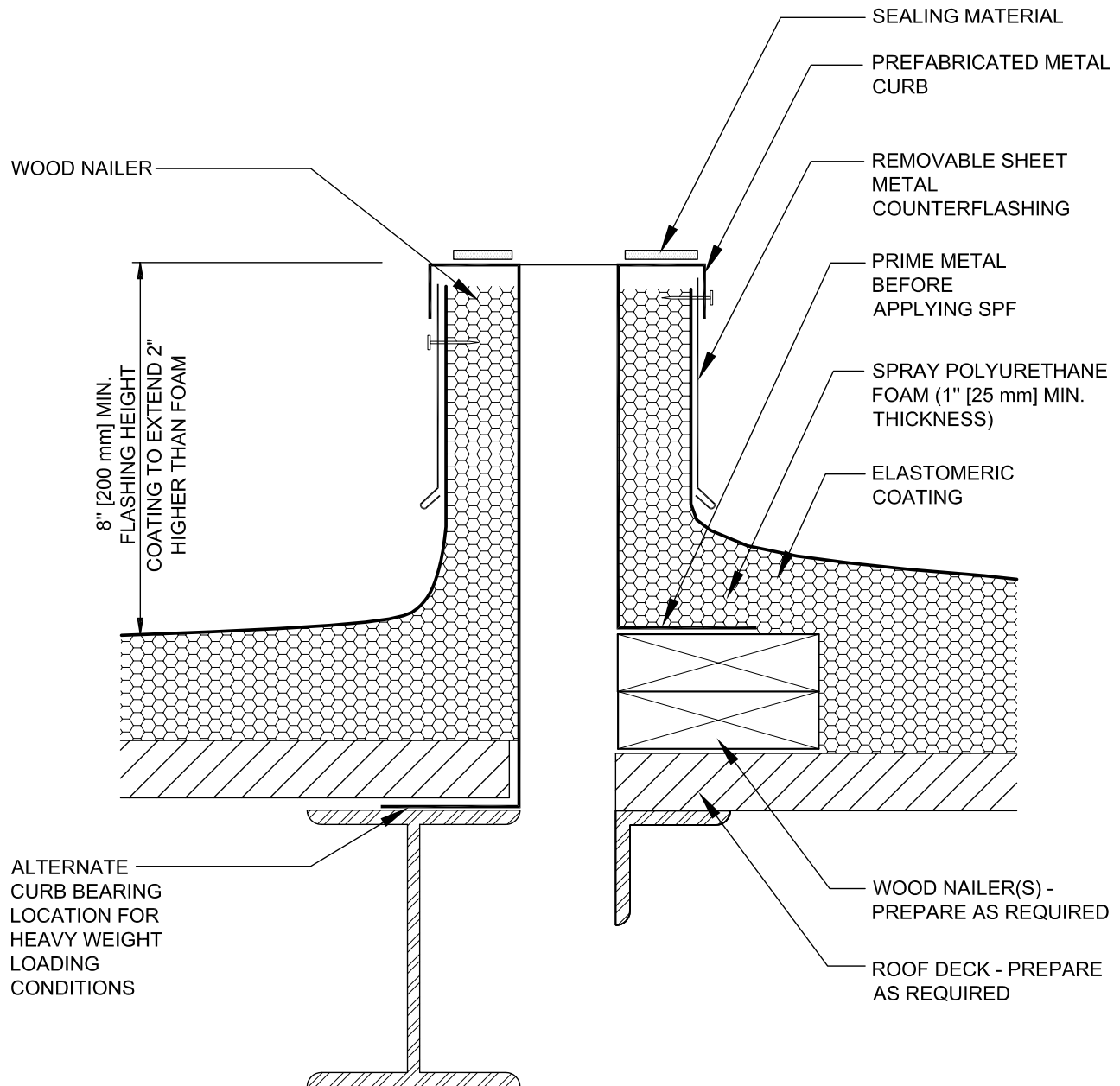
1. THE CURB, WOOD NAILER AND SEAL STRIP ARE TO BE SUPPLIED BY THE CURB MANUFACTURER.
2. WHEN POSSIBLE, THE MECHANICAL UNITS SHOULD NOT BE SET UNTIL THE ROOF SYSTEM HAS BEEN INSTALLED.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



**RAISED CURB DETAIL FOR ROOFTOP AIR  
HANDLING UNITS AND DUCTS  
(PREFABRICATED METAL CURB)  
2006**

NOT DRAWN TO SCALE

**SPF-12**



NOTES:

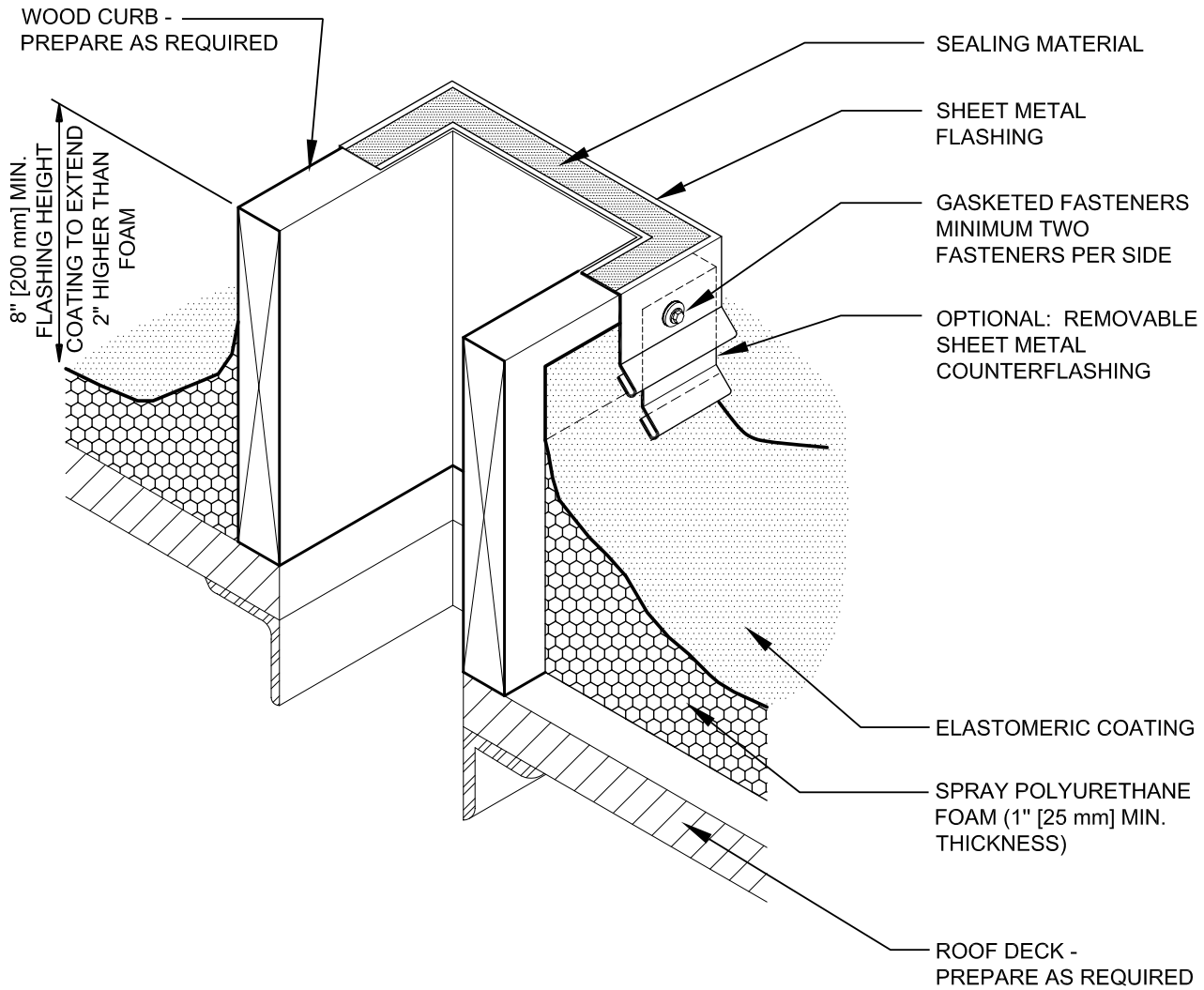
1. THE CURB, WOOD NAILER AND SEAL STRIP ARE TO BE SUPPLIED BY THE CURB MANUFACTURER.
2. WHEN POSSIBLE, THE MECHANICAL UNITS SHOULD NOT BE SET UNTIL THE ROOF SYSTEM HAS BEEN INSTALLED.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



**RAISED CURB DETAIL FOR ROOFTOP AIR HANDLING UNITS AND DUCTS (PREFABRICATED METAL CURB)**  
**2006**

NOT DRAWN TO SCALE

**SPF-12S**



NOTES:

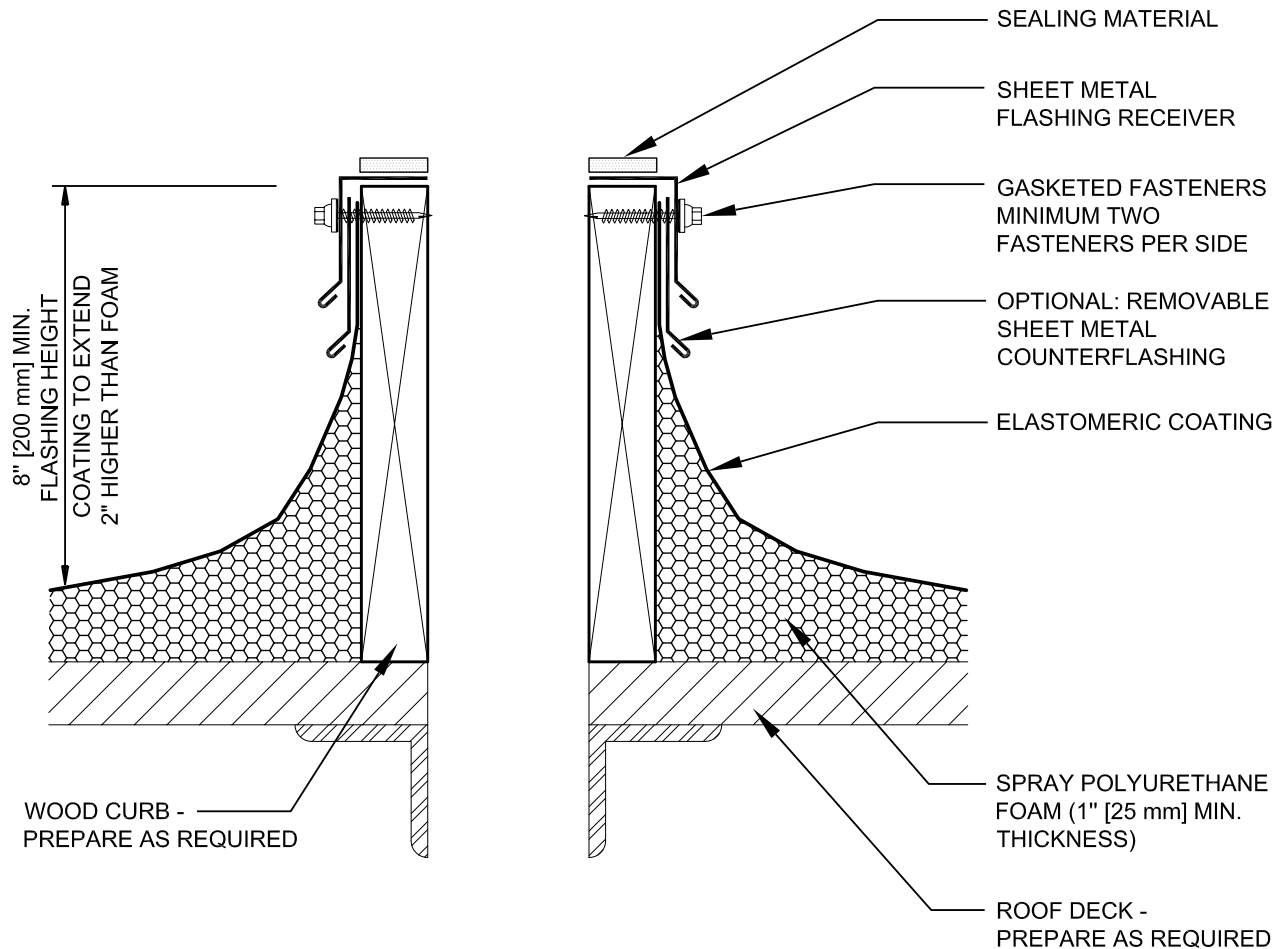
1. SELF FLASHING EQUIPMENT DOES NOT REQUIRE COUNTERFLASHING.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



**RAISED CURB DETAIL FOR ROOFTOP AIR  
HANDLING UNITS AND DUCTS  
(JOB SITE CONSTRUCTED WOOD CURB)  
2006**

NOT DRAWN TO SCALE

**SPF-13**



NOTES:

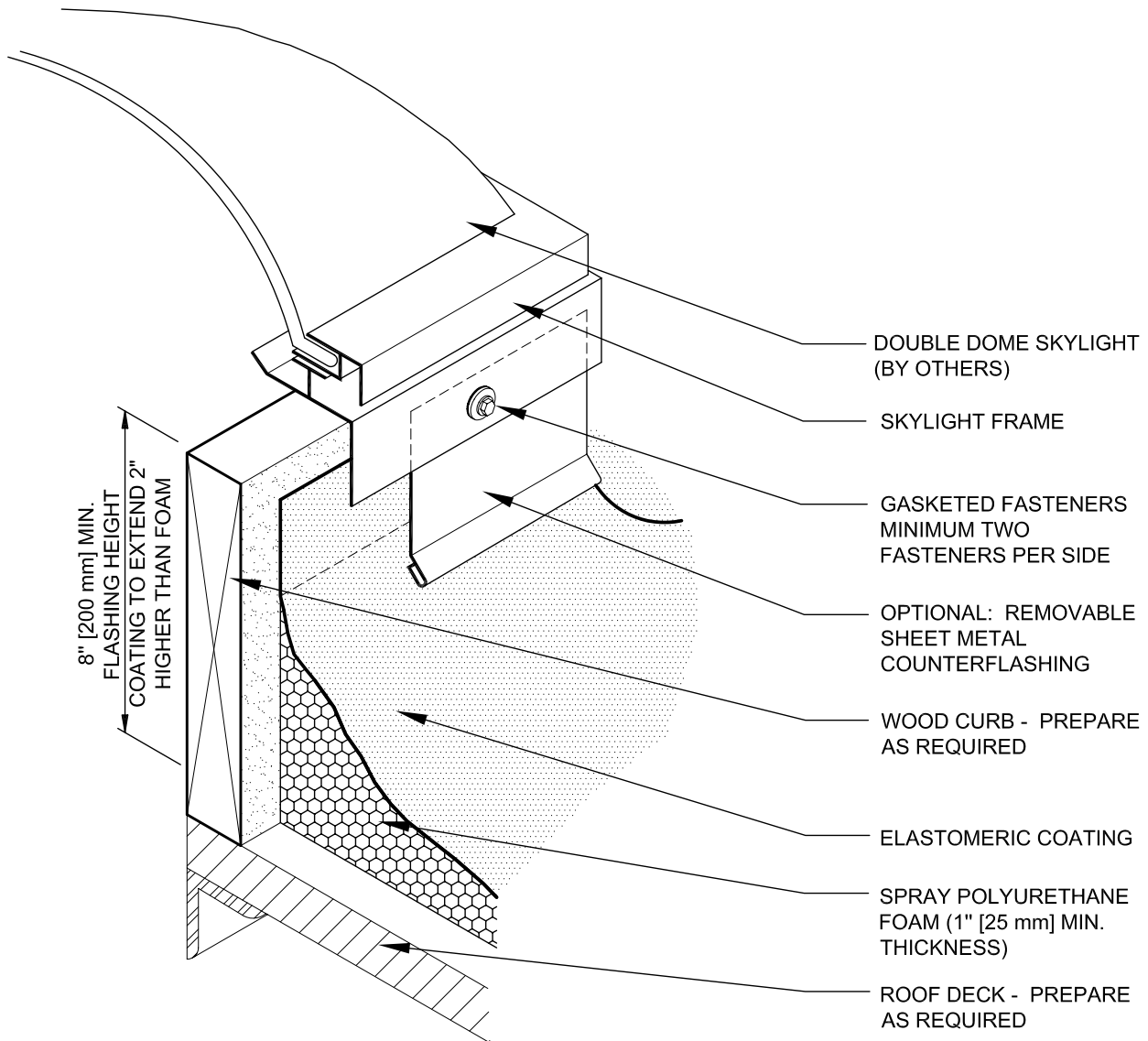
1. SELF FLASHING EQUIPMENT DOES NOT REQUIRE COUNTERFLASHING.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



**RAISED CURB DETAIL FOR ROOFTOP AIR  
HANDLING UNITS AND DUCTS  
(JOB SITE CONSTRUCTED WOOD CURB)  
2006**

NOT DRAWN TO SCALE

**SPF-13S**



NOTES:

1. IF UNIT COUNTERFLASHING EXTENDS 3" [75 mm] MIN. OVER FLASHING, COUNTERFLASHING IS NOT REQUIRED.
2. FOR SCUTTLES, ADDITIONAL WEAR SURFACE SHOULD BE CONSIDERED.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

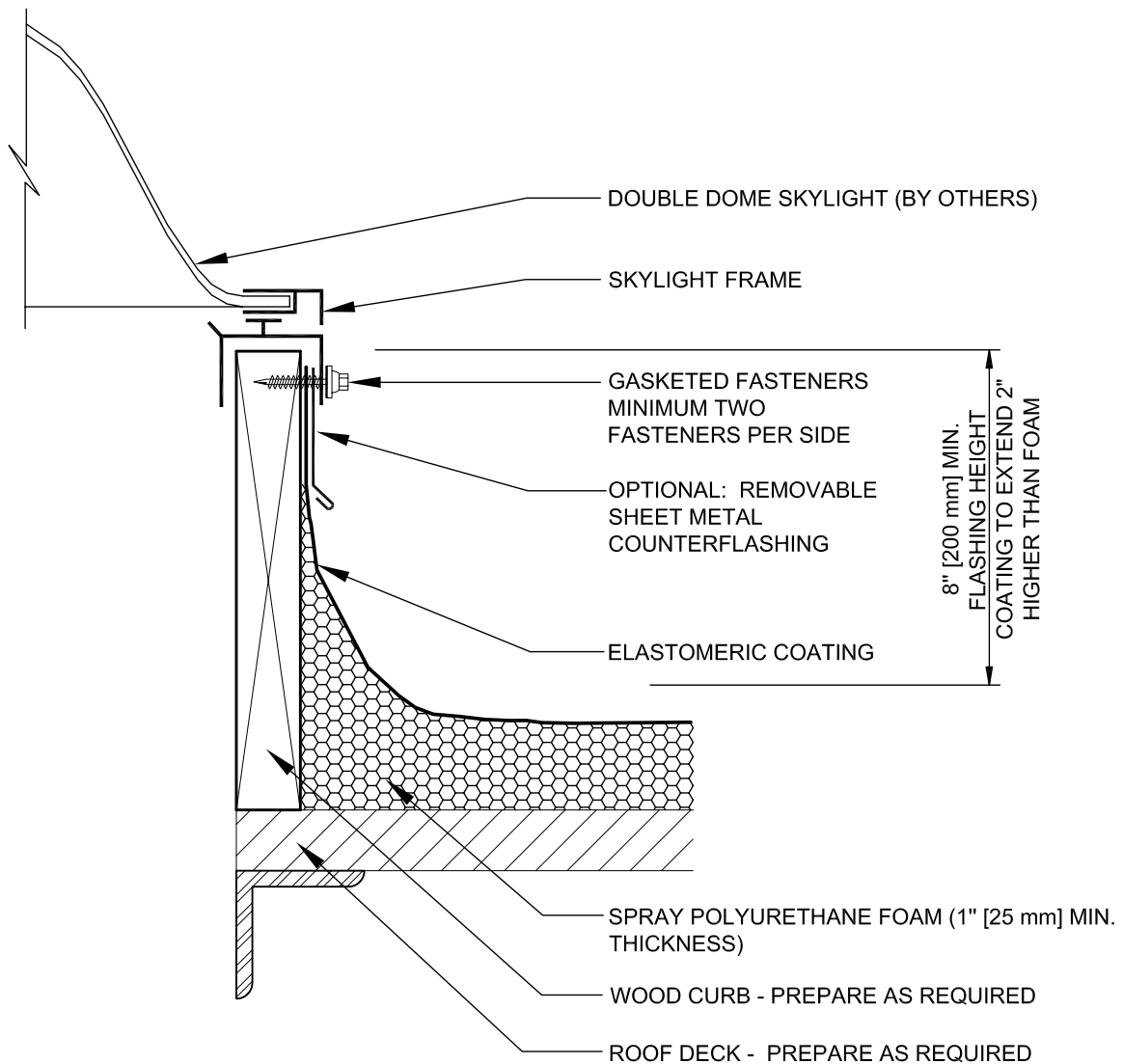


SKYLIGHT, SCUTTLE AND SMOKE VENT

2006

NOT DRAWN TO SCALE

SPF-14



NOTES:

1. IF UNIT COUNTERFLASHING EXTENDS 3" [75 mm] MIN. OVER FLASHING, COUNTERFLASHING IS NOT REQUIRED.
2. FOR SCUTTLES, ADDITIONAL WEAR SURFACE SHOULD BE CONSIDERED.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

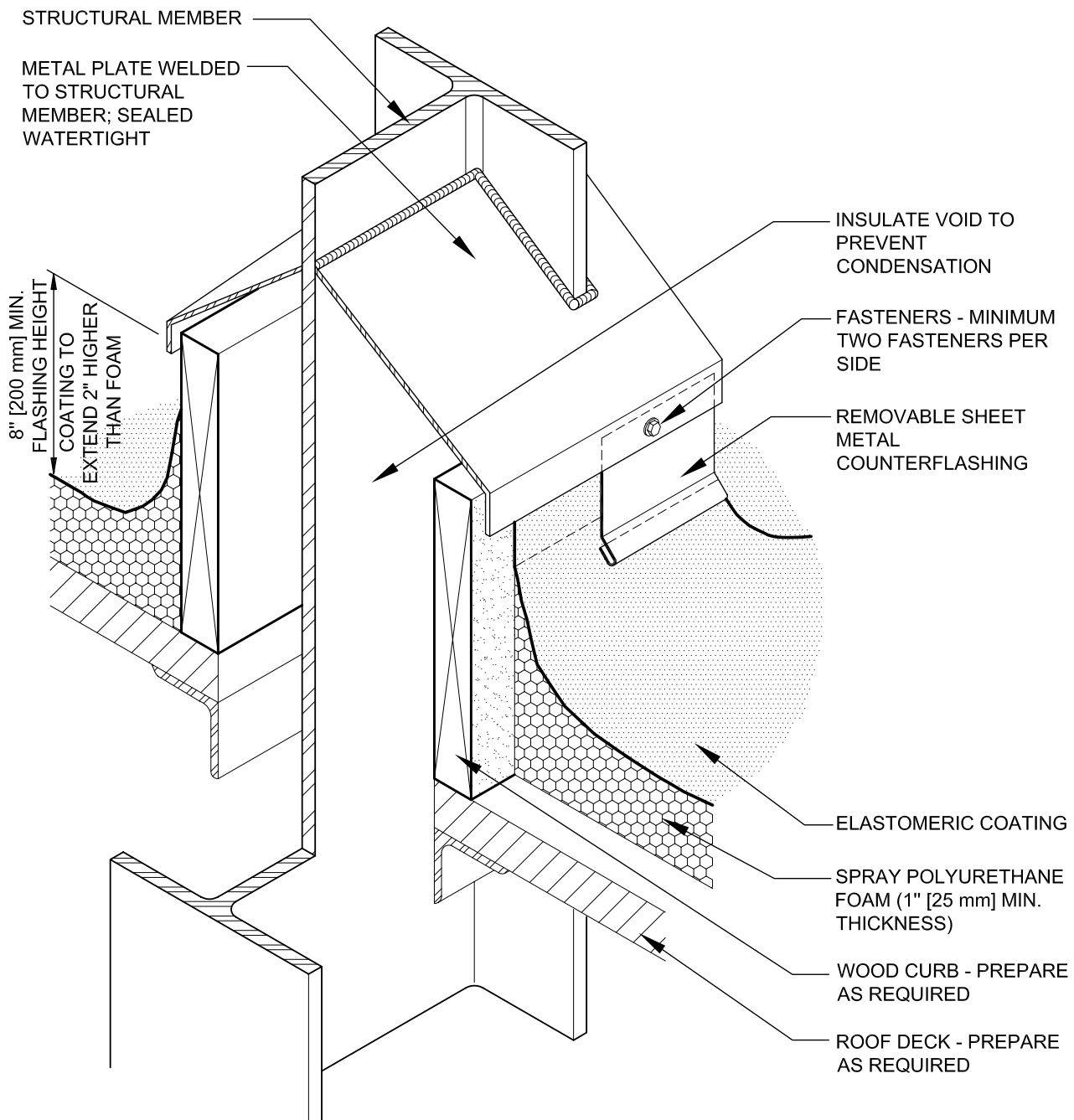


SKYLIGHT, SCUTTLE AND SMOKE VENT

2006

NOT DRAWN TO SCALE

SPF-14S



NOTES:

1. THIS DETAIL ILLUSTRATES ONE METHOD OF ELIMINATING PITCH POCKETS. THE CURB CONSTRUCTION ALLOWS FOR MOVEMENT IN THE STRUCTURAL MEMBER WITHOUT DISTURBING THE ROOFING SYSTEM.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

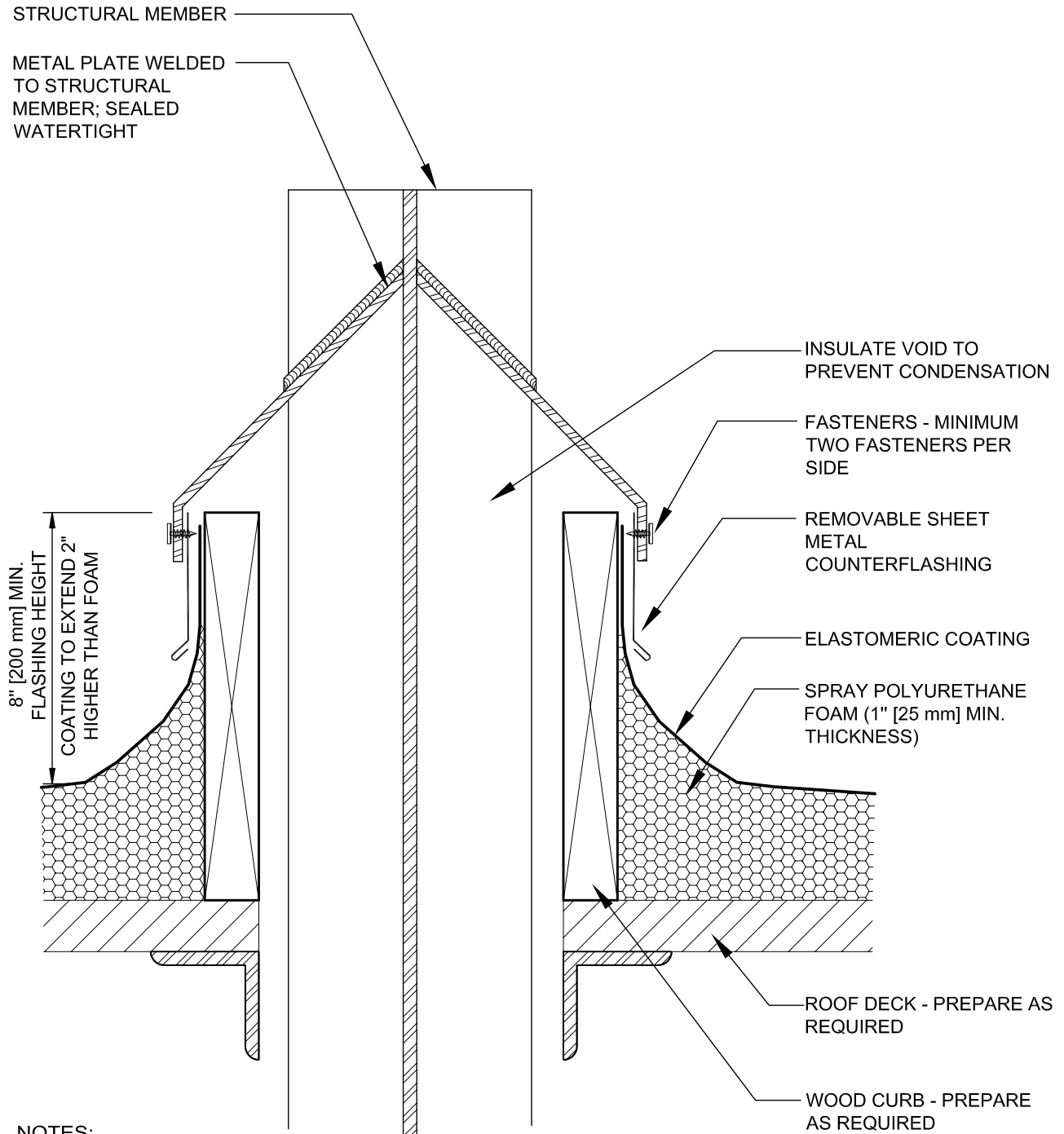


**STRUCTURAL MEMBER THROUGH ROOF DECK**

2006

NOT DRAWN TO SCALE

SPF-15



NOTES:

1. THIS DETAIL ILLUSTRATES ONE METHOD OF ELIMINATING PITCH POCKETS. THE CURB CONSTRUCTION ALLOWS FOR MOVEMENT IN THE STRUCTURAL MEMBER WITHOUT DISTURBING THE ROOFING SYSTEM.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

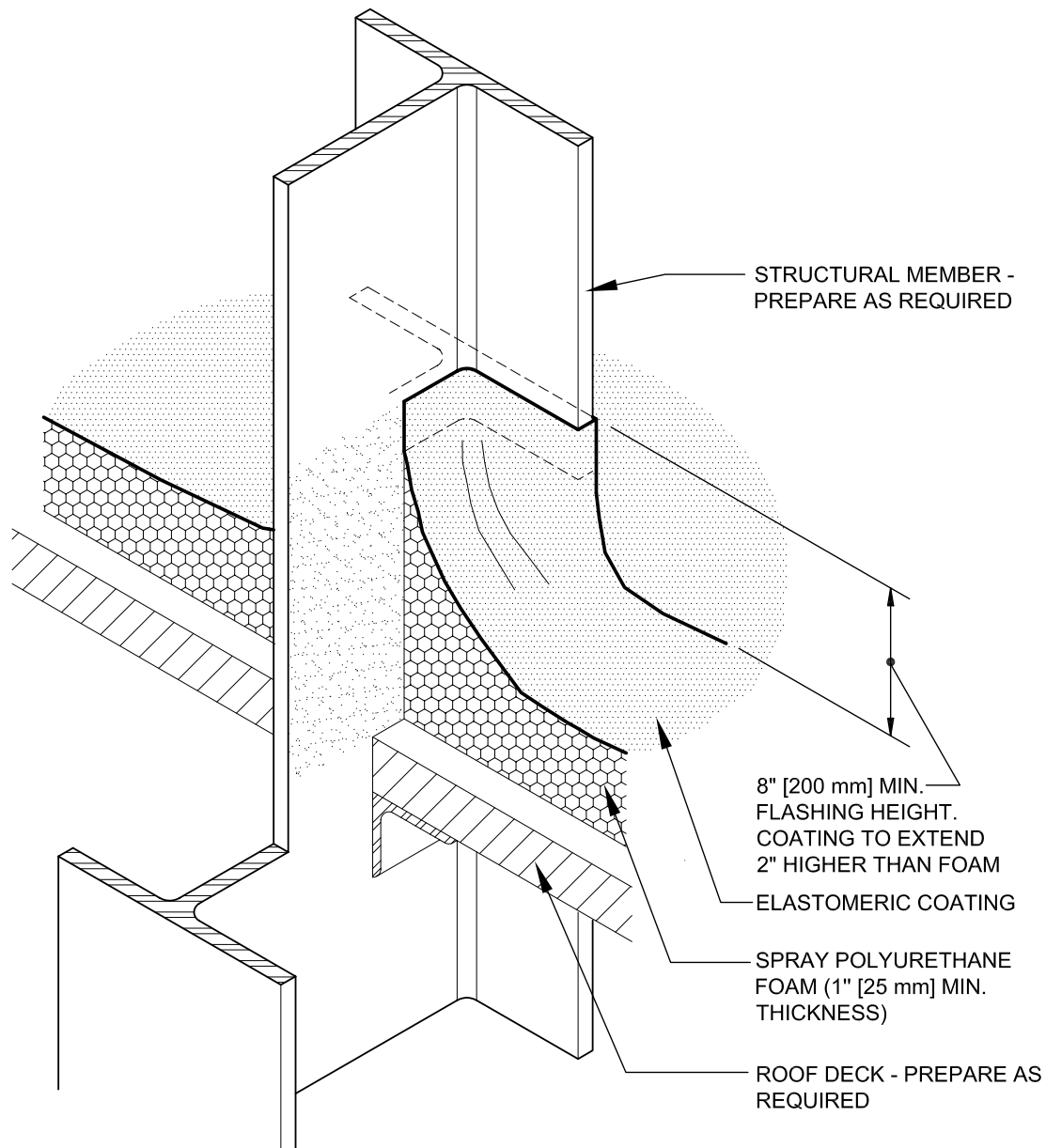


**STRUCTURAL MEMBER THROUGH ROOF DECK**

2006

NOT DRAWN TO SCALE

SPF-15S



NOTES:

1. THIS DETAIL ILLUSTRATES ONE METHOD OF ELIMINATING PITCH POCKETS. THE DECK AND STRUCTURAL MEMBER MUST MOVE IN CONJUNCTION WITH EACH OTHER.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.



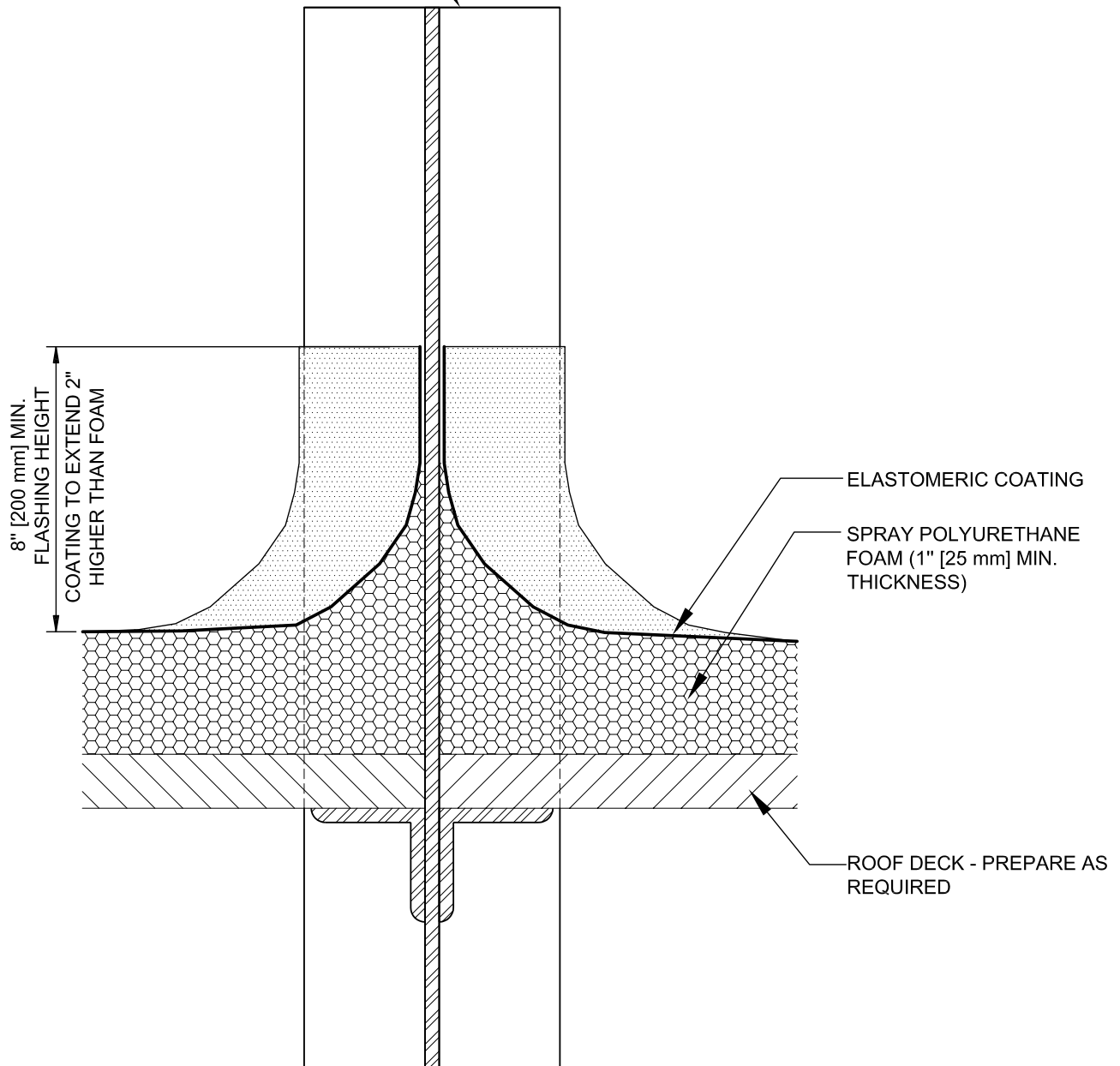
**STRUCTURAL MEMBER THROUGH ROOF DECK**

2006

NOT DRAWN TO SCALE

SPF-15A

STRUCTURAL MEMBER  
PREPARE AS REQUIRED



NOTES:

1. THIS DETAIL ILLUSTRATES ONE METHOD OF ELIMINATING PITCH POCKETS. THE DECK AND STRUCTURAL MEMBER MUST MOVE IN CONJUNCTION WITH EACH OTHER.
2. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
3. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

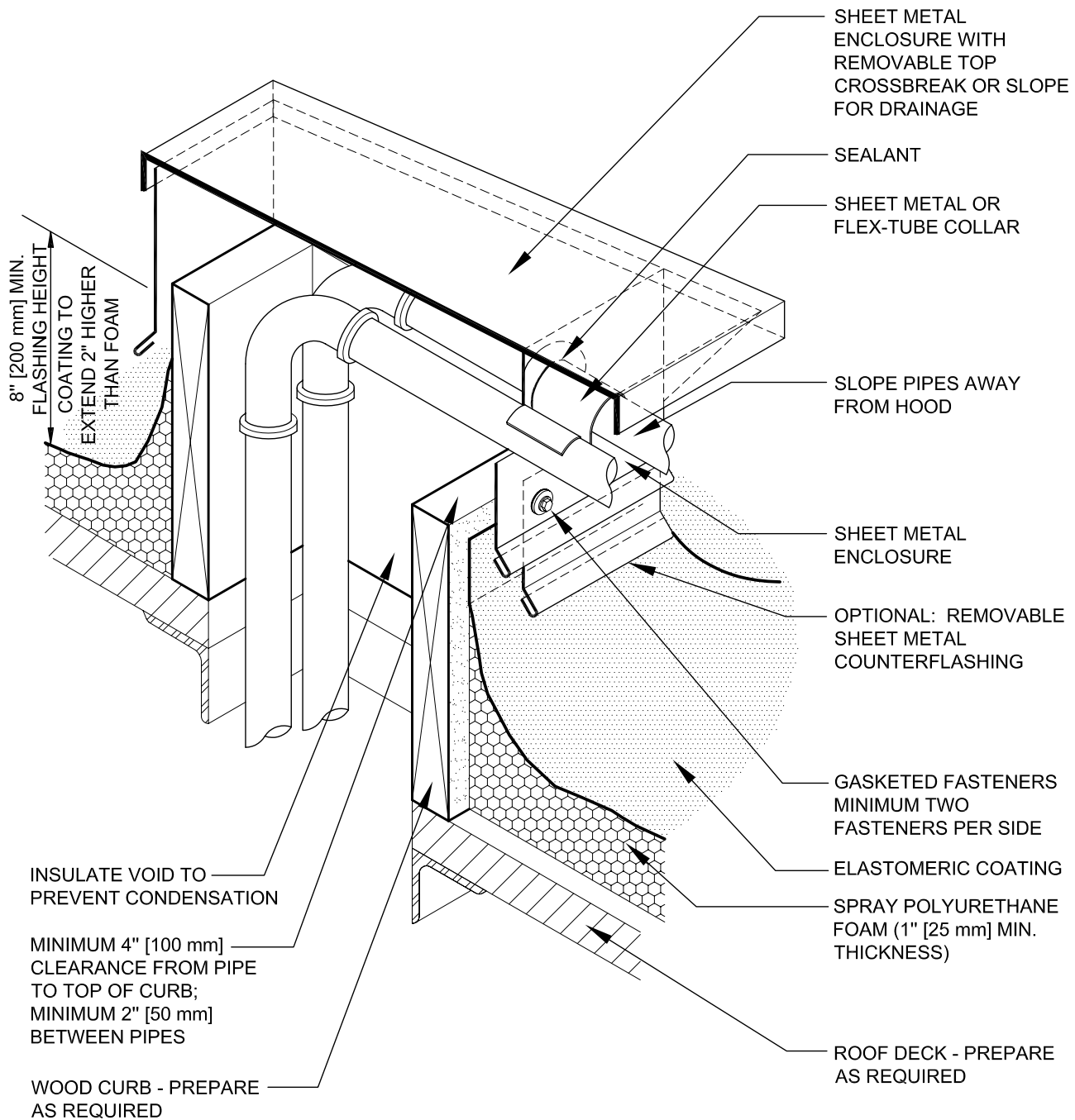


**STRUCTURAL MEMBER THROUGH ROOF DECK**

2006

NOT DRAWN TO SCALE

**SPF-15AS**



**NOTES:**

1. THIS DETAIL ILLUSTRATES ANOTHER METHOD OF ELIMINATING PITCH POCKETS AND GROUPING PIPING THAT MUST COME UP ABOVE THE ROOF SURFACE.
2. MANY MANUFACTURERS OFFER PREFABRICATED BOOTS AND OTHER MATERIALS FOR THIS PURPOSE. SPECIFICS ON THESE PROPRIETARY DESIGNS VARY GREATLY, AND INDIVIDUAL MANUFACTURERS' SPECIFICATIONS SHOULD BE CONSULTED FOR THEIR USE.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

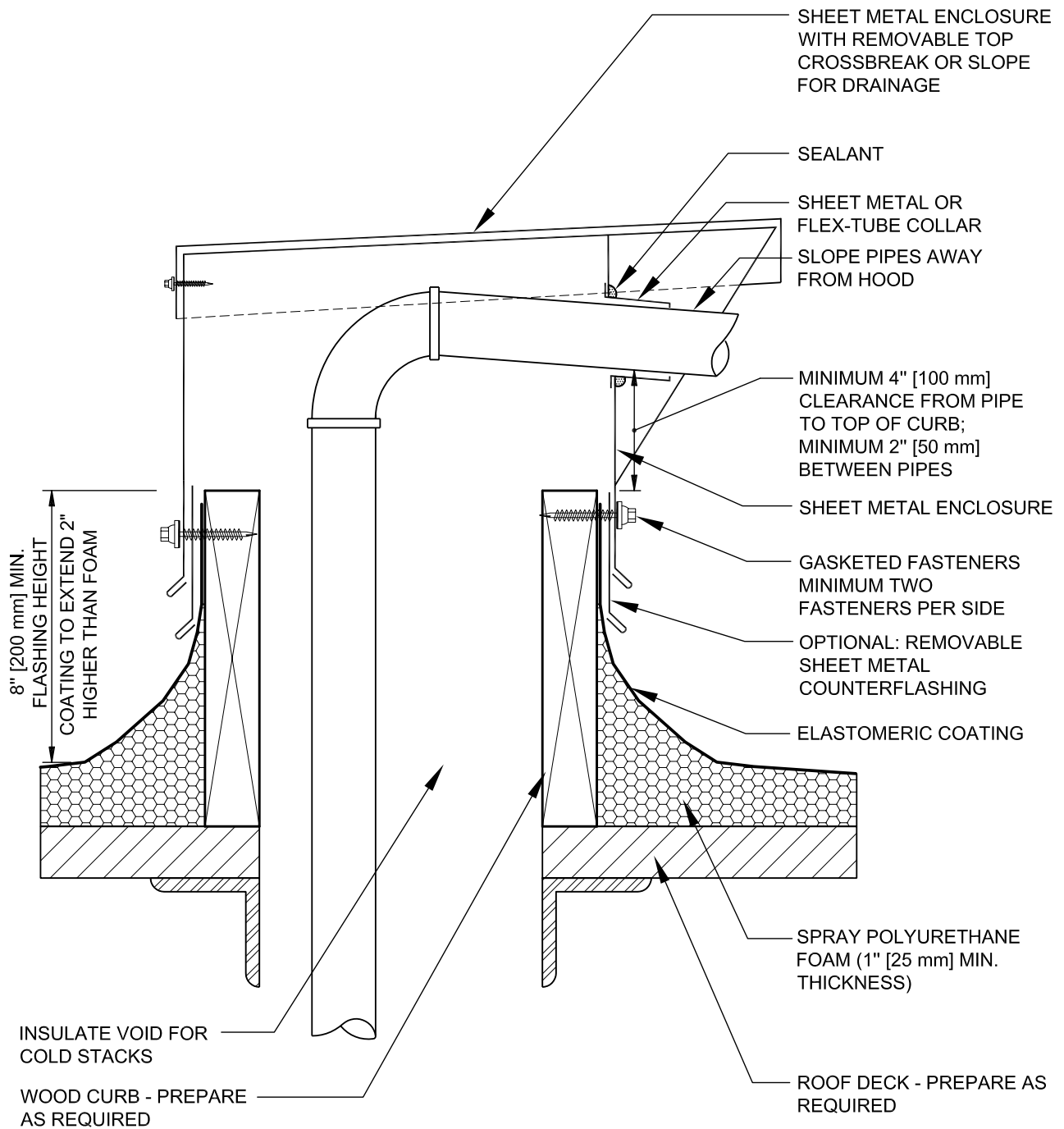


**SHEET METAL ENCLOSURE FOR PIPING**

2006

NOT DRAWN TO SCALE

SPF-16



**NOTES:**

1. THIS DETAIL ILLUSTRATES ANOTHER METHOD OF ELIMINATING PITCH POCKETS AND GROUPING PIPING THAT MUST COME UP ABOVE THE ROOF SURFACE.
2. MANY MANUFACTURERS OFFER PREFABRICATED BOOTS AND OTHER MATERIALS FOR THIS PURPOSE. SPECIFICS ON THESE PROPRIETARY DESIGNS VARY GREATLY, AND INDIVIDUAL MANUFACTURERS' SPECIFICATIONS SHOULD BE CONSULTED FOR THEIR USE.
3. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
4. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

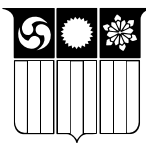
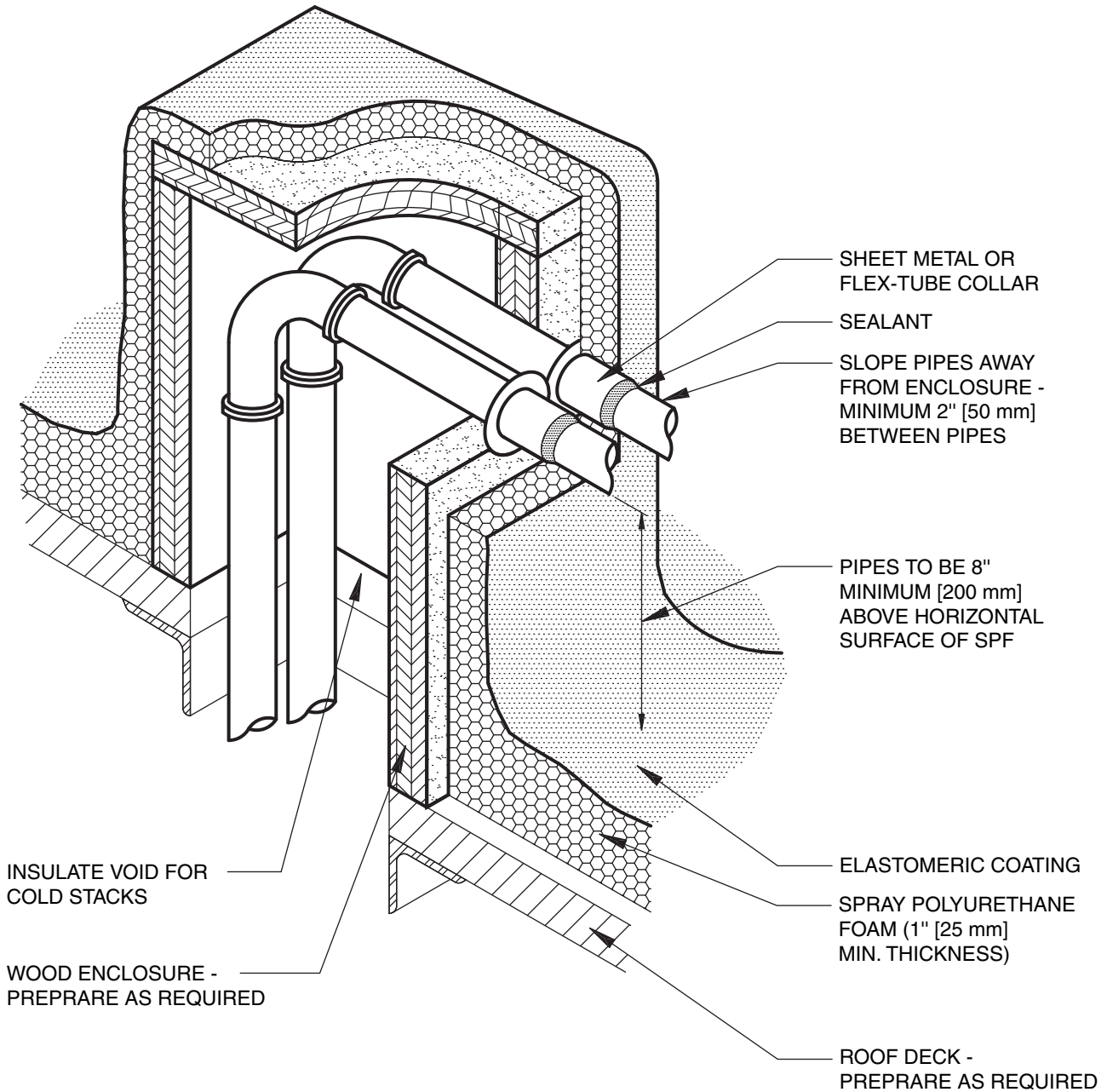


**SHEET METAL ENCLOSURE FOR PIPING**

2006

NOT DRAWN TO SCALE

**SPF-16S**



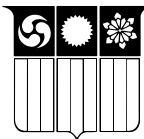
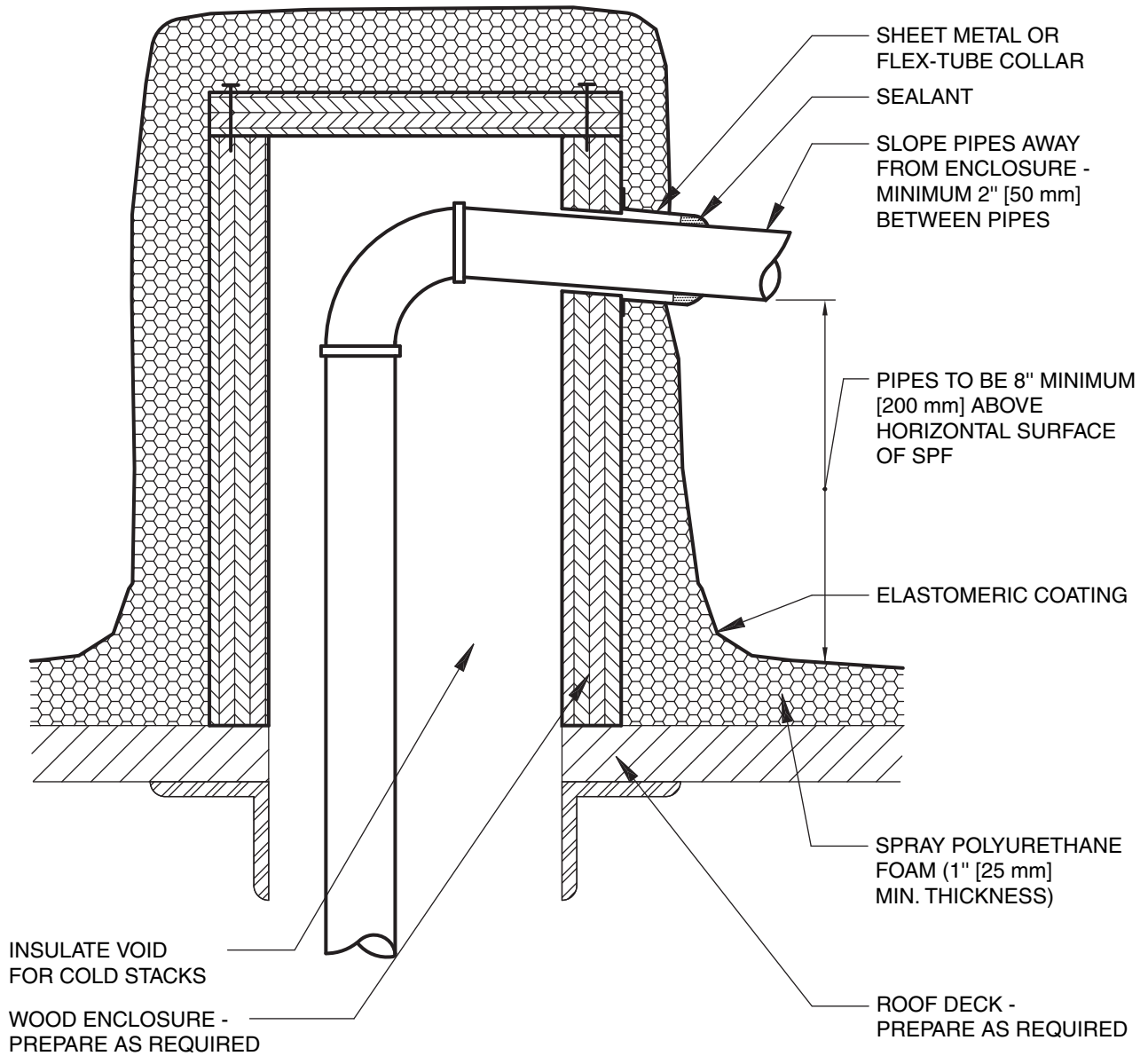
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

### SPF ENCLOSURE FOR PIPING

2001

NOT DRAWN TO SCALE

**SPF-16A**



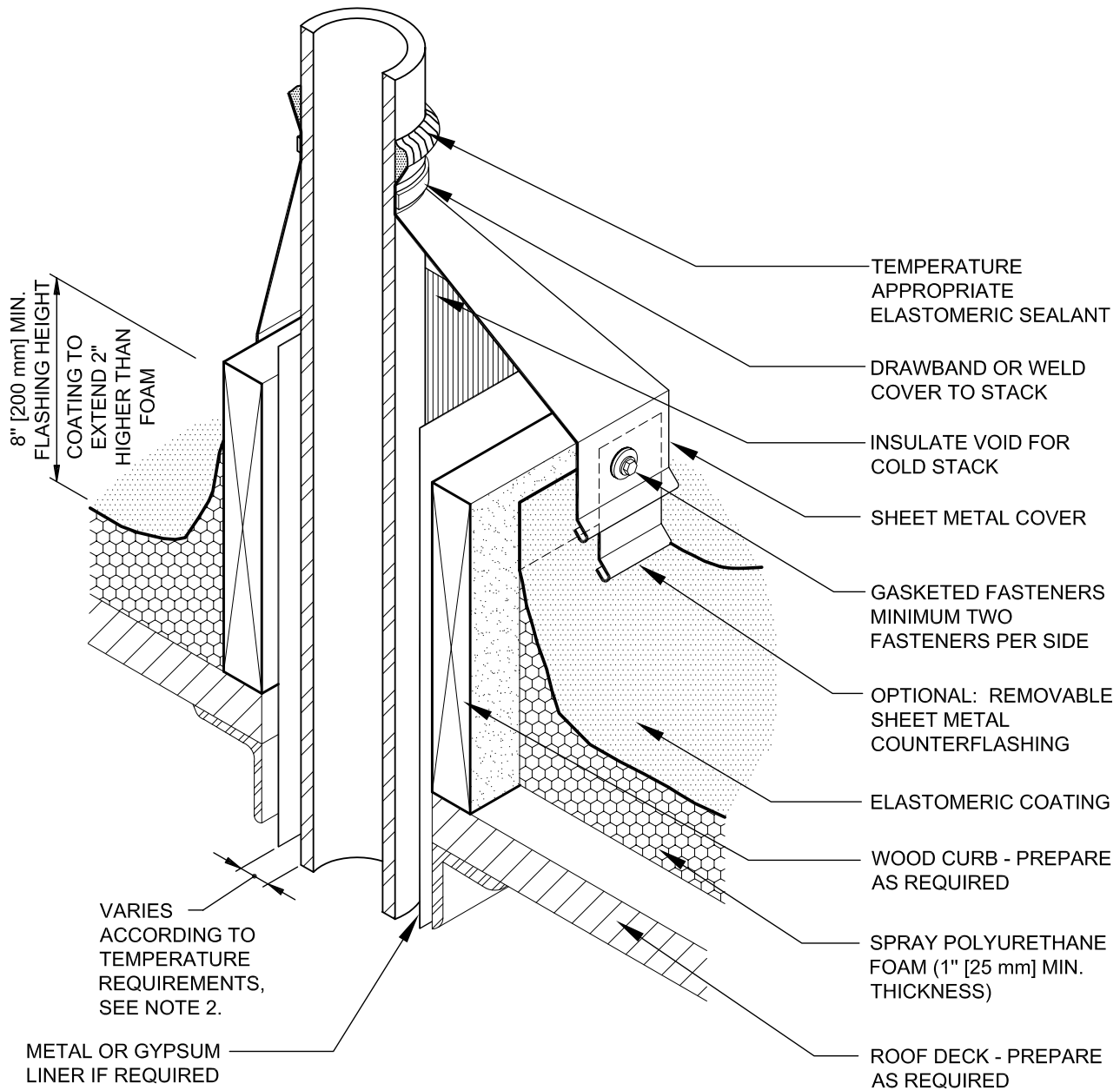
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**SPF ENCLOSURE FOR PIPING**

2001

NOT DRAWN TO SCALE

**SPF-16AS**



**NOTES:**

1. THIS DETAIL ALLOWS THE OPENING TO BE COMPLETED BEFORE THE STACK IS PLACED.
2. THE METAL LINER TYPE, THE CLEARANCE NECESSARY BETWEEN THE LINER AND THE STACK, AND THE NEED FOR INSULATION WILL DEPEND ON THE TEMPERATURE OF THE MATERIAL HANDLED BY THE STACK. THE SUBSTRATE TEMPERATURE IS REQUIRED TO BE BETWEEN -125 AND +180 DEGREES F. VERIFY SUBSTRATE TEMPERATURE RANGE WITH SPF MANUFACTURER.
3. IF COVER EXTENDS OVER FLASHING 3", COUNTERFLASHING IS NOT REQUIRED.
4. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
5. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

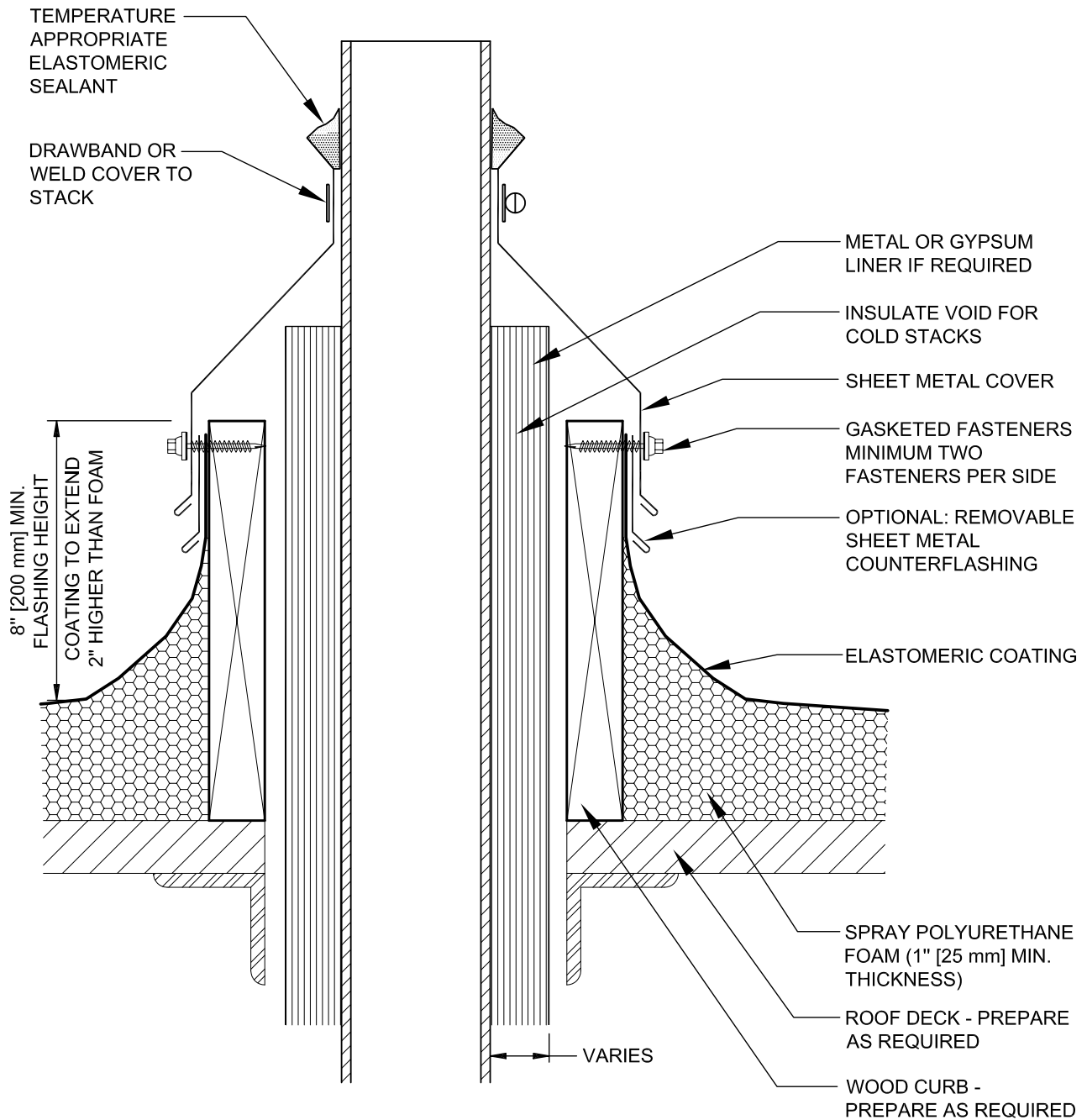


**ISOLATED STACK FLASHING**

**2006**

NOT DRAWN TO SCALE

**SPF-17**



NOTES:

1. THIS DETAIL ALLOWS THE OPENING TO BE COMPLETED BEFORE THE STACK IS PLACED.
2. THE METAL LINER TYPE, THE CLEARANCE NECESSARY BETWEEN THE LINER AND THE STACK, AND THE NEED FOR INSULATION WILL DEPEND ON THE TEMPERATURE OF THE MATERIAL HANDLED BY THE STACK. THE SUBSTRATE TEMPERATURE IS REQUIRED TO BE BETWEEN -125 AND +180 DEGREES F. VERIFY SUBSTRATE TEMPERATURE RANGE WITH SPF MANUFACTURER.
3. IF COVER EXTENDS OVER FLASHING 3", COUNTERFLASHING IS NOT REQUIRED.
4. REFER TO THE SHEET METAL SECTION OF THE METAL ROOFING MANUAL FOR JOINERY AND SECUREMENT OPTIONS FOR SHEET METAL.
5. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

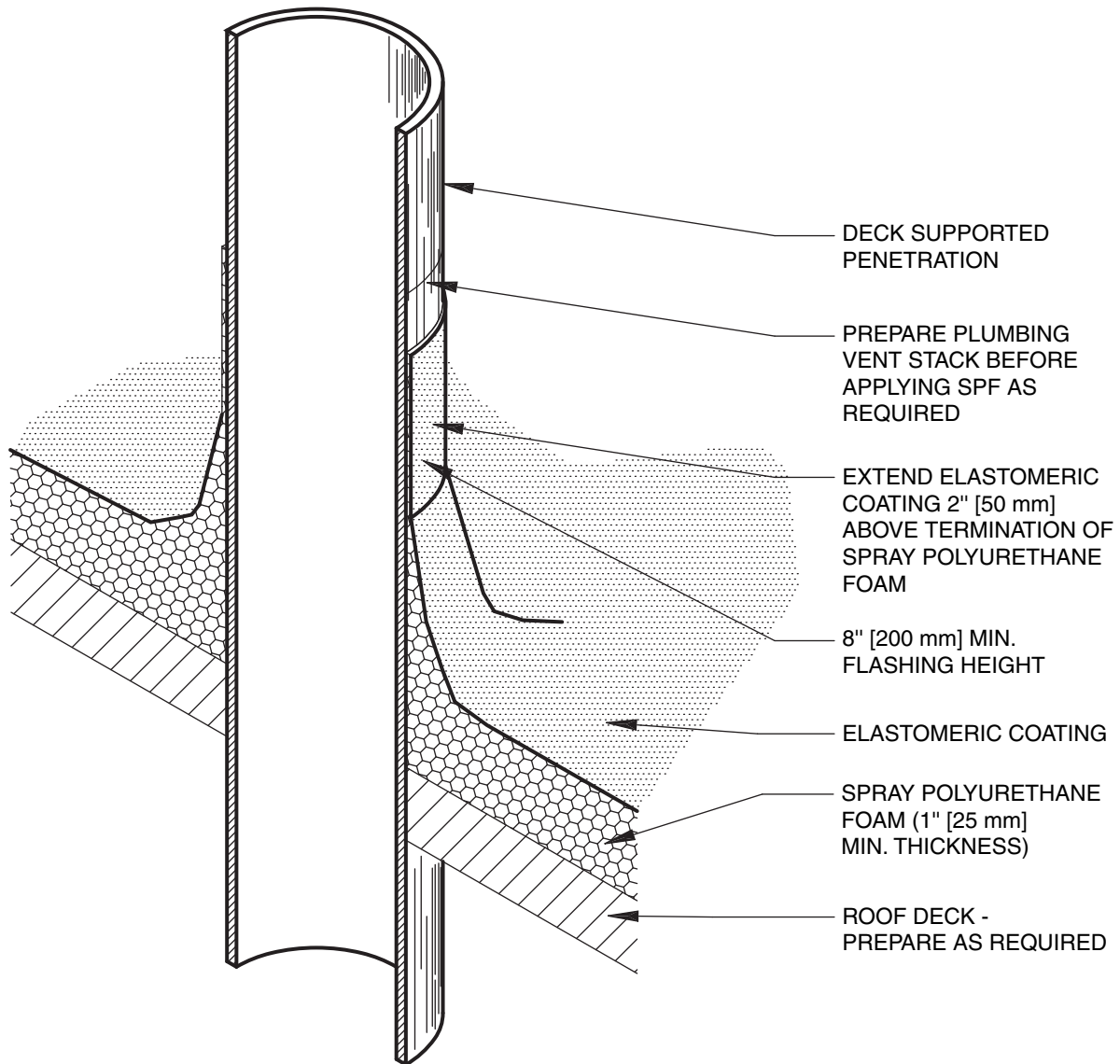


**ISOLATED STACK FLASHING**

2006

NOT DRAWN TO SCALE

**SPF-17S**

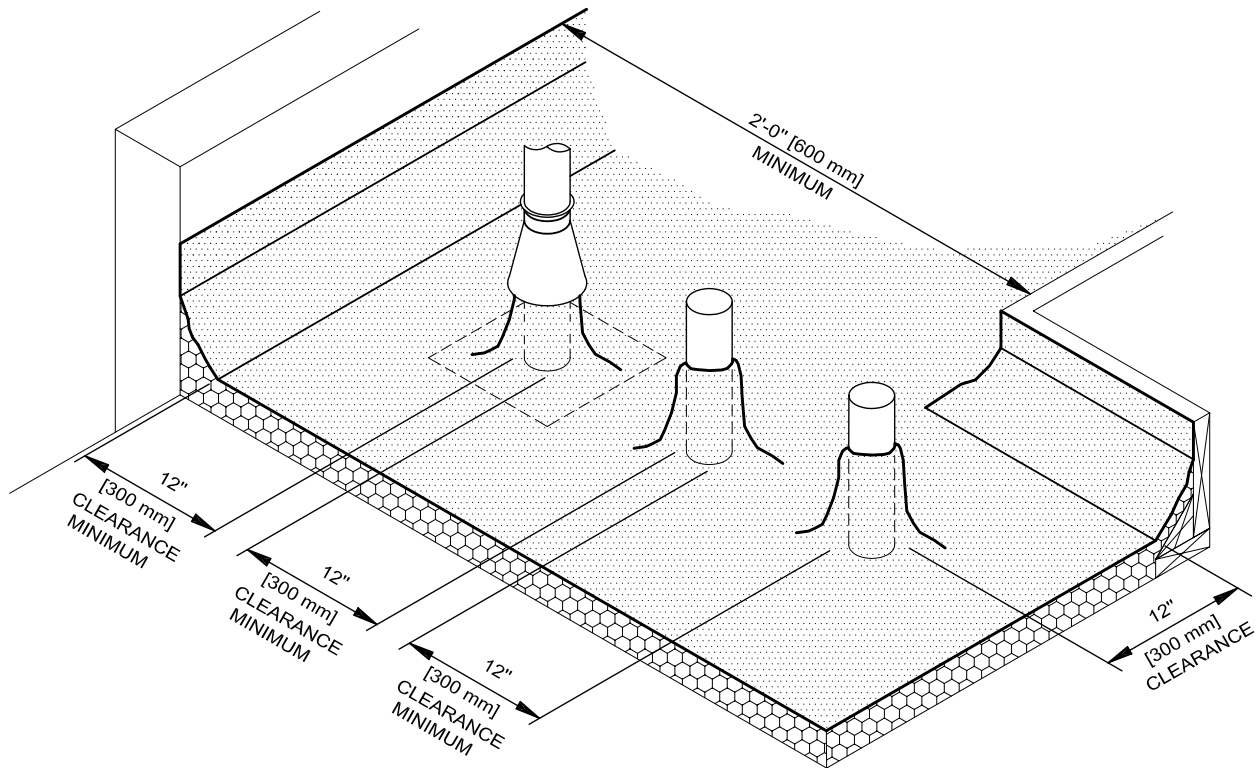
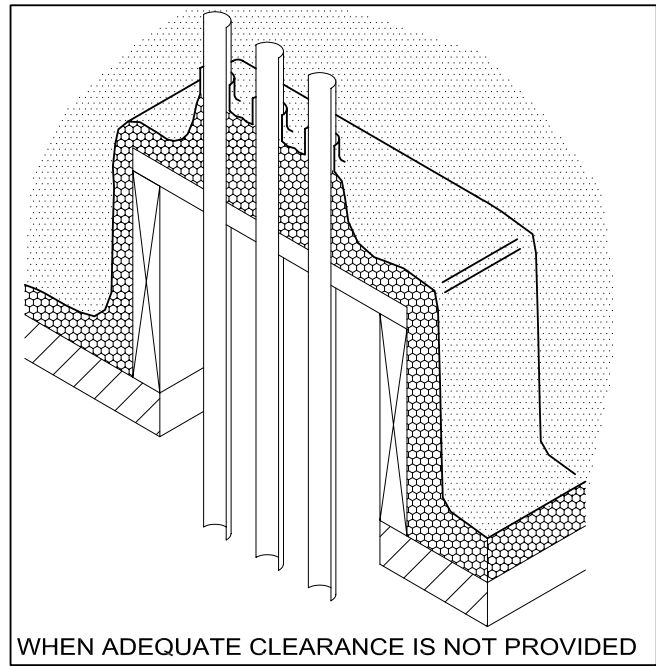


NOTES :

1. WHERE DIFFERENTIAL MOVEMENT IS A CONCERN, SEE DETAIL SPF-19.
2. VENT STACKS AND OTHER PIPES SHOULD HAVE A MINIMUM OF 12 INCHES [300 mm] OF CLEARANCE ON ALL SIDES FROM WALLS, CURBS AND OTHER PROJECTIONS TO FACILITATE PROPER FLASHING.

	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>DECK SUPPORTED PENETRATION</b>	
		2001	NOT DRAWN TO SCALE

**SPF-18**



NOTES:

1. THE DECK AND PENETRATIONS MUST MOVE IN CONJUNCTION WITH EACH OTHER.
2. REFER TO INTRODUCTION FOR ADDITIONAL INFORMATION.

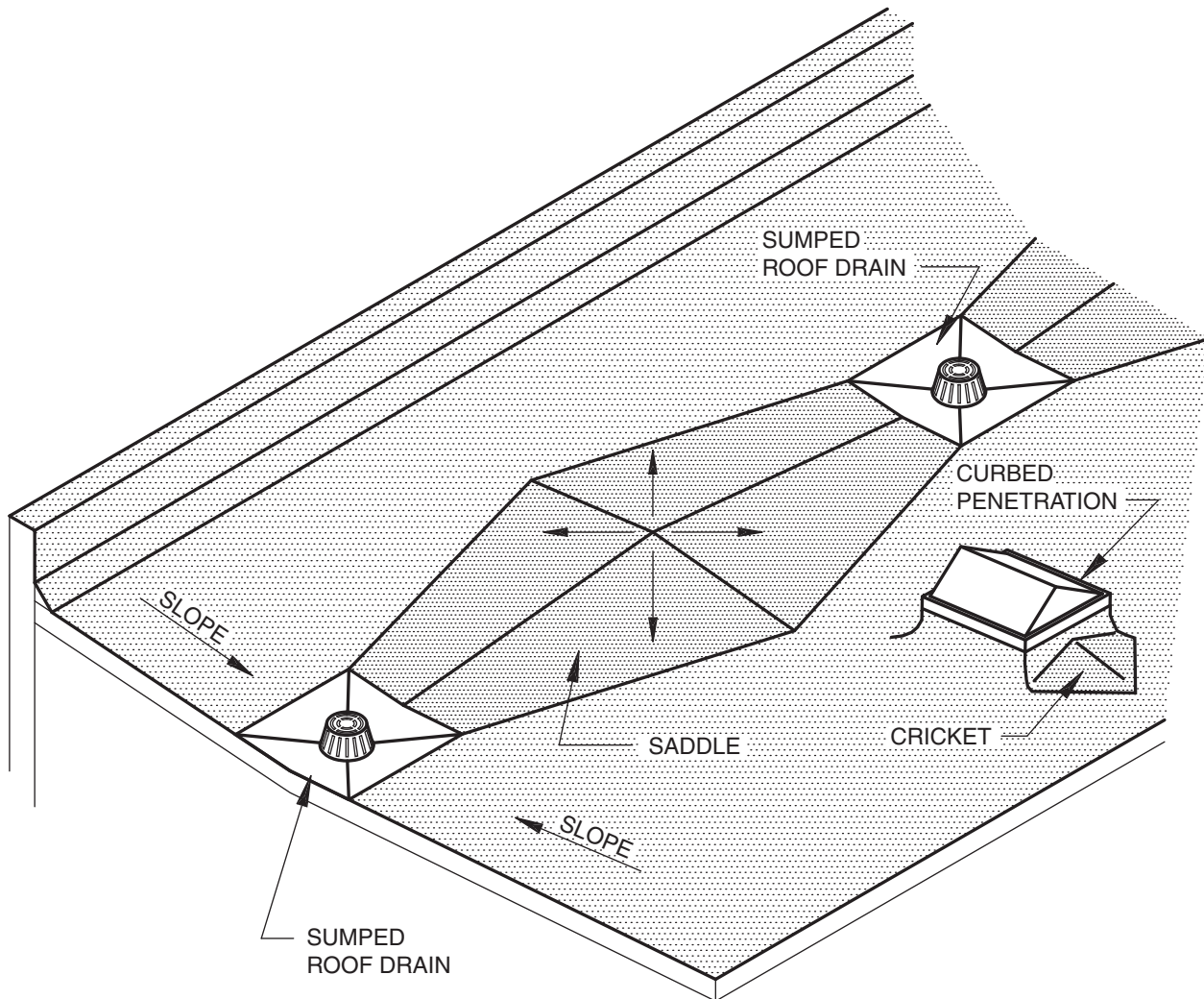


GUIDE FOR CLEARANCES BETWEEN PIPES

2006

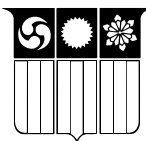
NOT DRAWN TO SCALE

SPF-TABLE 4



NOTES :

1. SADDLES SHOULD BE LOCATED IN VALLEYS BETWEEN ROOF DRAINS AND CRICKETS ON THE HIGH SIDE OF CURBS.
2. LOCATE ROOF DRAINS AT POINTS OF MAXIMUM DECK DEFLECTION / LOW AREAS FOR DRAINAGE.



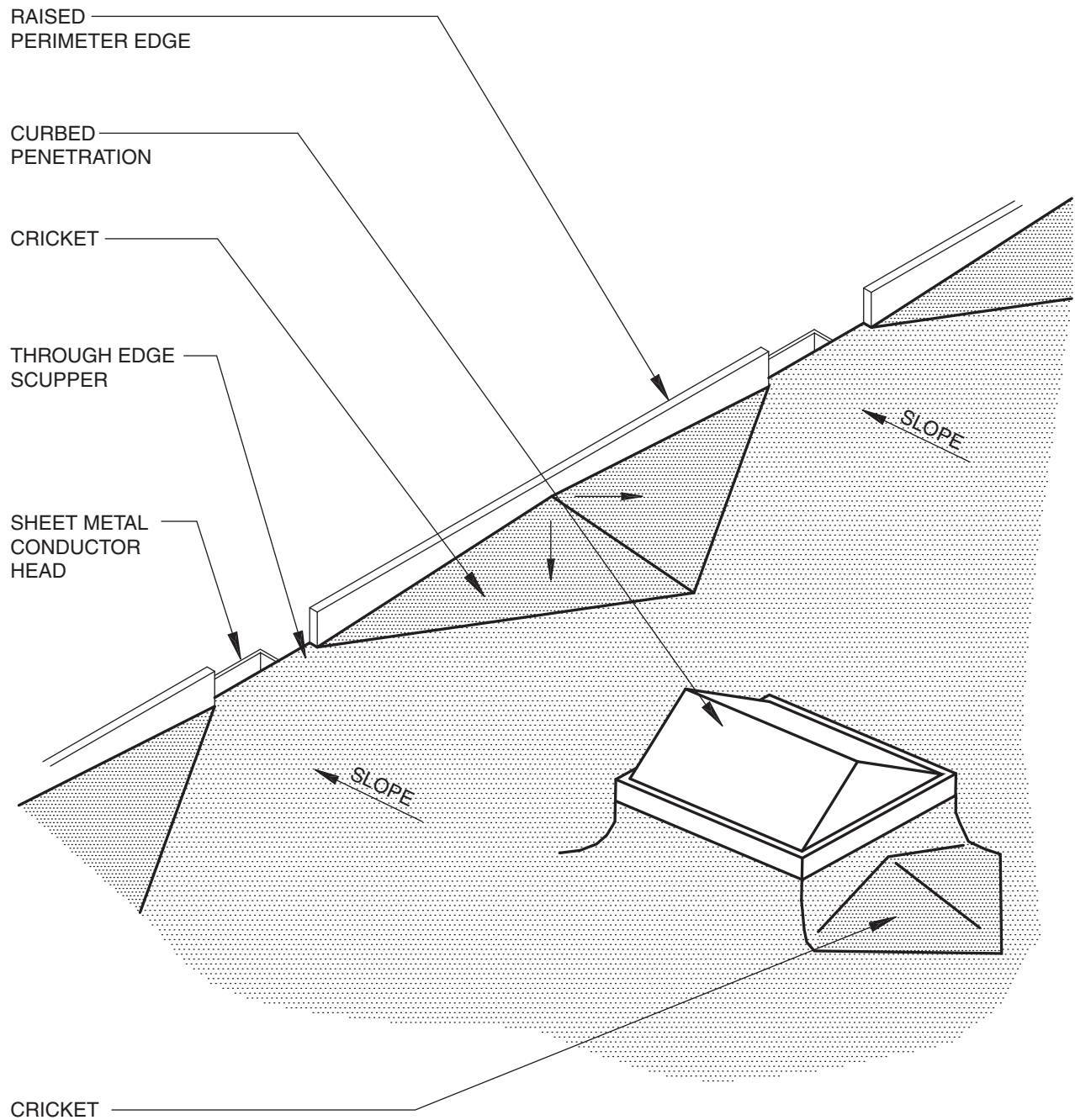
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

2001

**GUIDE FOR CRICKETS AND SADDLES**

NOT DRAWN TO SCALE

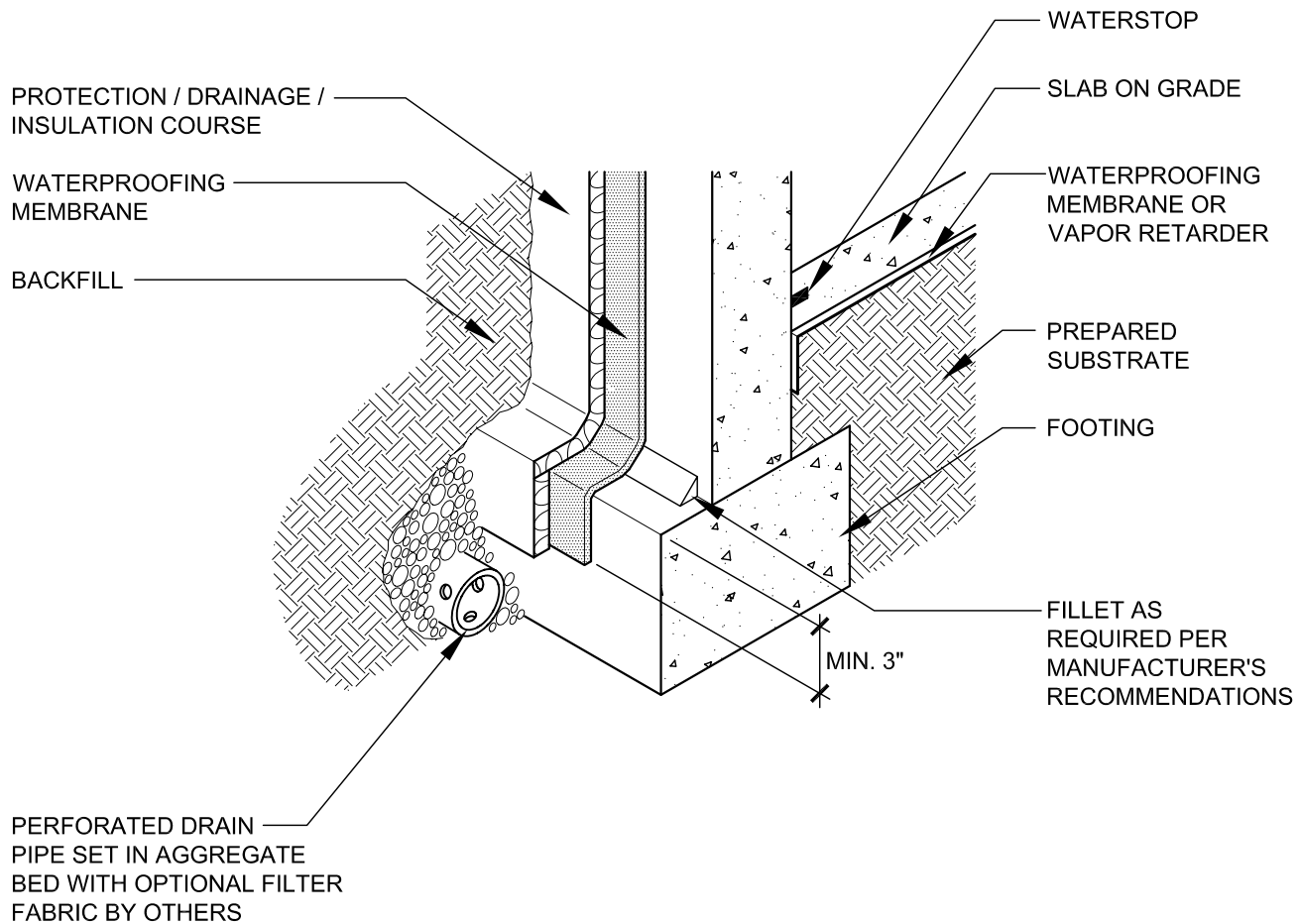
**SPF - TABLE 5**



NOTES :

1. SADDLE SHOULD BE LOCATED BETWEEN THROUGH-EDGE OR WALL SCUPPERS AND CRICKETS ON THE HIGH SIDE OF CURBS.
2. RAISED PERIMETER EDGES WHERE TAPERED CRICKETS ARE USED NECESSITATE THE SPECIFICATION OF RELATIVELY WIDE (TALL) DIMENSIONAL LUMBER OR THE ERECTION OF FRAMED WALLS.

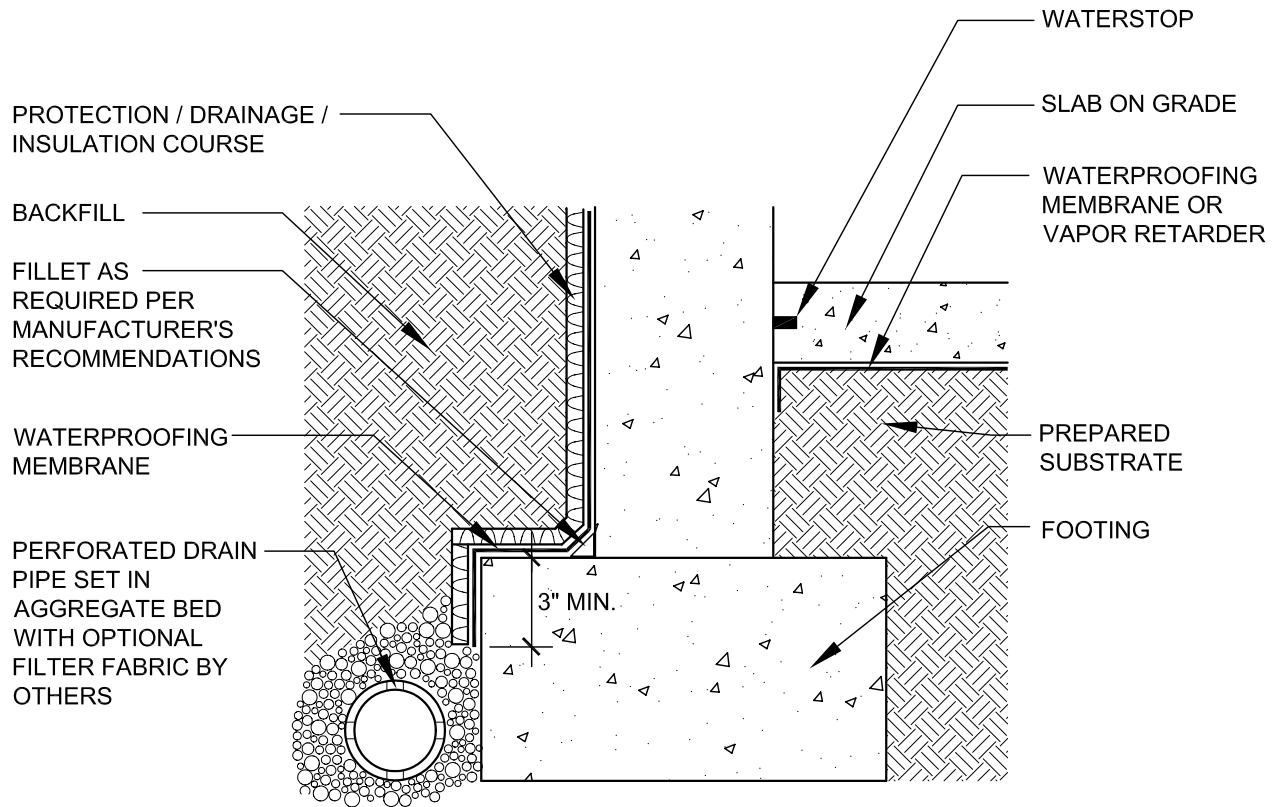
	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>GUIDE FOR EDGE SCUPPERS WITH TAPERED SADDLES</b></p>	<p><b>SPF - TABLE 6</b></p>
	2001	<i>NOT DRAWN TO SCALE</i>	



**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

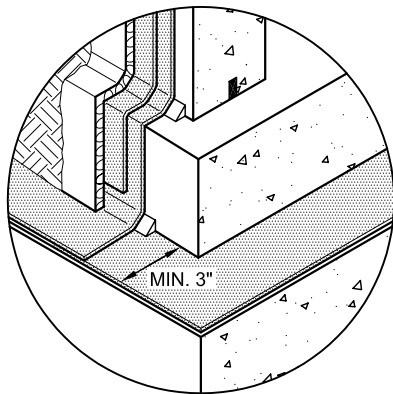
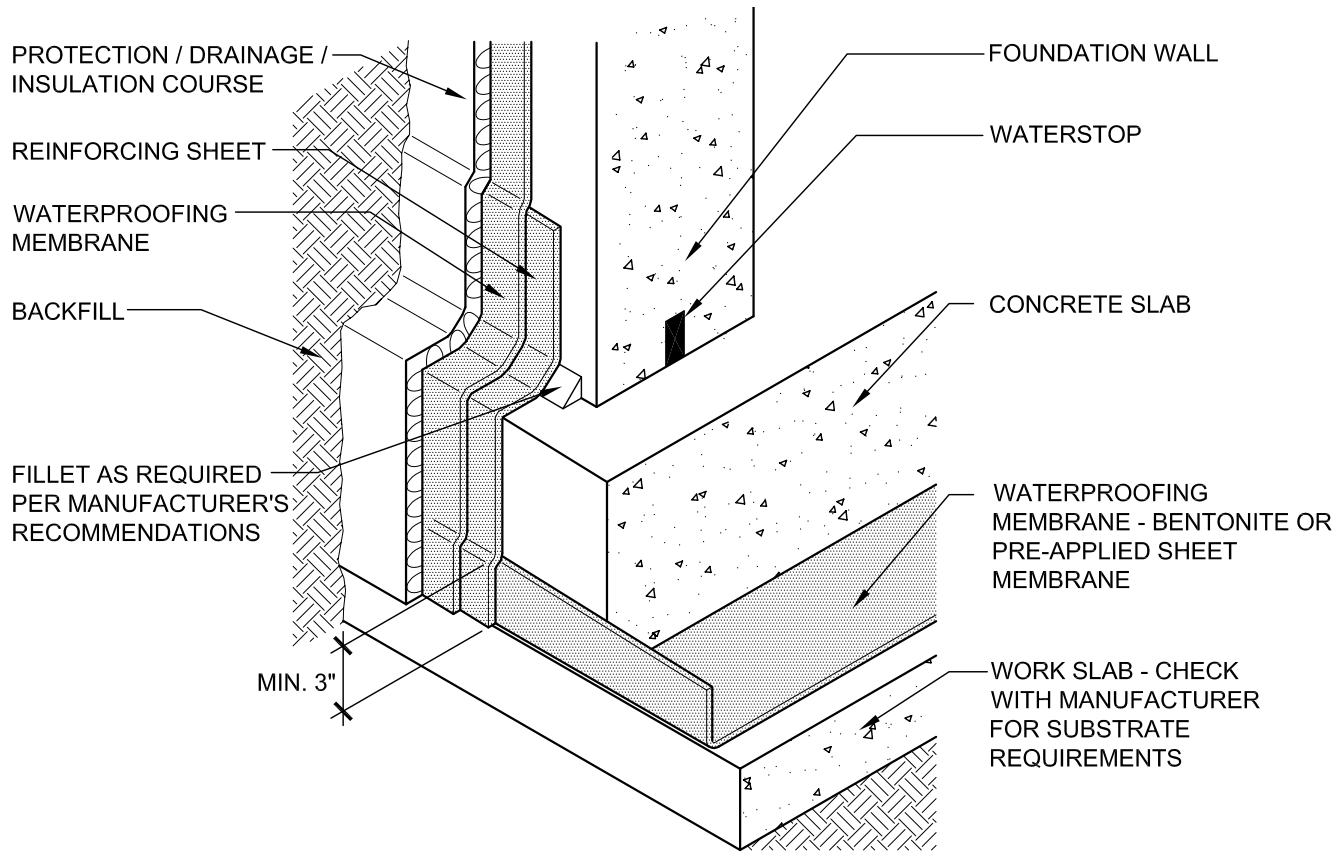
	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>FOUNDATION WALL WITH DRAINAGE SYSTEM</b></p>	<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-1</b></p>
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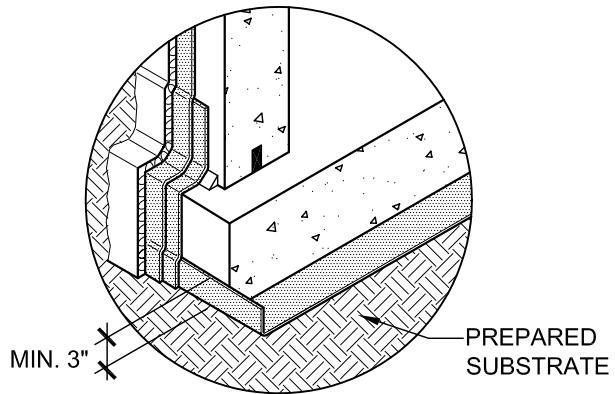
**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>FOUNDATION WALL WITH DRAINAGE SYSTEM</b></p>	<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-1S</b></p>
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ALTERNATE SLAB EDGE FLASHING



ALTERNATE SUBSTRATE

**NOTES:**

1. DRAINAGE SYSTEM NOT SHOWN.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

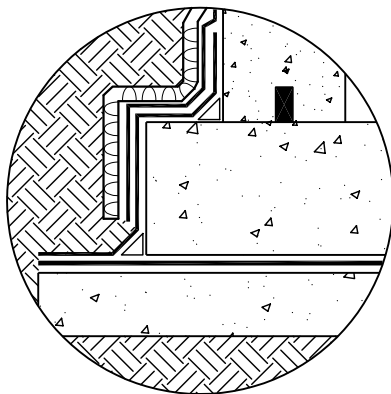
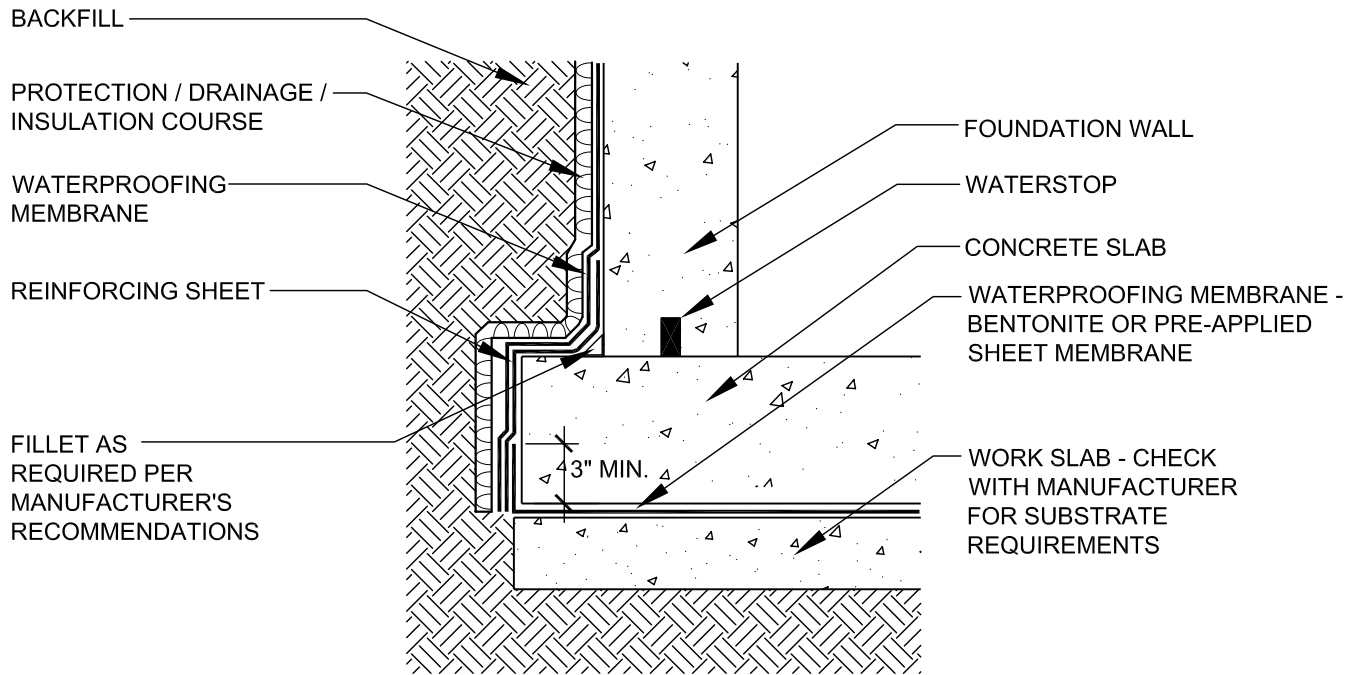


**FOUNDATION WALL AND SLAB BELOW GRADE**

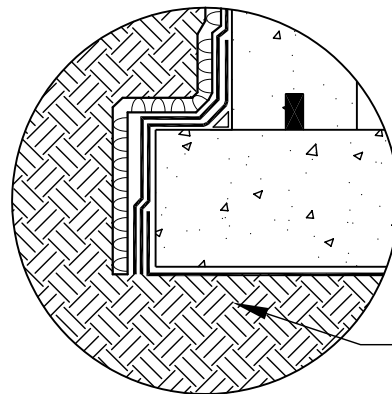
2005

NOT DRAWN TO SCALE

**WP-2**



ALTERNATE SLAB EDGE FLASHING




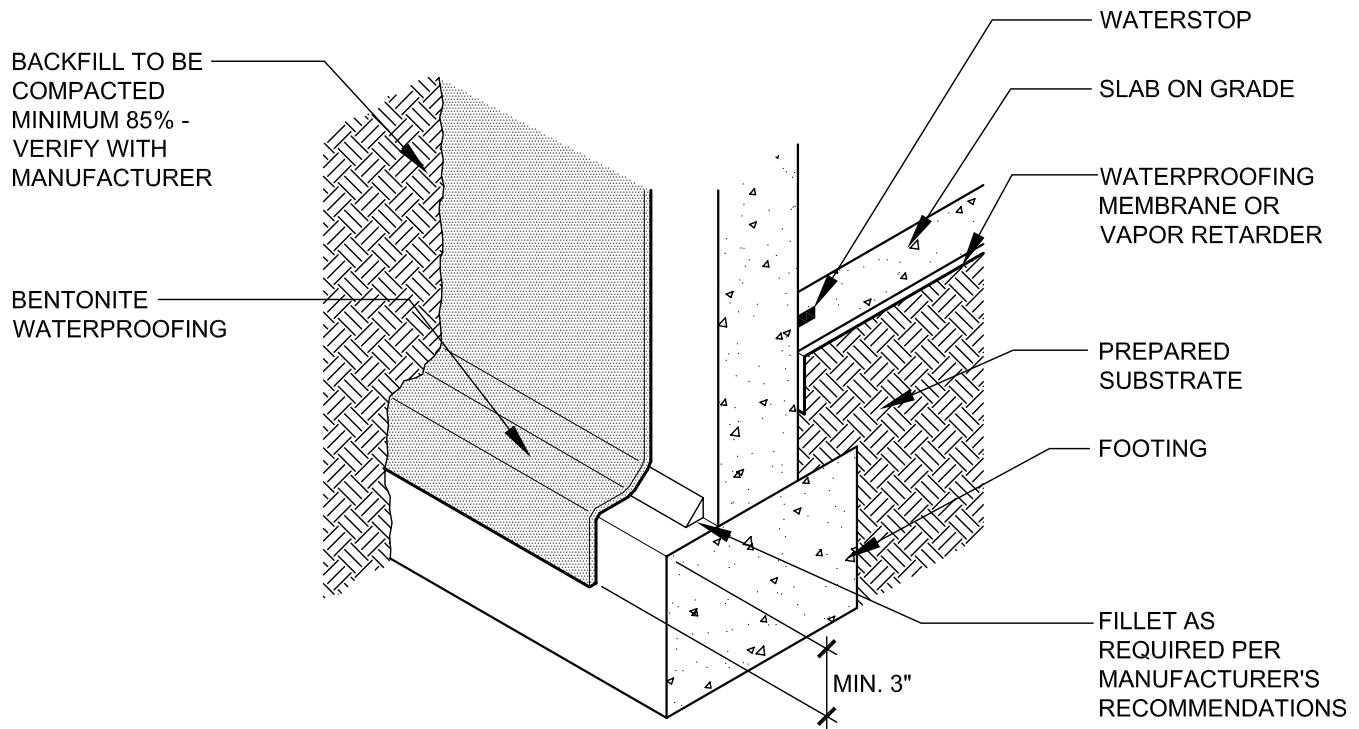
PREPARED SUBSTRATE

ALTERNATE SUBSTRATE

NOTES:

1. DRAINAGE SYSTEM NOT SHOWN.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>FOUNDATION WALL AND SLAB BELOW GRADE</b></p>
<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-2S</b></p>



**NOTES:**

1. DRAINAGE SYSTEM AND PROTECTION COURSE NOT SHOWN.
2. PROTECTION COURSE AS RECOMMENDED BY THE MANUFACTURER FOR BACKFILL PROTECTION.
3. DRAINAGE COURSE SHOULD NOT BE INSTALLED IN DIRECT CONTACT WITH BENTONITE WATERPROOFING.
4. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



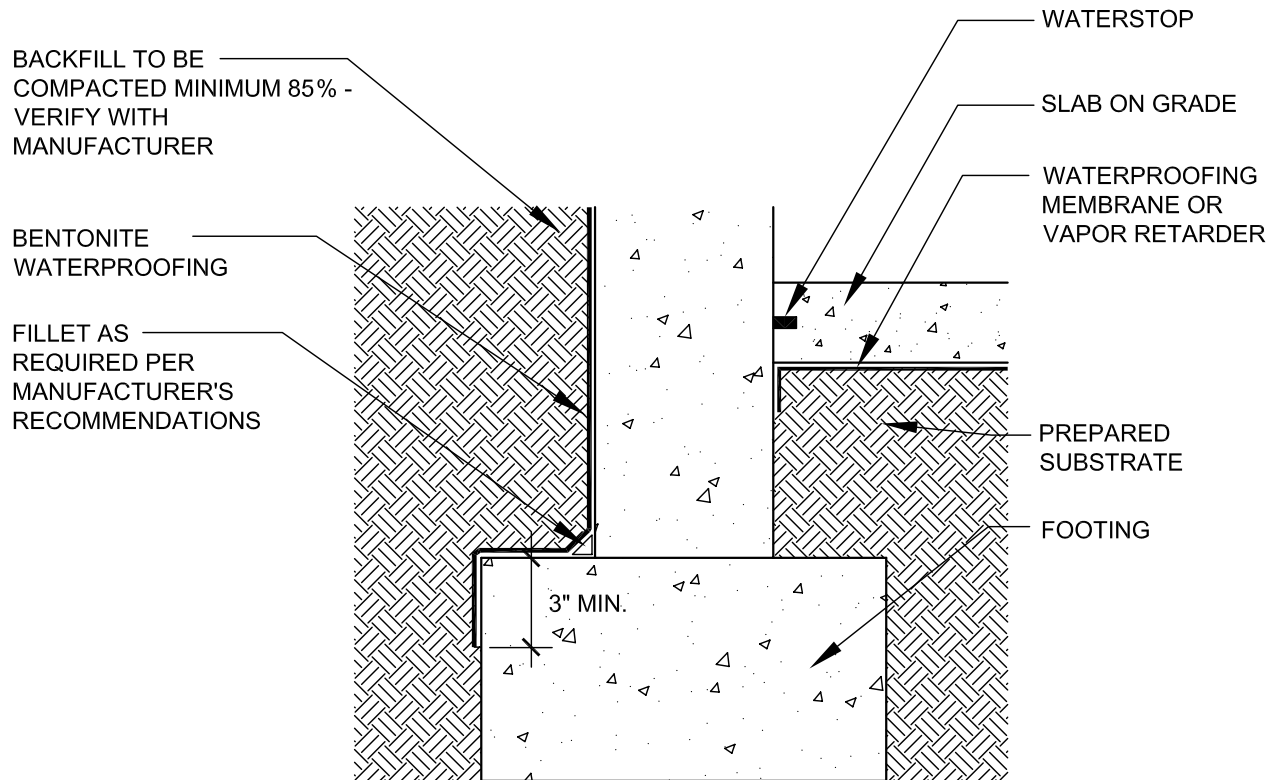
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**BENTONITE FOUNDATION WALL**

**2005**

*NOT DRAWN TO SCALE*

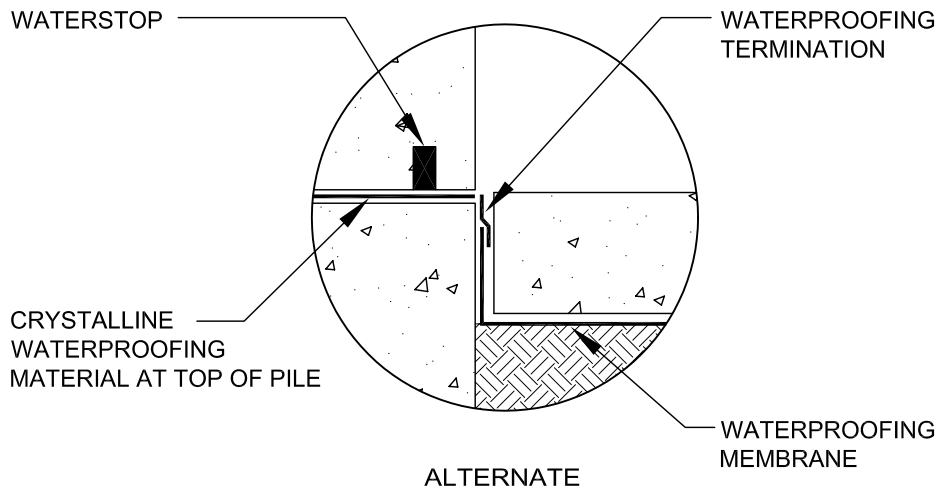
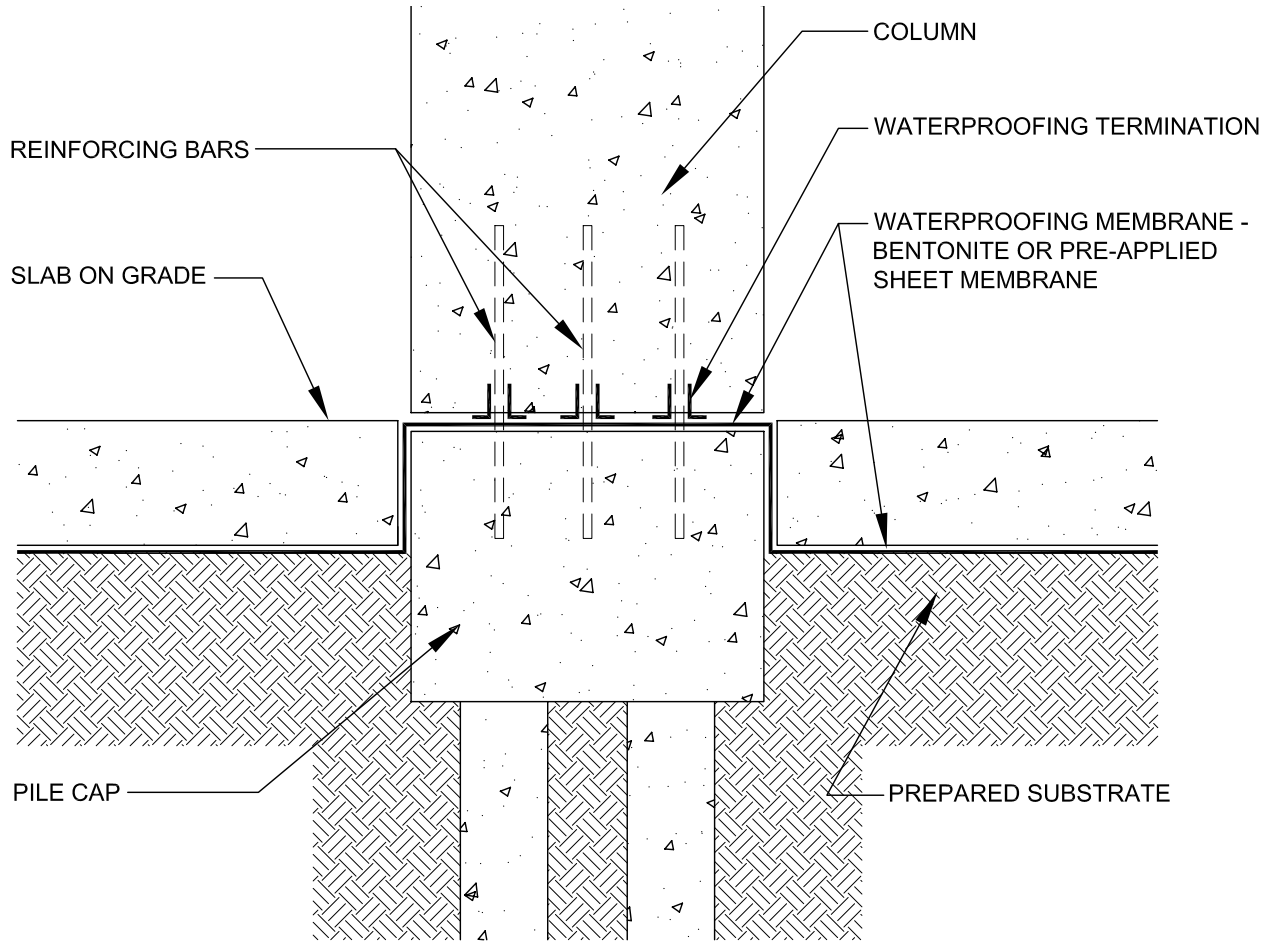
**WP-3**



**NOTES:**

1. DRAINAGE SYSTEM AND PROTECTION COURSE NOT SHOWN.
2. PROTECTION COURSE AS RECOMMENDED BY THE MANUFACTURER FOR BACKFILL PROTECTION.
3. DRAINAGE COURSE SHOULD NOT BE INSTALLED IN DIRECT CONTACT WITH BENTONITE WATERPROOFING.
4. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>BENTONITE FOUNDATION WALL</b></p>	<p><b>2005</b></p>
		<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-3S</b></p>



**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

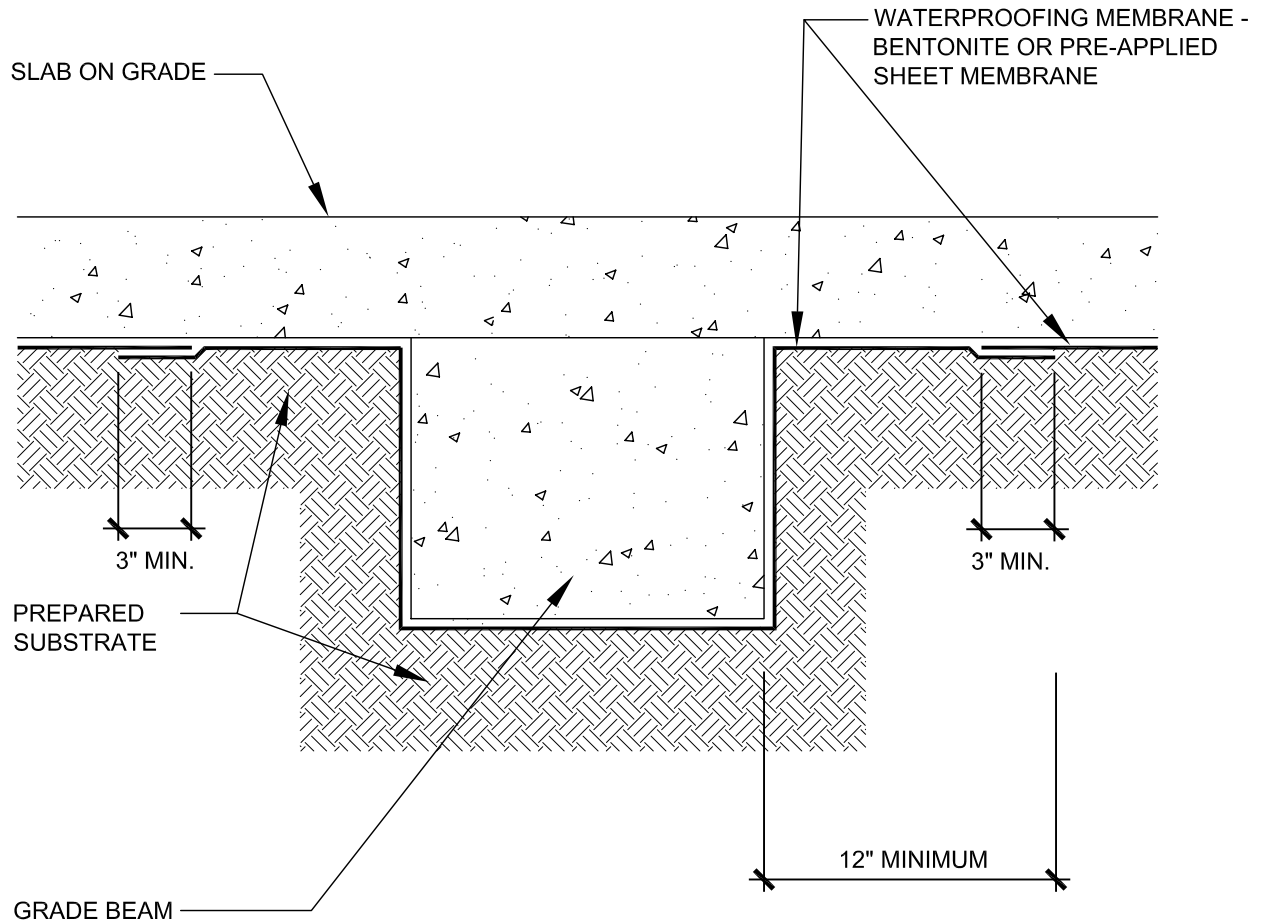


**PILE CAP WATERPROOFING**

2005

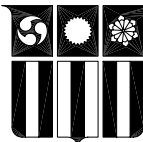
NOT DRAWN TO SCALE

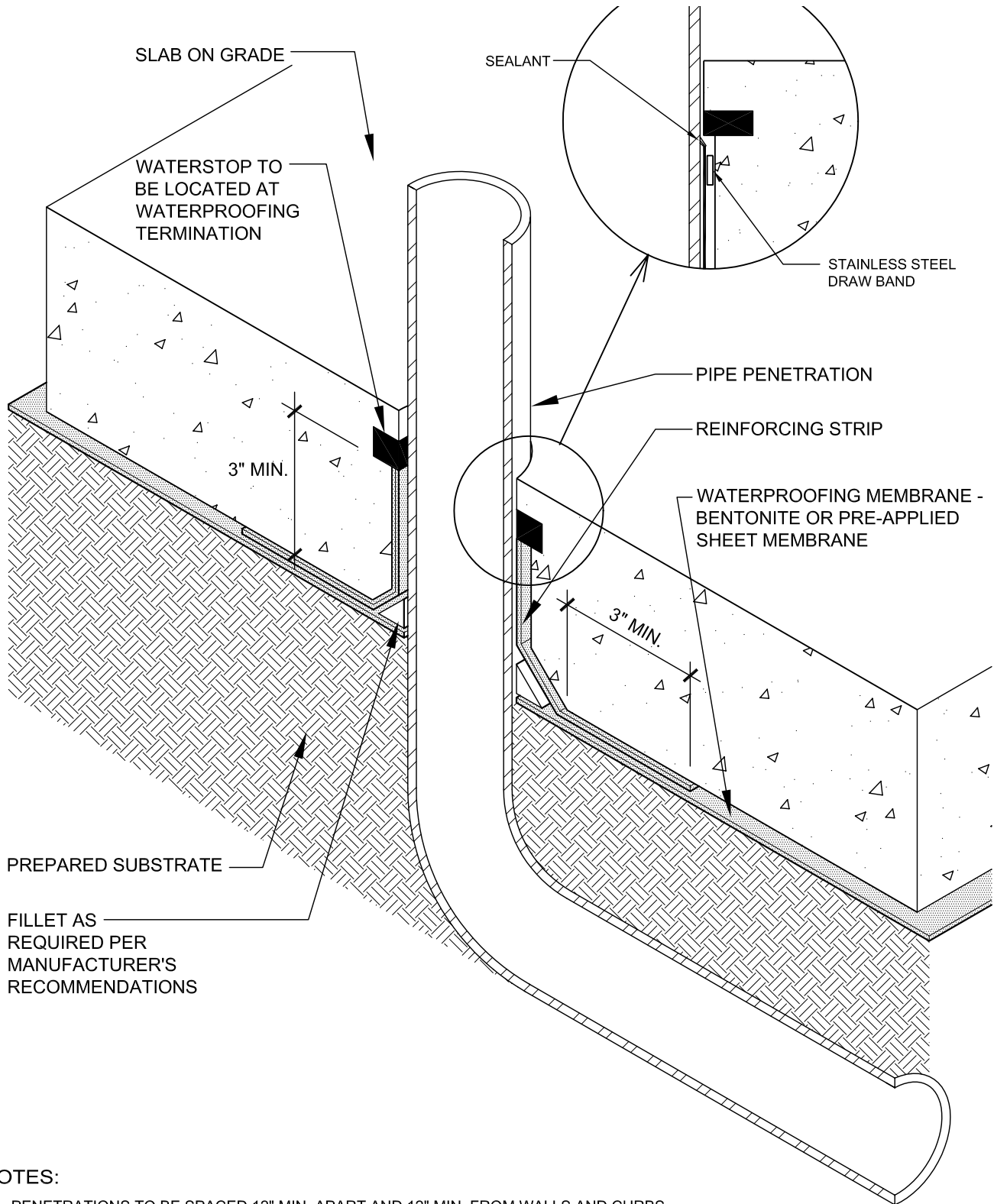
**WP-4**



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

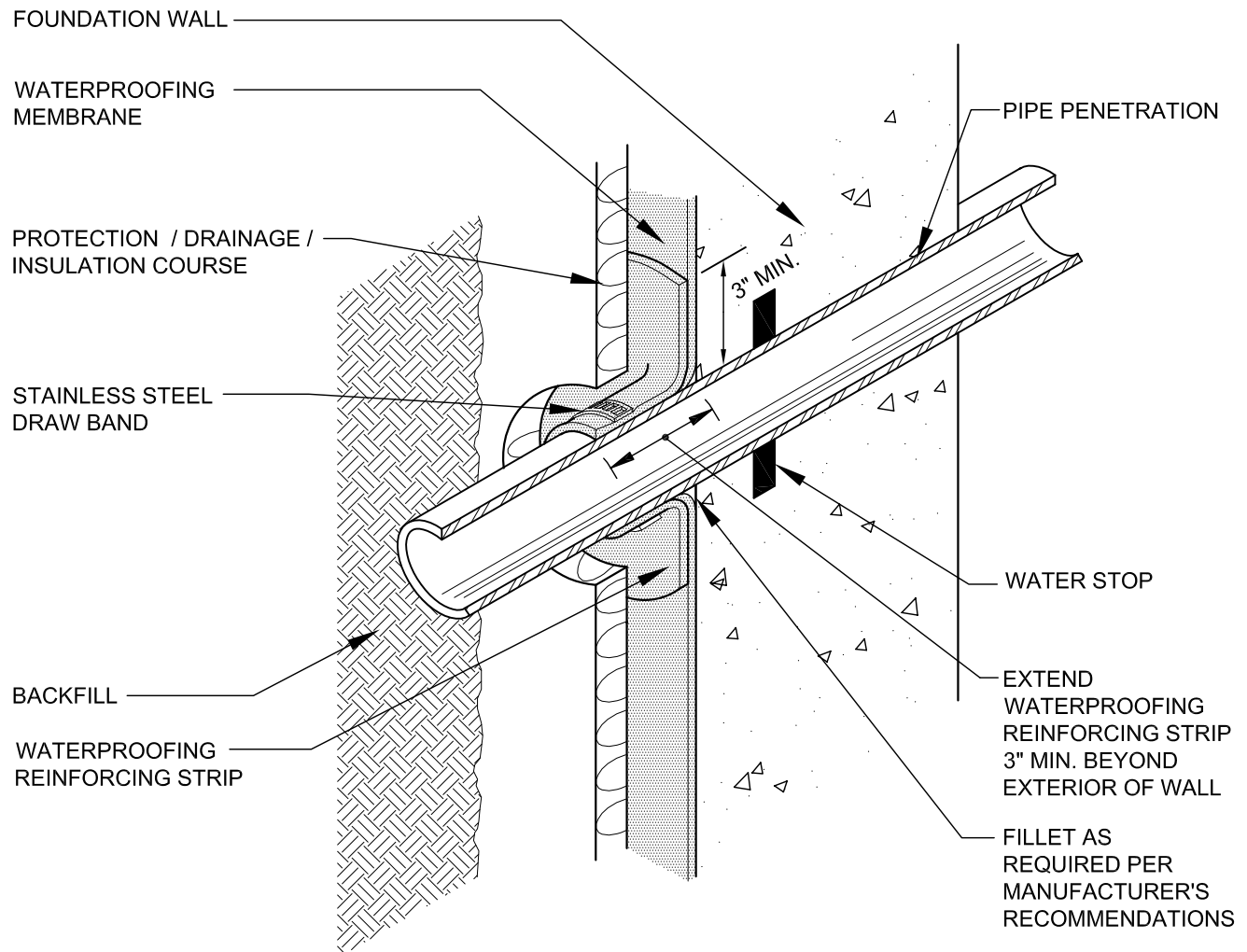
	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>FIELD GRADE BEAM WATERPROOFING</b>
2005	NOT DRAWN TO SCALE	<b>WP-5</b>



**NOTES:**

1. PENETRATIONS TO BE SPACED 12" MIN. APART AND 12" MIN. FROM WALLS AND CURBS.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

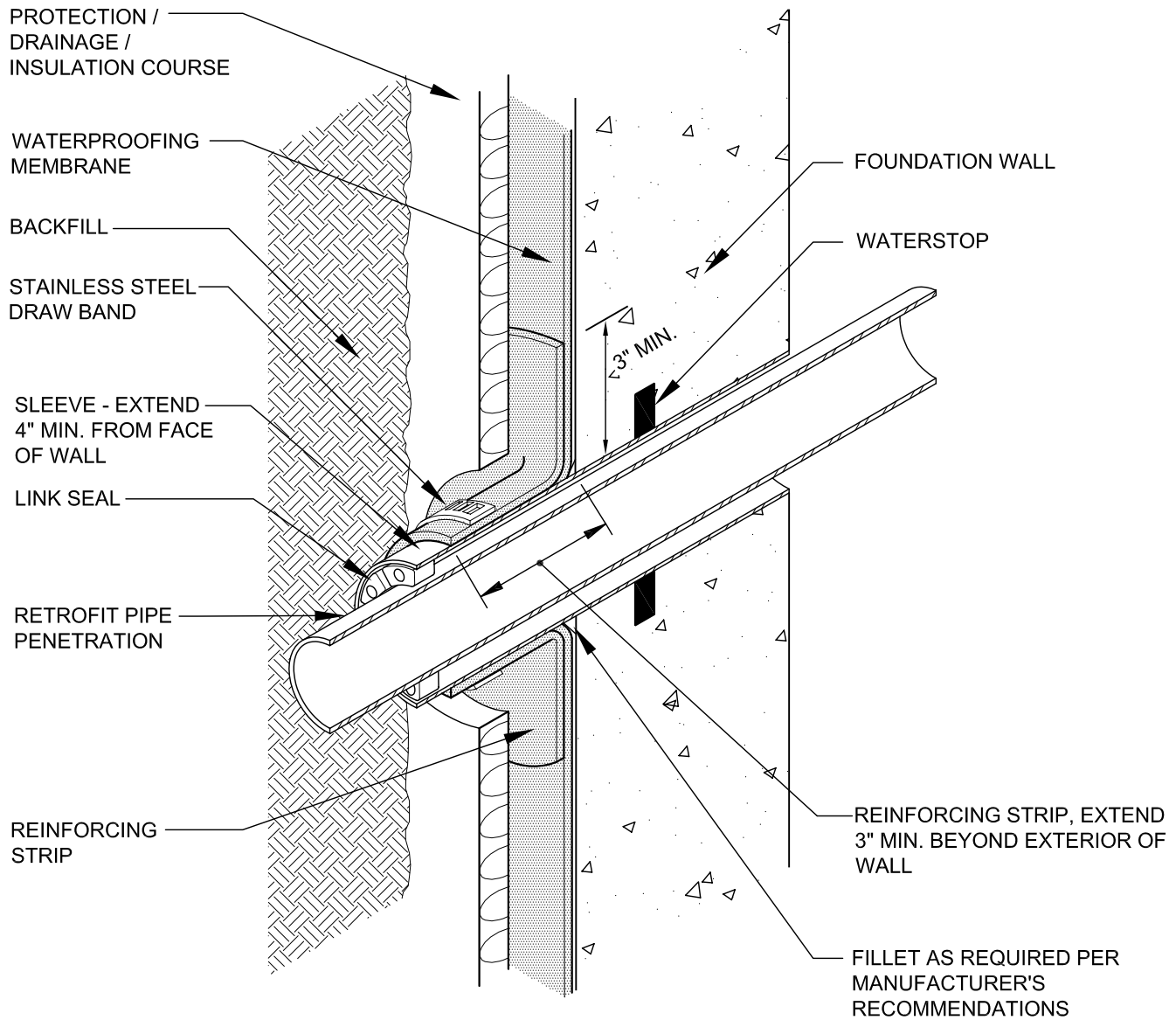
	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>VERTICAL PENETRATION FOR BELOW-GRADE WATERPROOFING MEMBRANE</b></p> <p>2005</p> <p style="font-size: small;">NOT DRAWN TO SCALE</p>	<p><b>WP-6</b></p>
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**NOTES:**


1. PENETRATIONS TO BE SPACED 12" MIN. APART AND 12" MIN. FROM WALLS AND CURBS.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

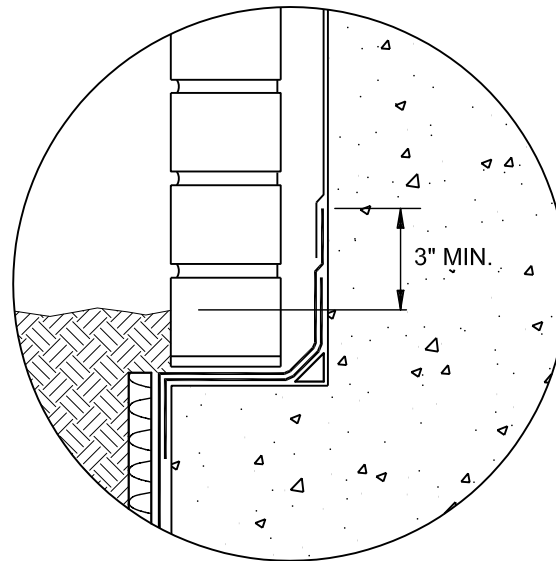
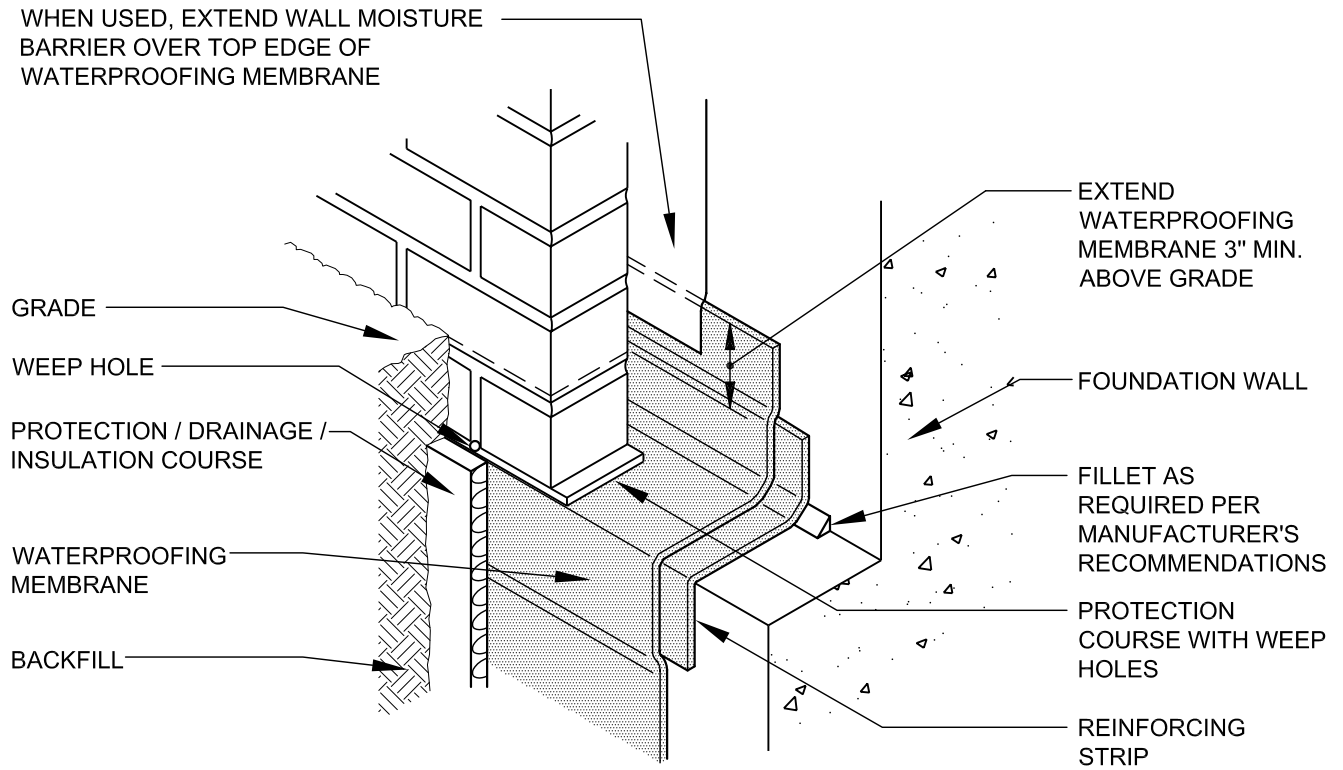
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>FOUNDATION WALL WITH POURED-IN-PLACE PIPE PENETRATION</b></p> <p>2005</p> <p style="font-size: small;">NOT DRAWN TO SCALE</p>	<p><b>WP-7</b></p>
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NOTES:

1. PENETRATIONS TO BE SPACED 12" MIN. APART AND 12" MIN. FROM WALLS AND CURBS.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PIPE SLEEVE PENETRATION DETAIL</b></p> <p>2005</p> <p>NOT DRAWN TO SCALE</p>	<p><b>WP-8</b></p>
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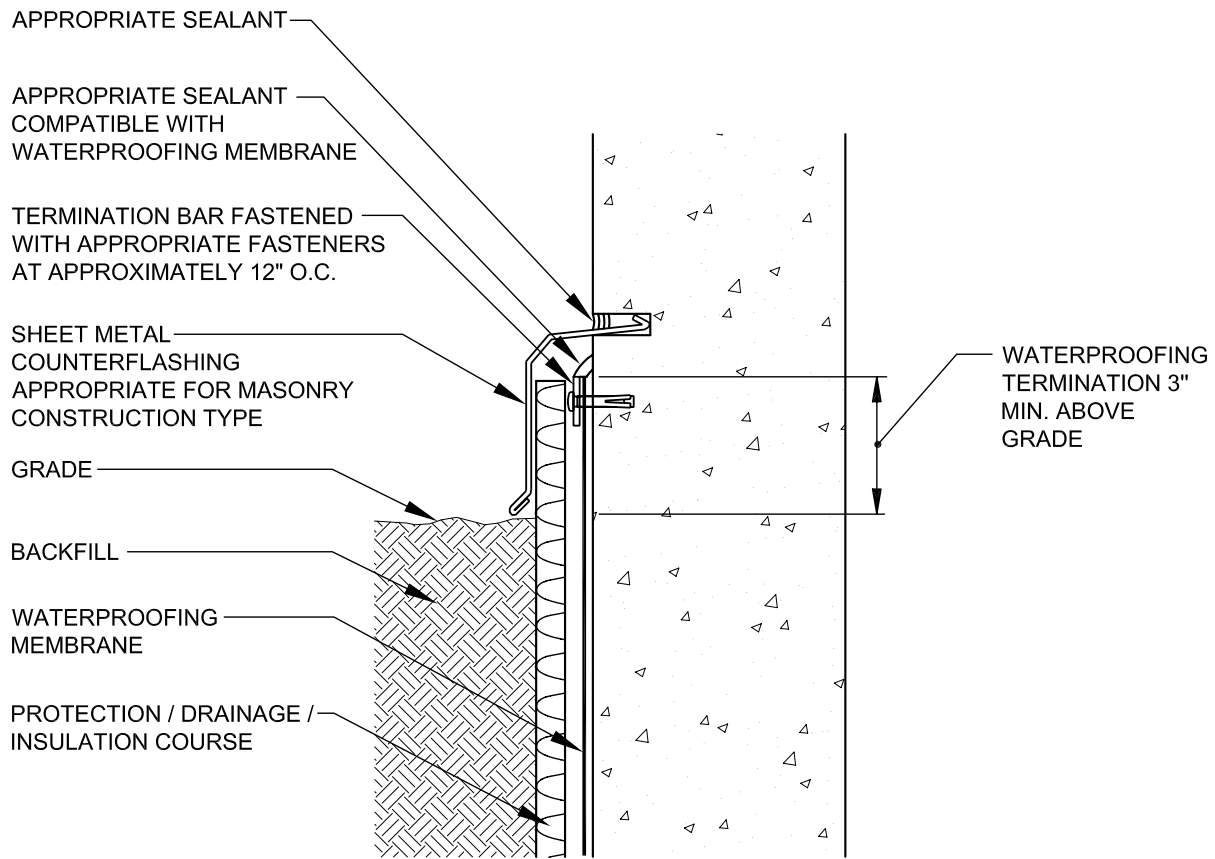
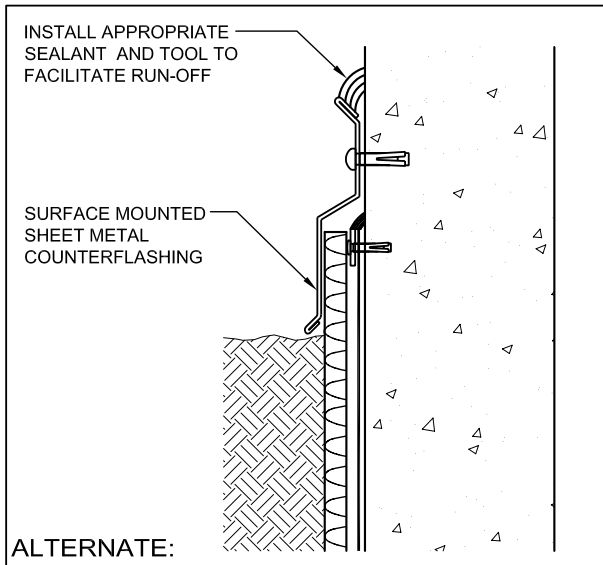


SECTION

NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>FOUNDATION WALL BRICK LEDGE TERMINATION</b></p>	<p><b>2005</b></p>	<p>NOT DRAWN TO SCALE</p>	<p><b>WP-9</b></p>
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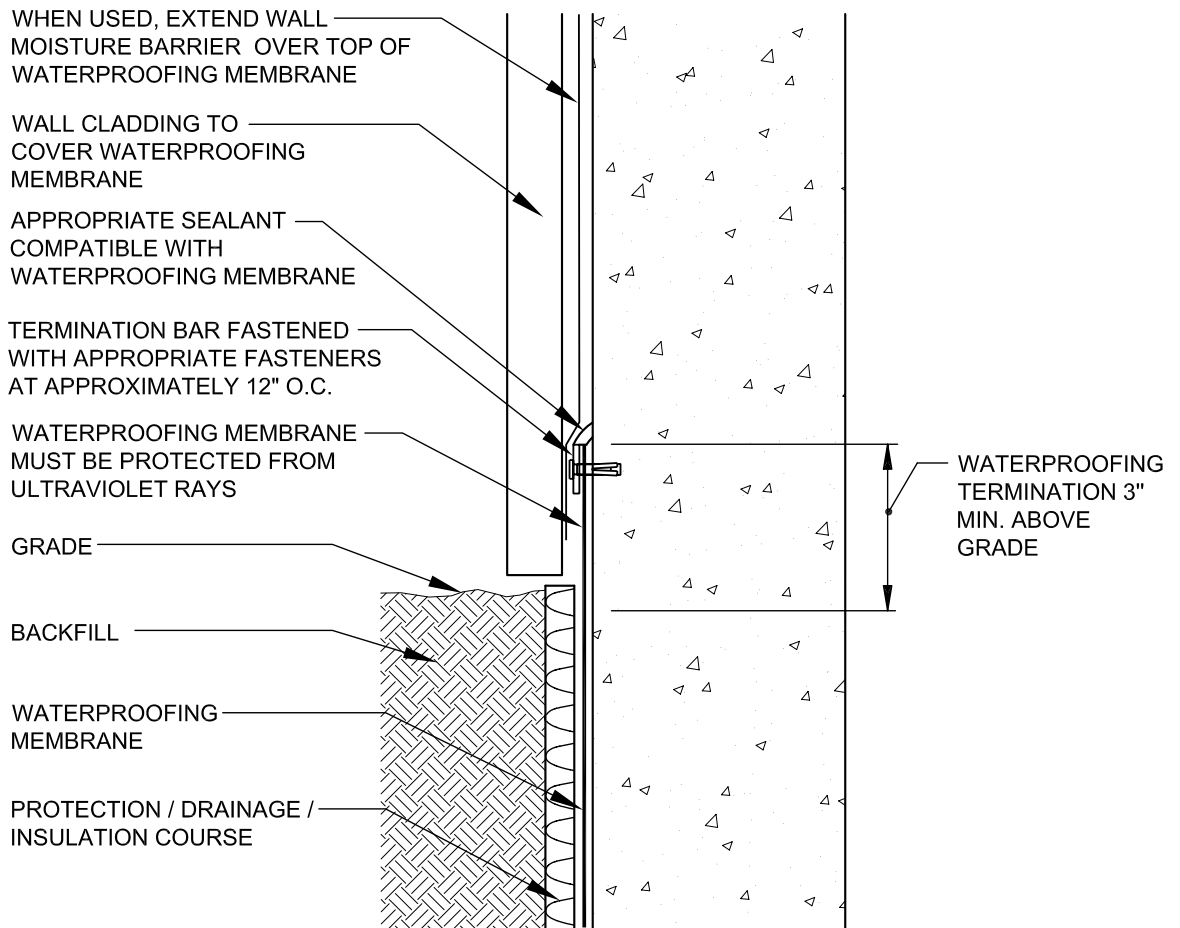
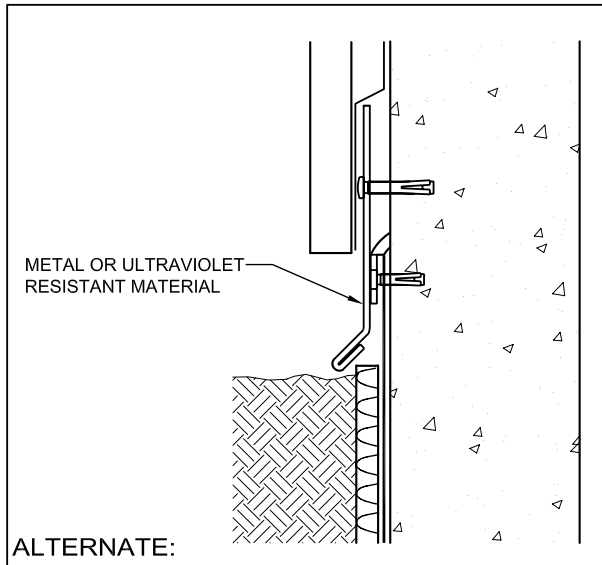


NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>WATERPROOFING MEMBRANE TERMINATION AT GRADE</b></p>
	<p><b>2005</b></p>

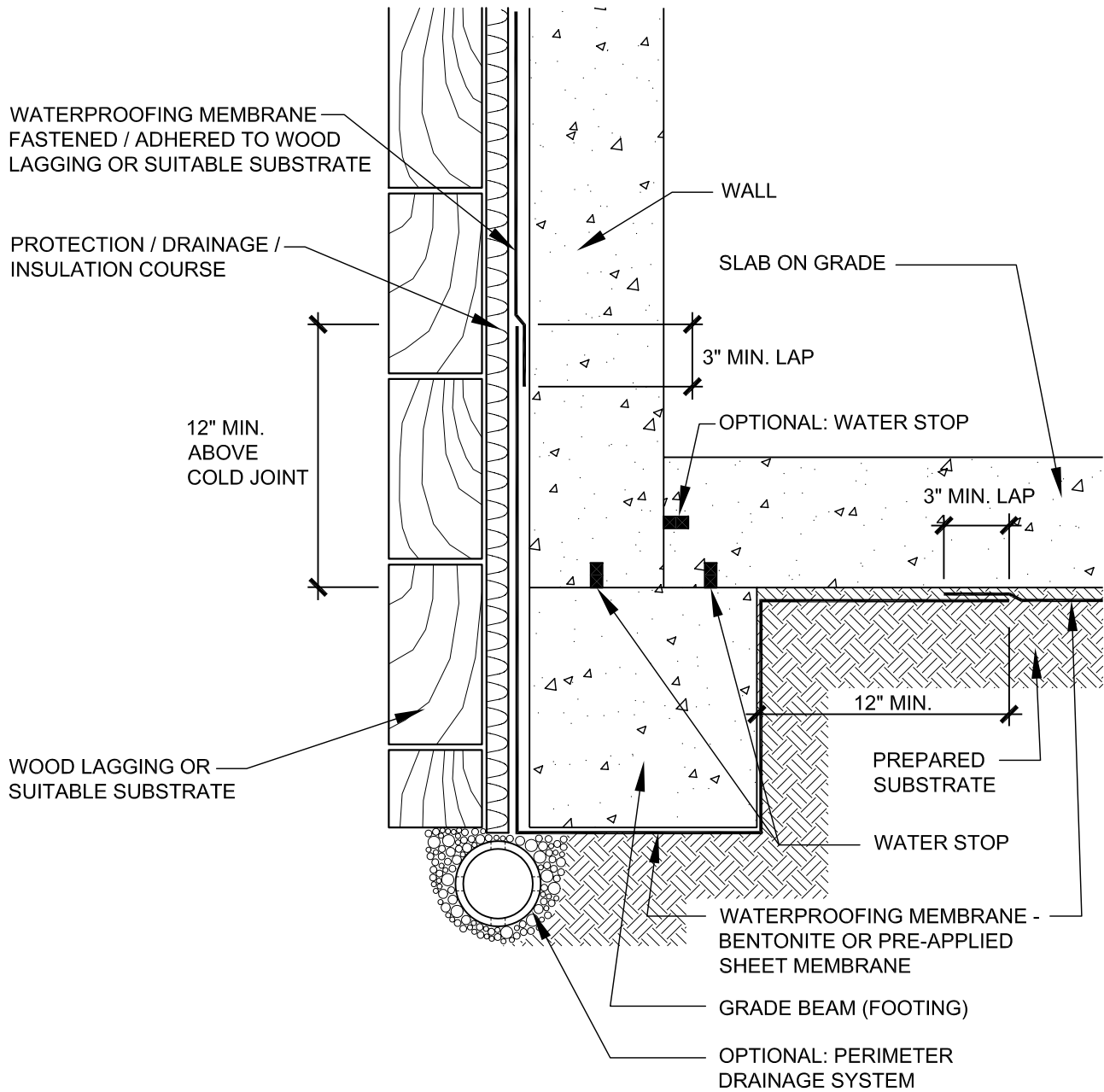
NOT DRAWN TO SCALE **WP-10**



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

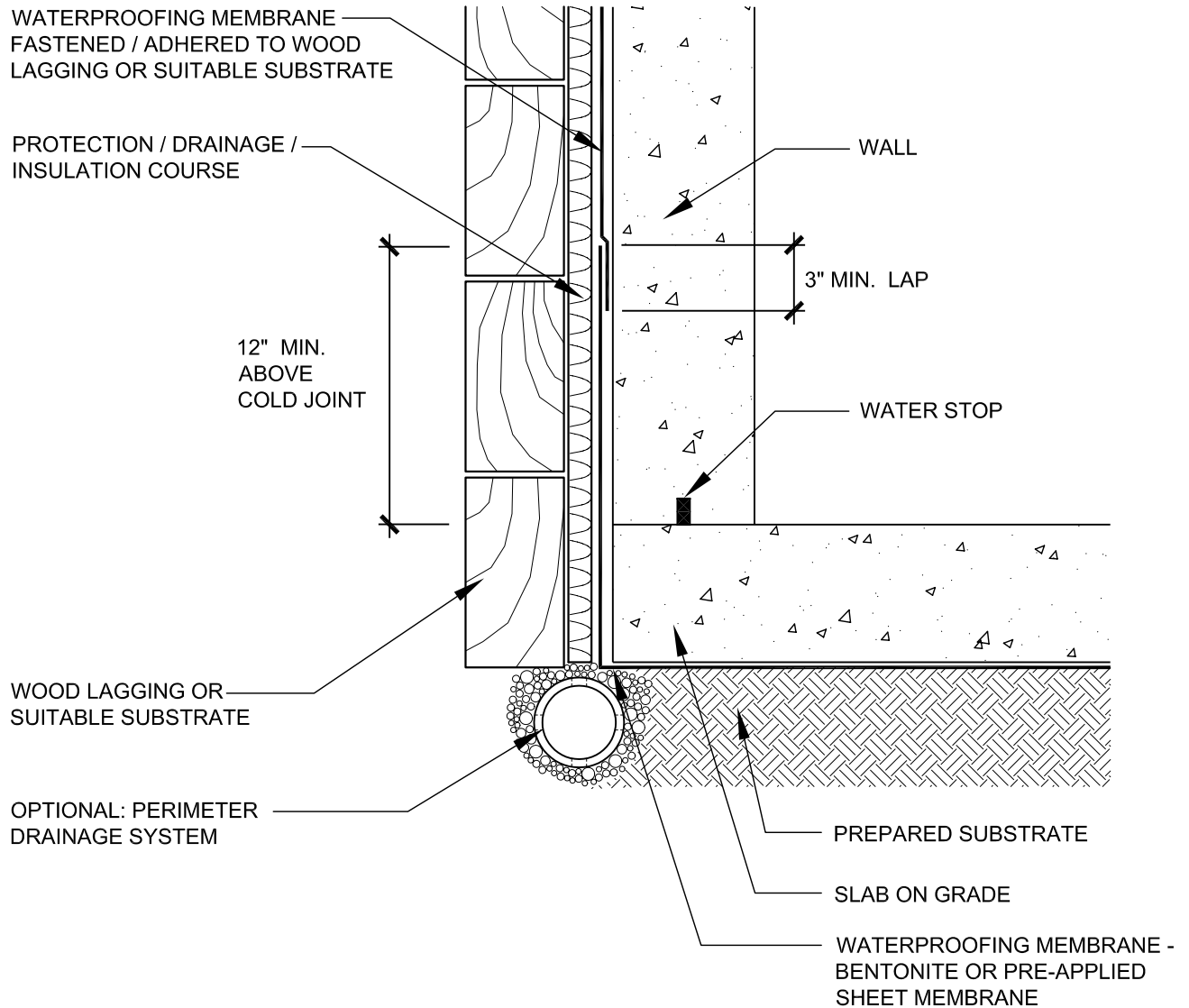
	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>FOUNDATION WALL/EXTERIOR WALL CLADDING TIE-IN</b>	<b>2005</b>	<i>NOT DRAWN TO SCALE</i>	<b>WP-11</b>



**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

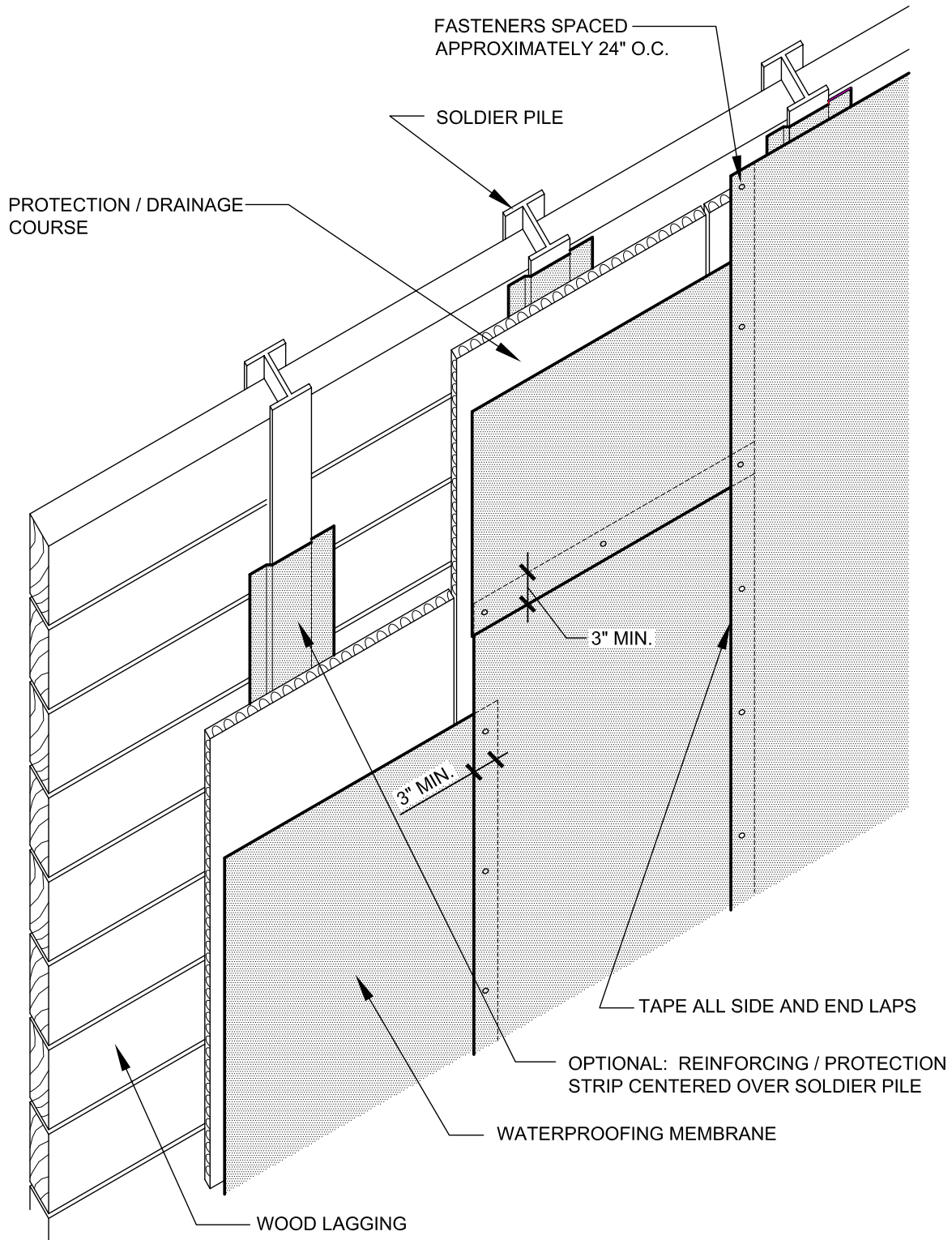
	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>BLIND SIDE WATERPROOFING AT GRADE BEAM</b></p>
<p><b>2005</b></p>	<p>NOT DRAWN TO SCALE</p>	<p><b>WP-12</b></p>



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>BLIND SIDE WATERPROOFING AT SLAB</b></p>	<p><b>2005</b></p>	<p>NOT DRAWN TO SCALE</p>	<p><b>WP-13</b></p>
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NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

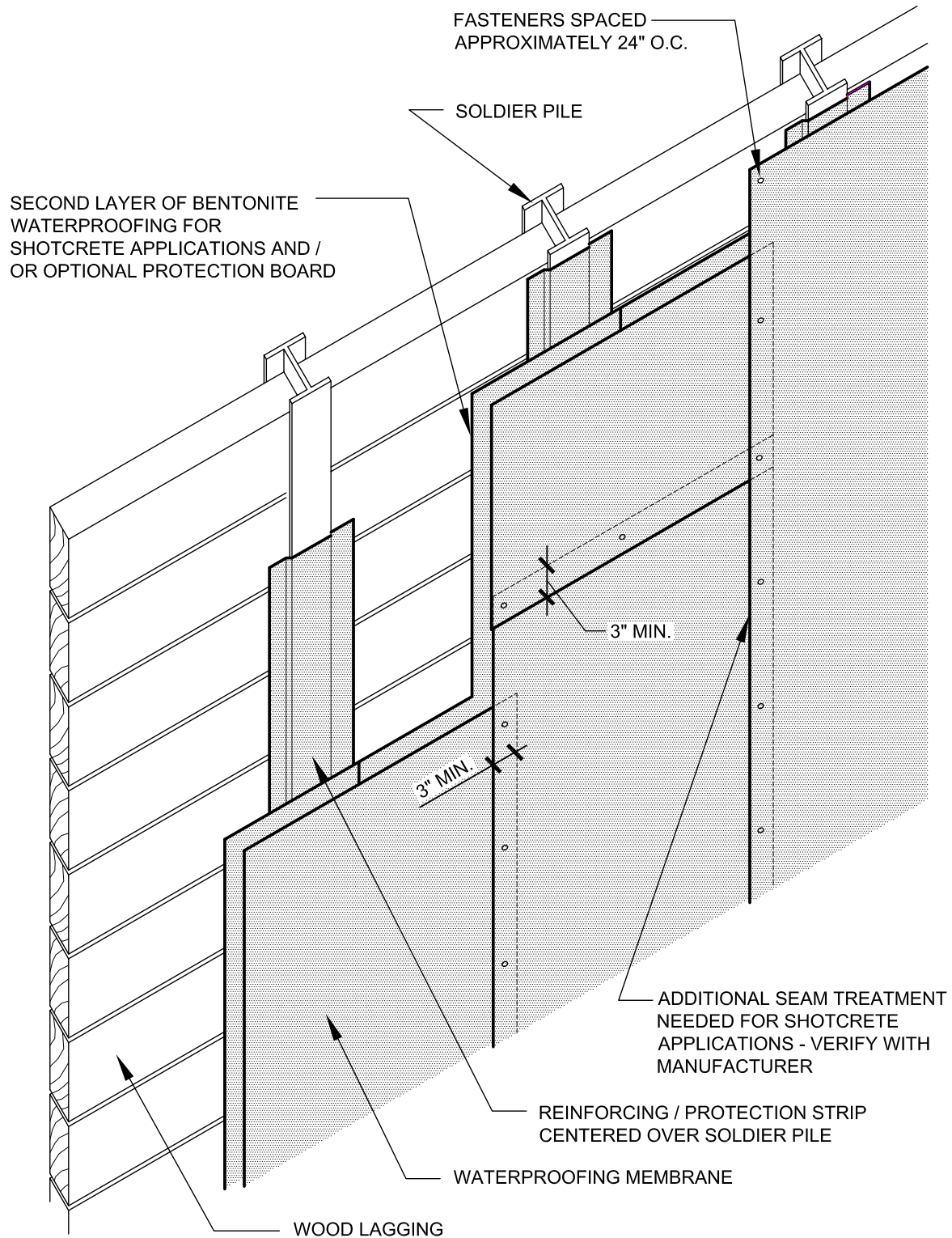


**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**BLIND SIDE WATERPROOFING AT  
WOOD LAGGING FOR PRE-APPLIED SHEET  
MEMBRANE  
2005**

NOT DRAWN TO SCALE

**WP-14**



NOTE:

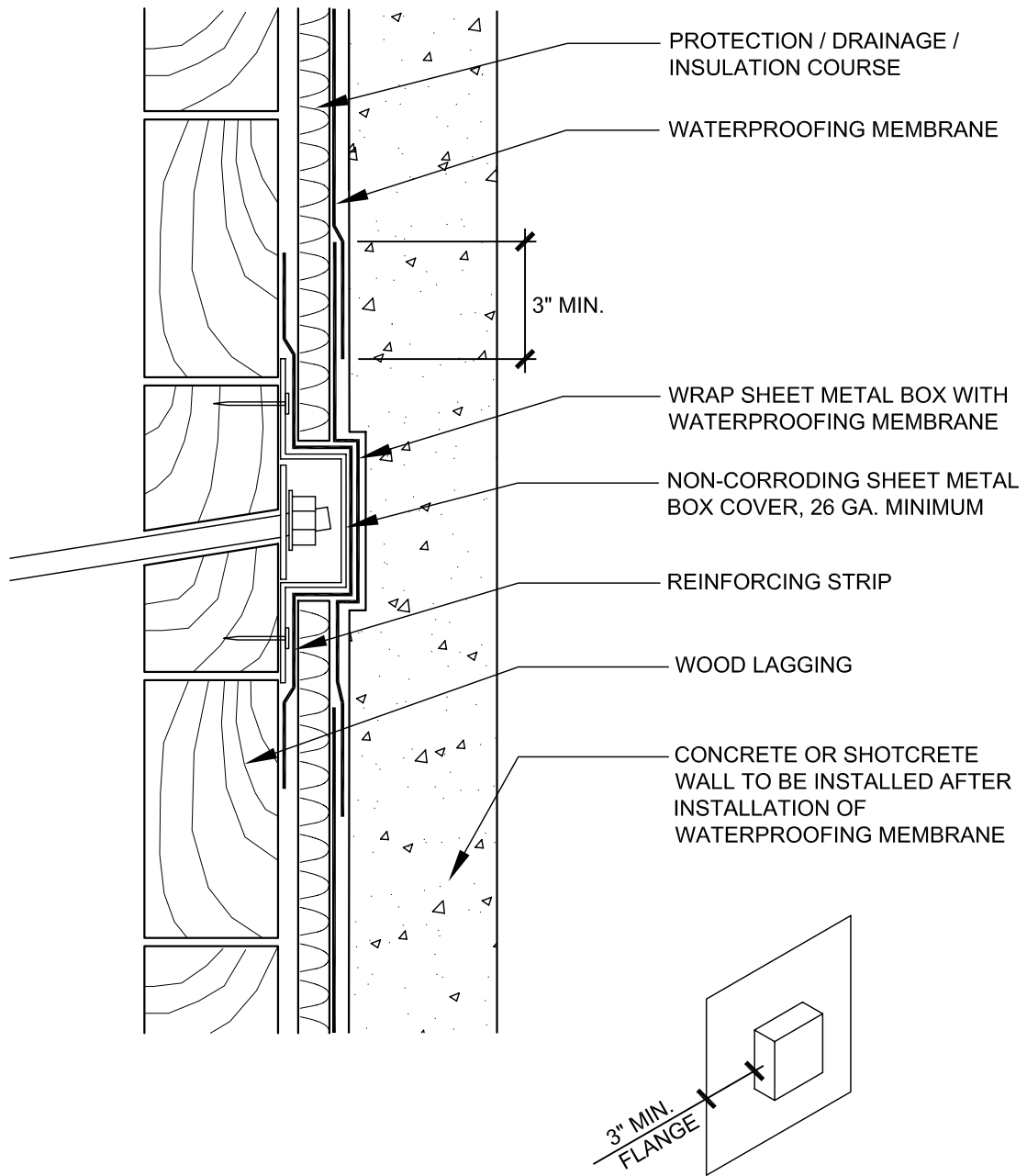
1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



**BLIND SIDE WATERPROOFING AT  
WOOD LAGGING FOR BENTONITE  
WATERPROOFING SYSTEMS**  
2005

NOT DRAWN TO SCALE

**WP-15**



NOTES:

1. INTERIOR OF BOX CAN BE FILLED WITH BENTONITE WATERPROOFING.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

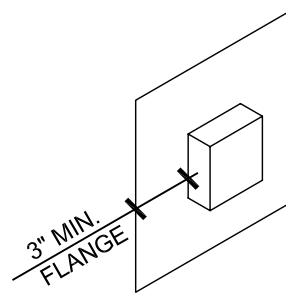
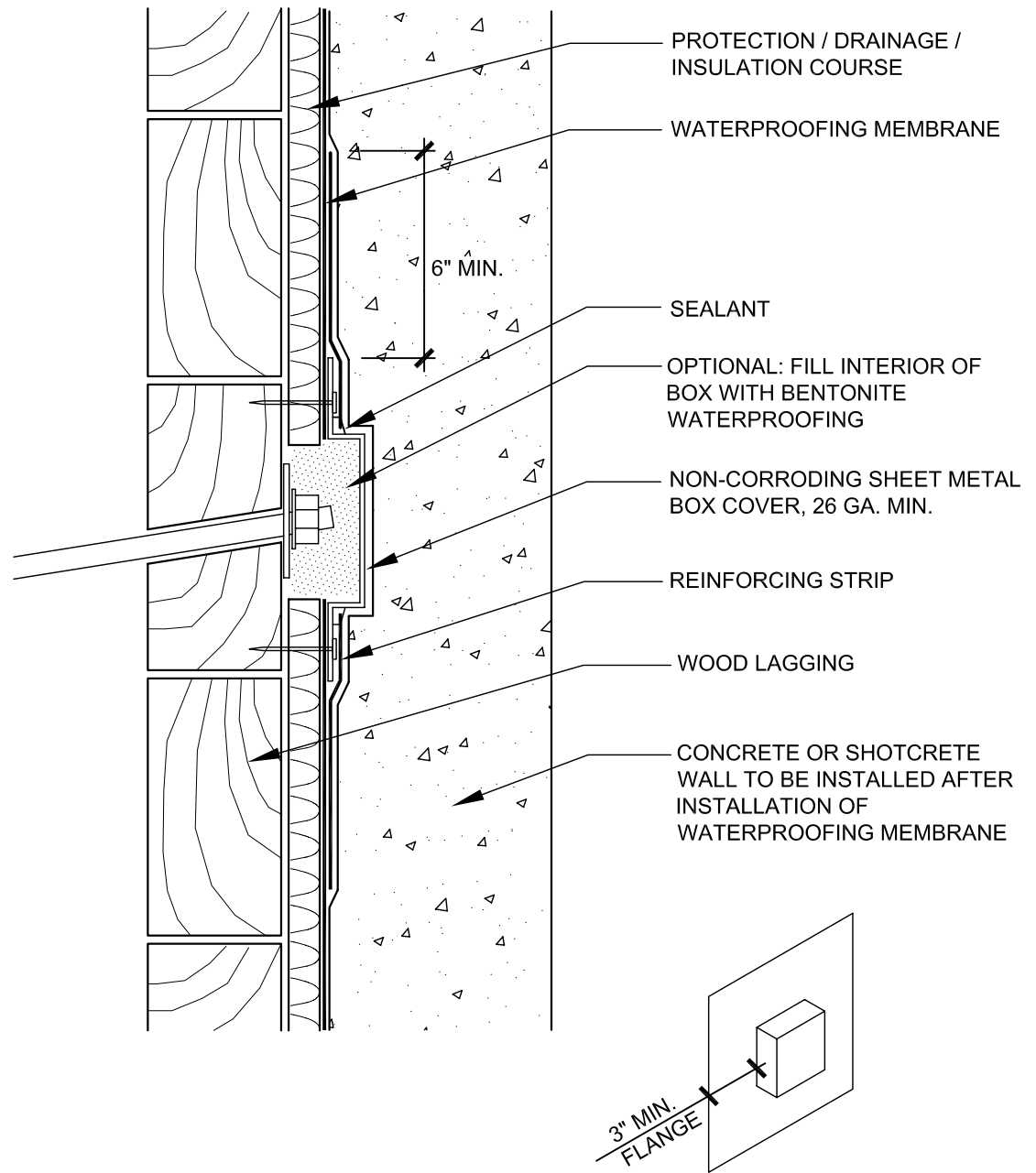


**BLIND SIDE WATERPROOFING AT TIE-BACK HEAD FOR PRE-APPLIED SHEET MEMBRANE**

2005

NOT DRAWN TO SCALE

WP-16

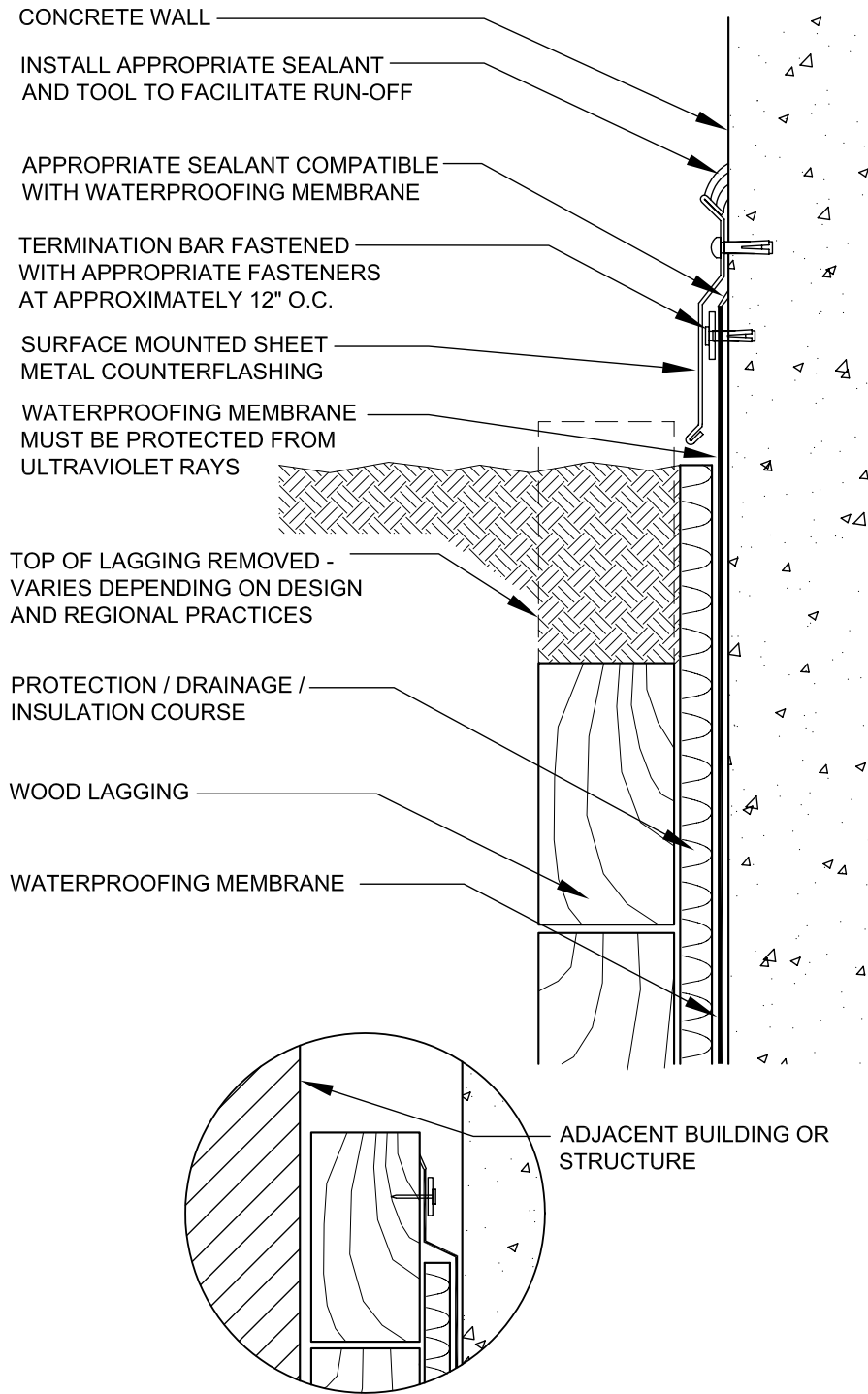


TIE-BACK COVER

NOTES:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

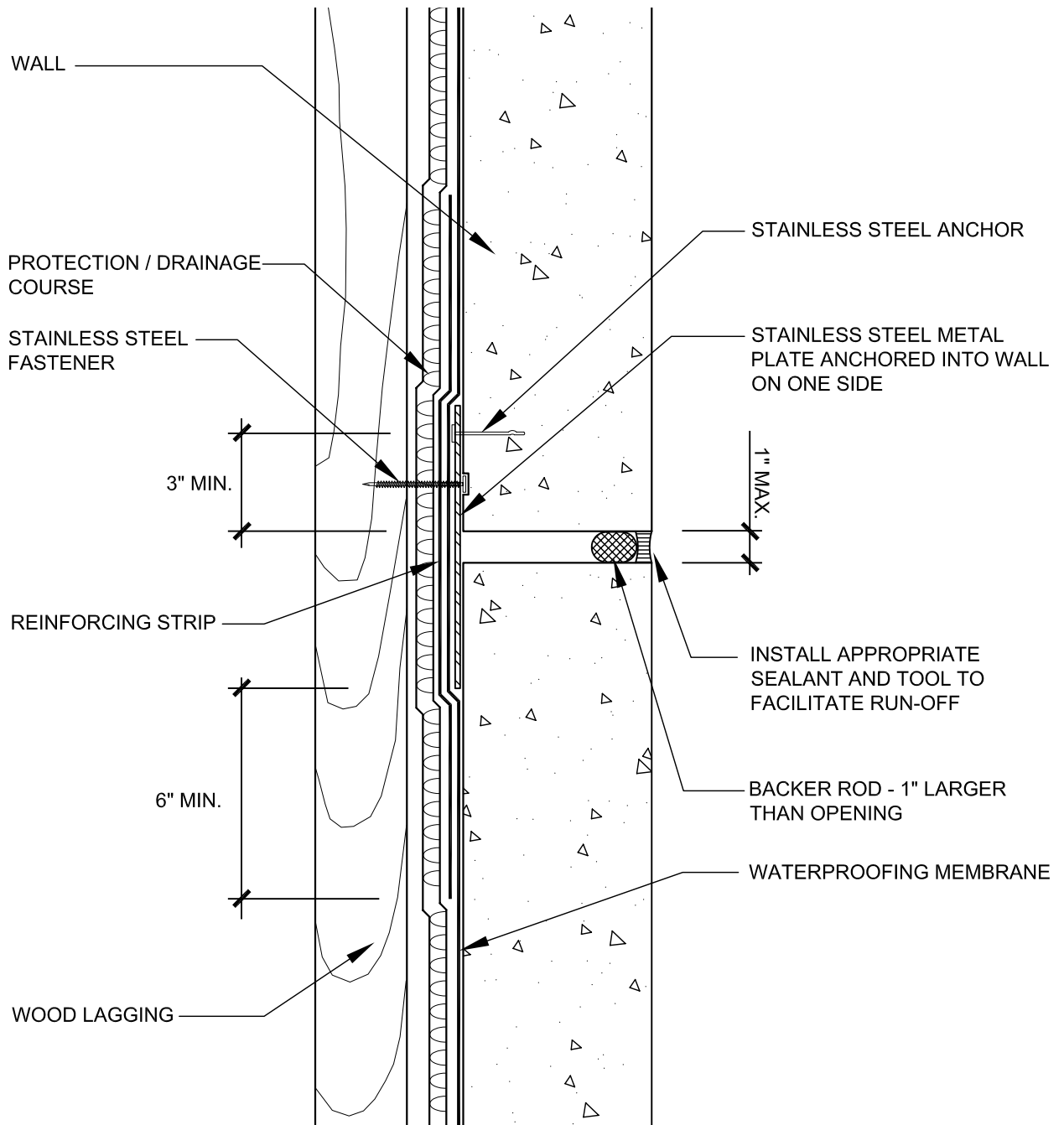
	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>BLIND SIDE WATERPROOFING AT TIE-BACK HEAD FOR BENTONITE WATERPROOFING SYSTEMS</b></p>	<p><b>2005</b></p>	<p>NOT DRAWN TO SCALE</p>	<p><b>WP-16A</b></p>
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NOTES:

1. INSTALL CEMENT BOARD IN LIEU OF PROTECTION / DRAINAGE COURSE WHERE SOLDIER BEAMS ARE TO BE REMOVED.
2. THIS DETAIL IS FOR USE WHEN THE TERMINATION IS ACCESSIBLE.
3. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

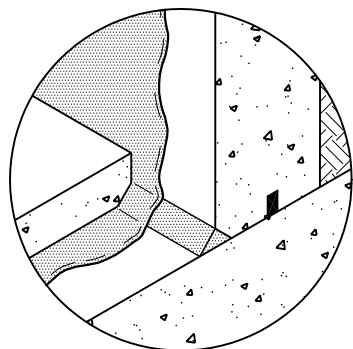
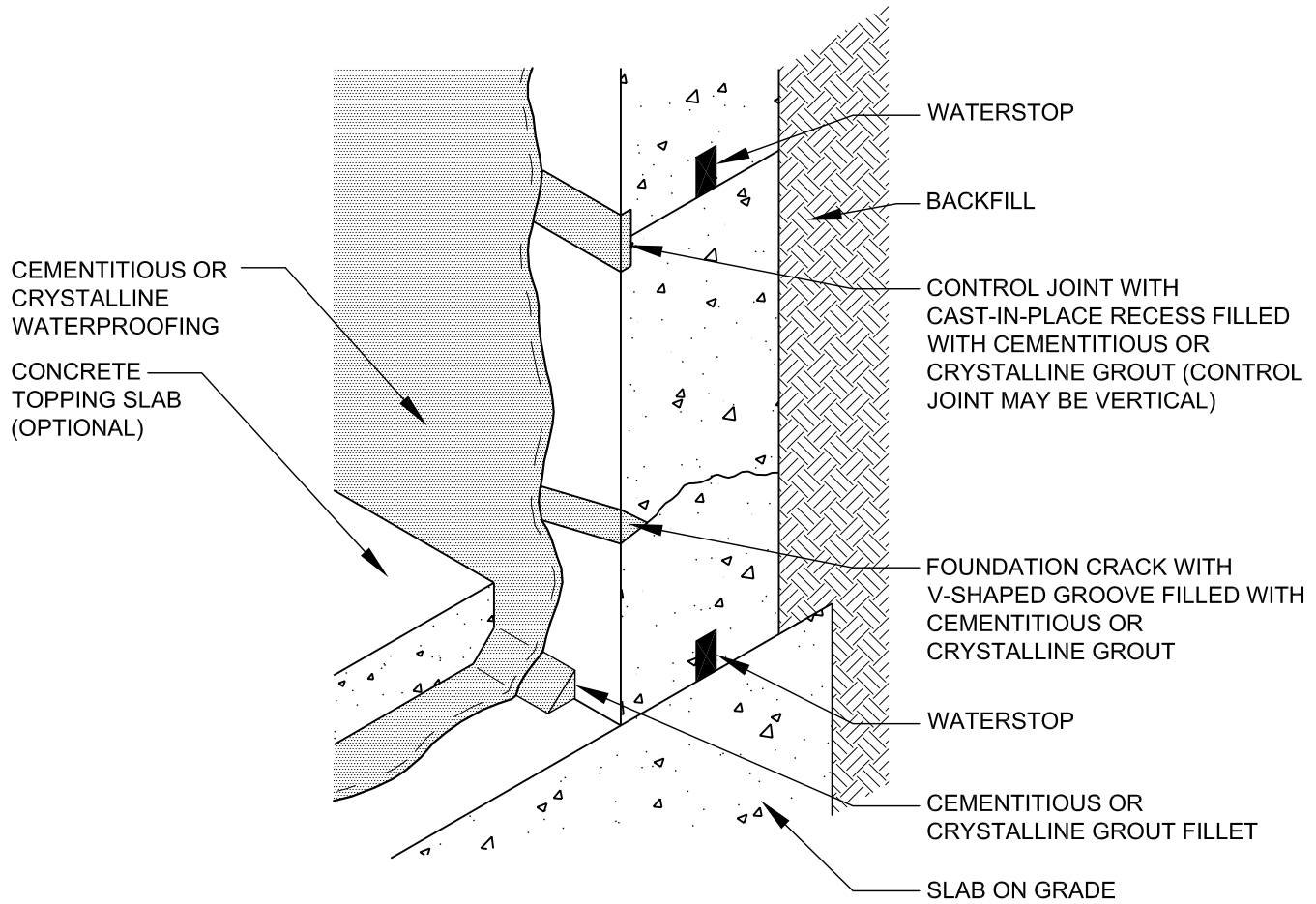
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>BLIND SIDE WATERPROOFING AT TOP TERMINATION</b></p> <p><b>2005</b></p> <p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-17</b></p>
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**NOTES:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.
2. THIS DETAIL IS SHOWN IN PLAN VIEW.

 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>VERTICAL EXPANSION JOINT (PLAN VIEW)</b></p> <p>2005</p> <p style="font-size: small;">NOT DRAWN TO SCALE</p>	<p><b>WP-18</b></p>
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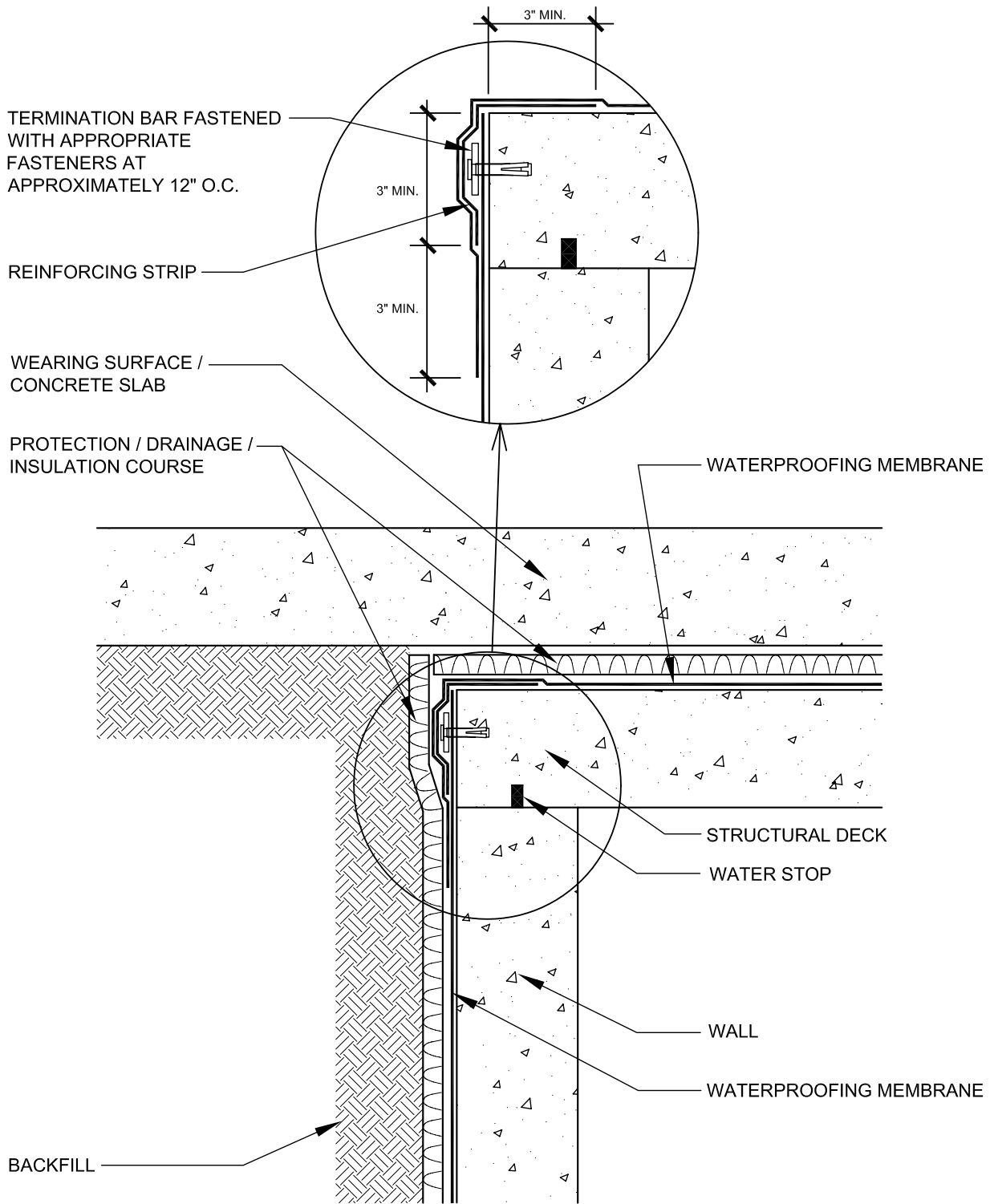


ALTERNATE CORNER DETAIL FOR CRYSTALLINE WATERPROOFING

NOTES:


1. FOR AREAS SUBJECT TO FOOT TRAFFIC, A TOPPING SLAB IS REQUIRED.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

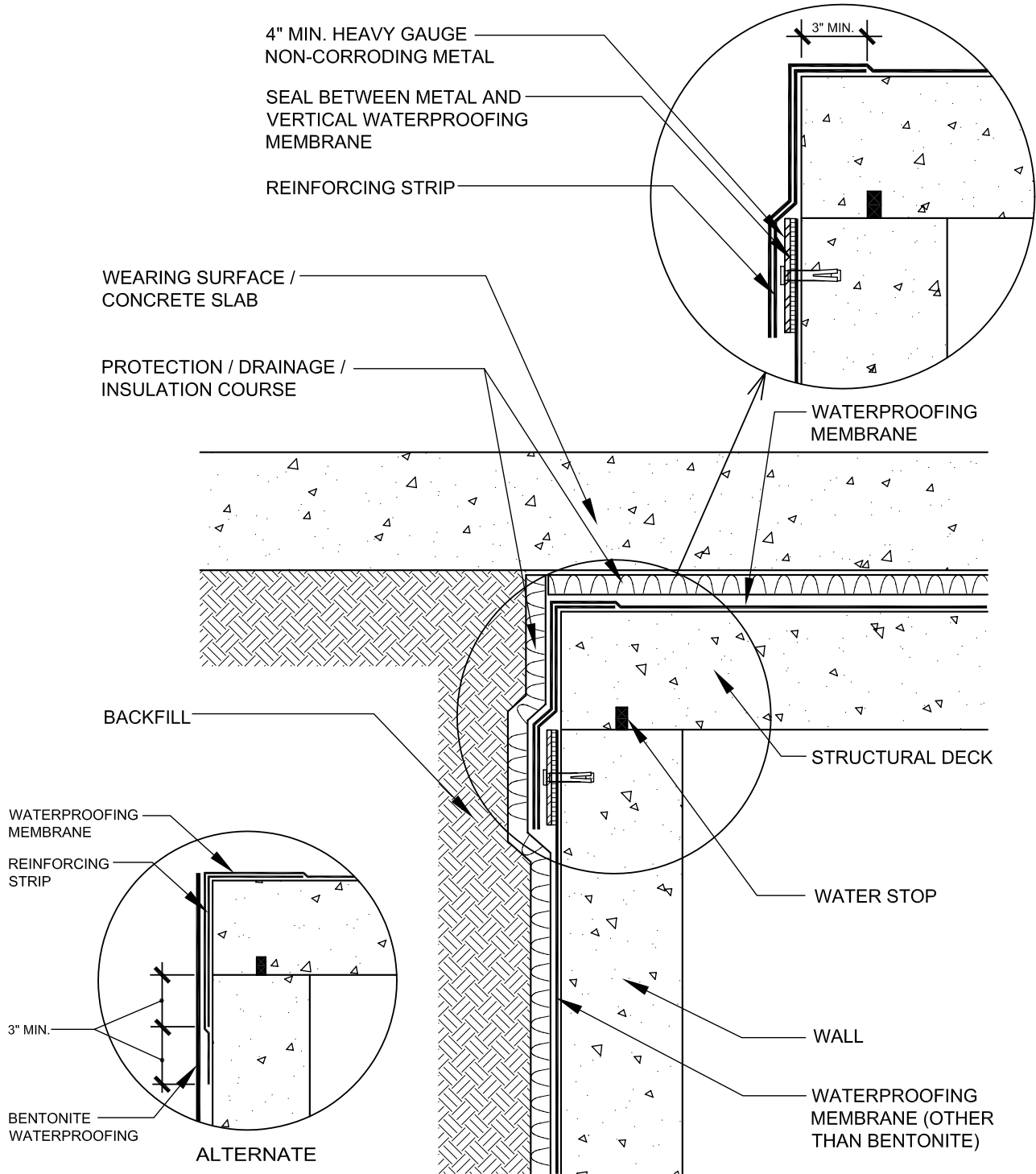
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>NEGATIVE SIDE WATERPROOFING FOR CEMENTITIOUS AND CRYSTALLINE WATERPROOFING</b></p> <p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p> <p><b>WP-19</b></p>
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**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

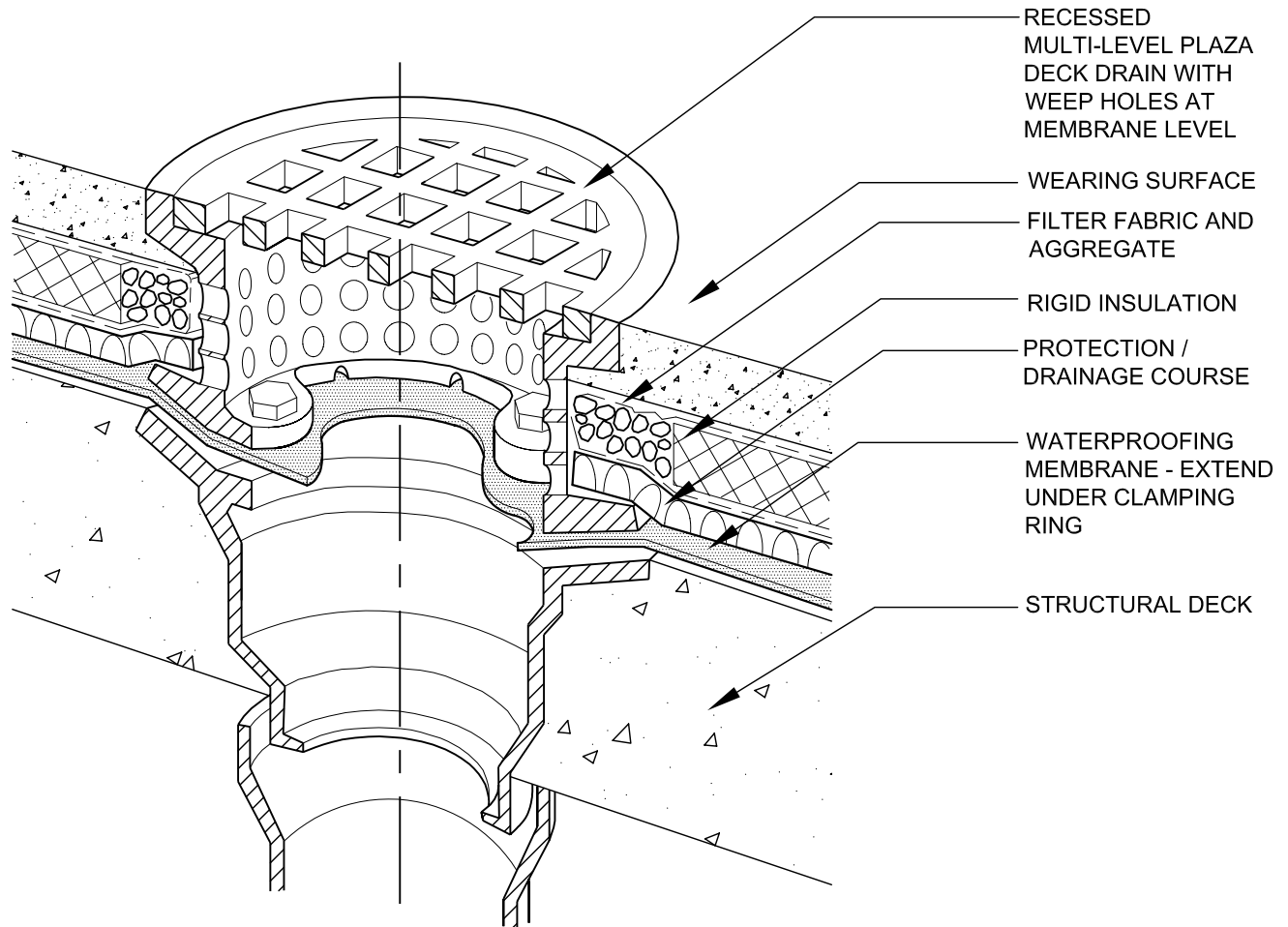
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PERIMETER EDGE DETAIL AT GRADE- COMPATIBLE WATERPROOFING MATERIALS</b></p>	<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-20</b></p>
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**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PERIMETER EDGE DETAIL AT GRADE- DISSIMILAR WATERPROOFING MATERIALS</b></p>	<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-21</b></p>
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**NOTES:**

1. WEARING SURFACE MAY BE CAST-IN-PLACE CONCRETE OR MORTAR-SET TOPPING MATERIAL.
2. RIGID INSULATION MUST BE MOISTURE RESISTANT AND HAVE HIGH COMPRESSIVE STRENGTH (25 PSI MIN.; CONSULT ENGINEER).
3. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



**PLAZA DECK DRAIN WITH WEARING SURFACE**

2005

NOT DRAWN TO SCALE

WP-22

PRECAST CONCRETE PAVERS  
OR STONE - MARK PAVER OVER  
DRAIN TO IDENTIFY LOCATION

PAVER PEDESTAL

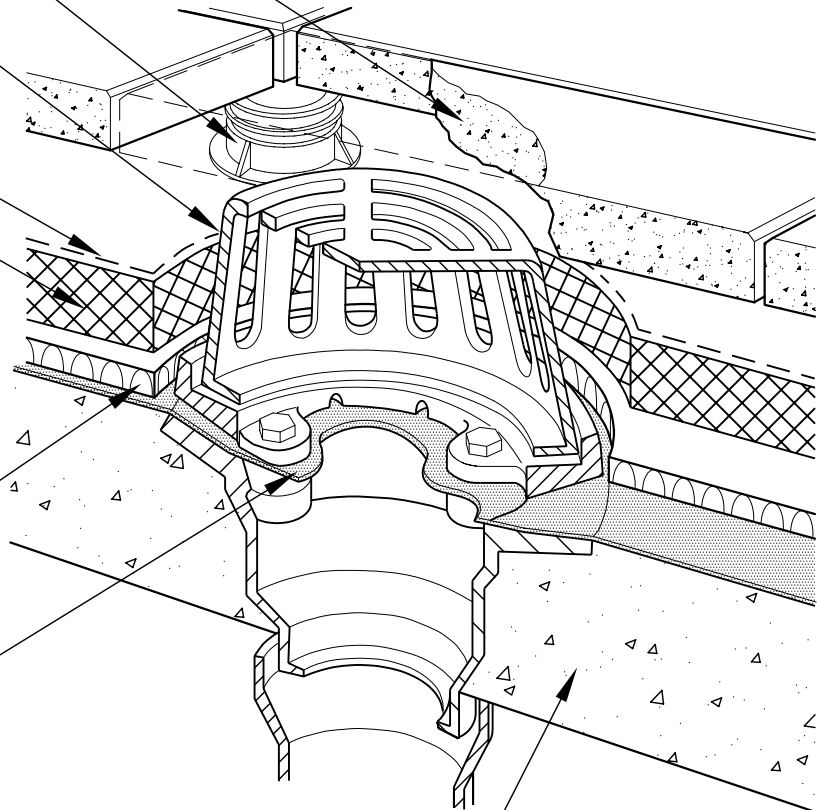
RECESSED DRAIN WITH WEEP  
HOLES AT MEMBRANE LEVEL

OPTIONAL:  
FILTER FABRIC

RIGID INSULATION

PROTECTION /  
DRAINAGE COURSE

WATERPROOFING MEMBRANE -  
EXTEND MEMBRANE UNDER  
DRAIN CLAMPING RING



STRUCTURAL  
DECK

**NOTES:**

1. RIGID INSULATION MUST BE MOISTURE RESISTANT AND HAVE HIGH COMPRESSIVE STRENGTH (25 PSI MIN.; CONSULT ENGINEER).
2. DRAIN STRAINER SHOULD NOT COME IN CONTACT WITH PAVERS.
3. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

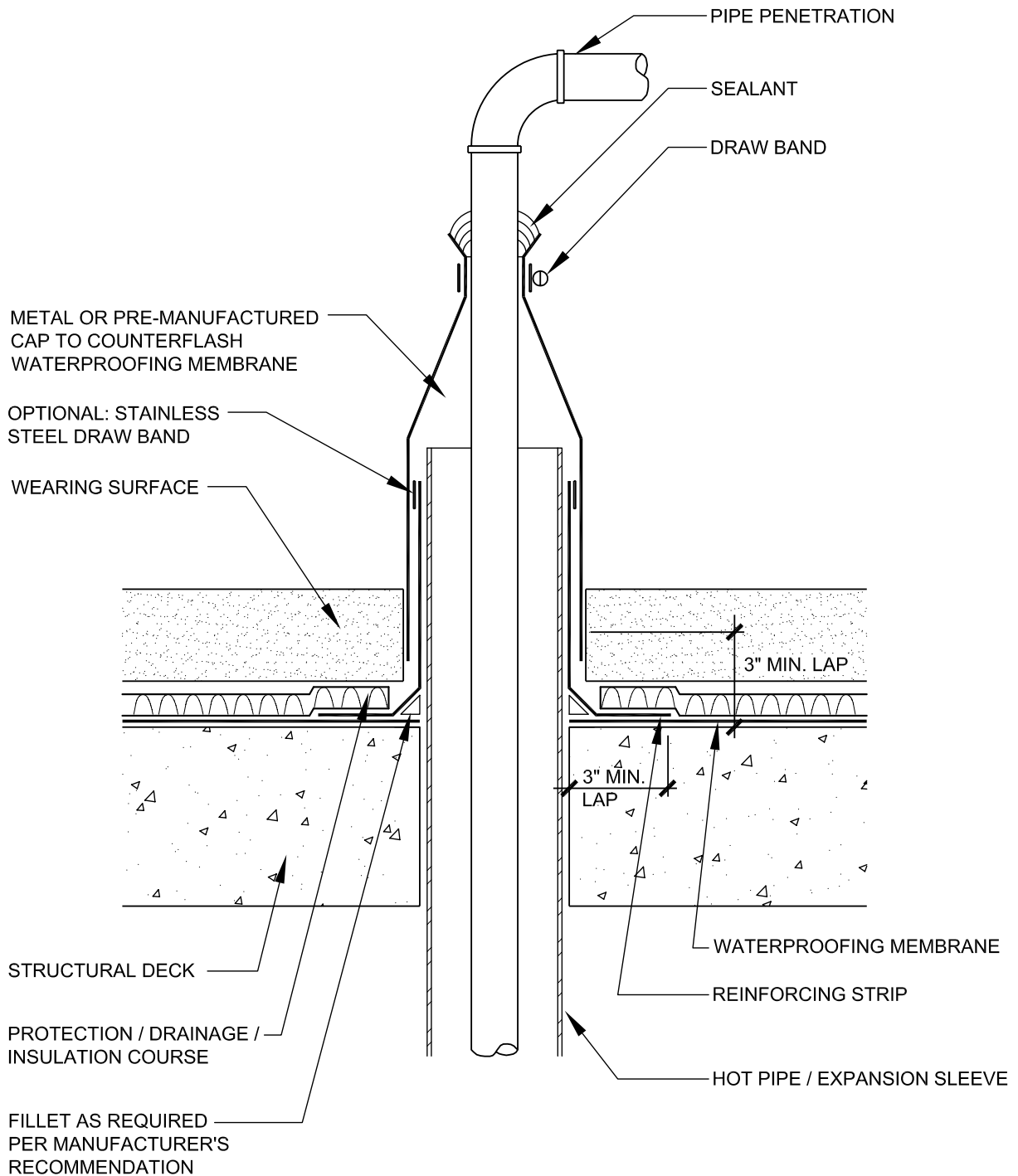


**PLAZA DECK DRAIN WITH PEDESTAL AND PAVER  
WEARING SURFACE**

**2005**


NOT DRAWN TO SCALE

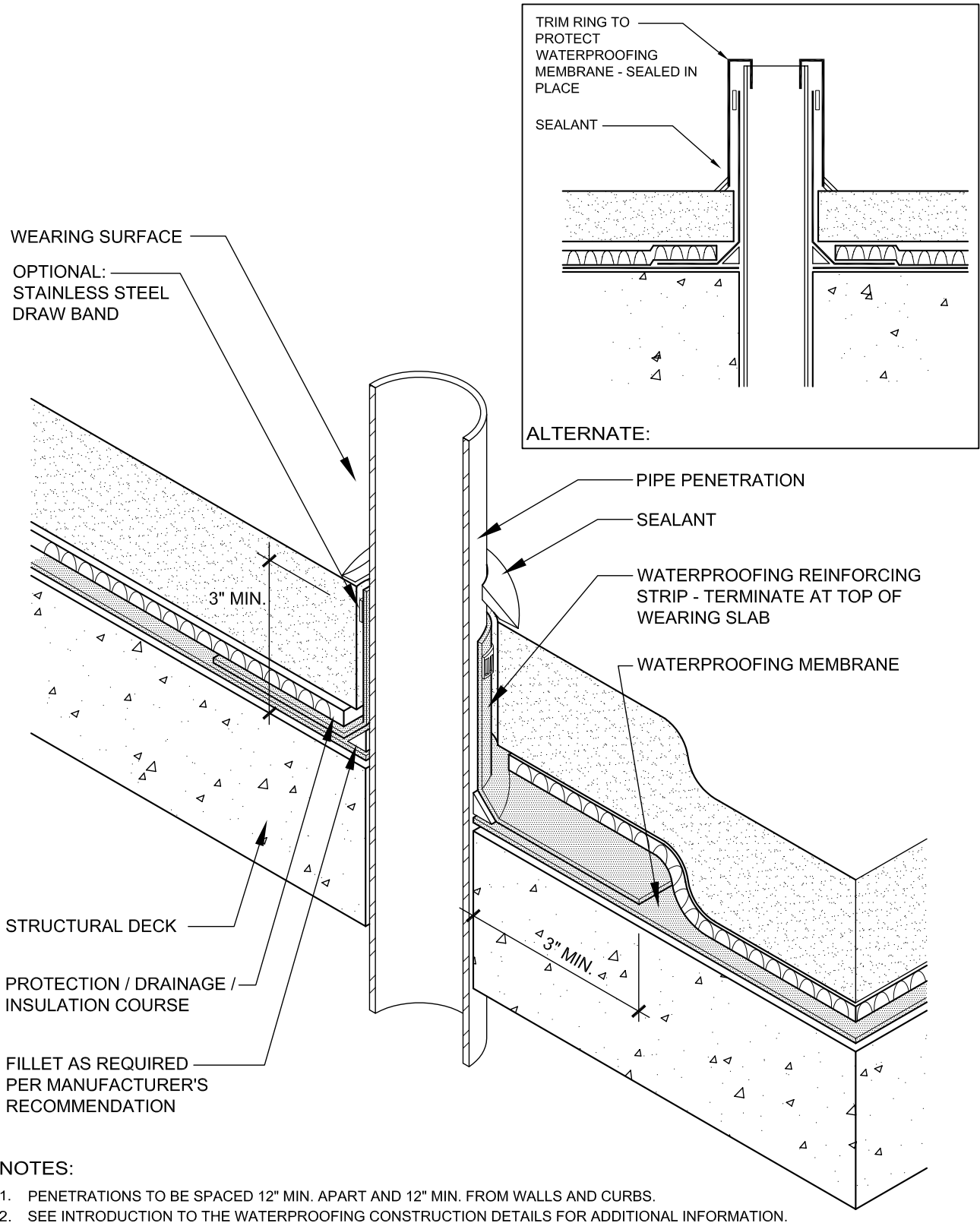
**WP-23**



**NOTES:**

1. PENETRATIONS TO BE SPACED 12" MIN. APART AND 12" MIN. FROM WALLS AND CURBS.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>HOT PIPE / EXPANSION SLEEVE PENETRATION THROUGH PLAZA DECK</b></p> <p>2005</p> <p style="font-size: small;">NOT DRAWN TO SCALE</p>	<p><b>WP-24</b></p>
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**NOTES:**

1. PENETRATIONS TO BE SPACED 12" MIN. APART AND 12" MIN. FROM WALLS AND CURBS.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

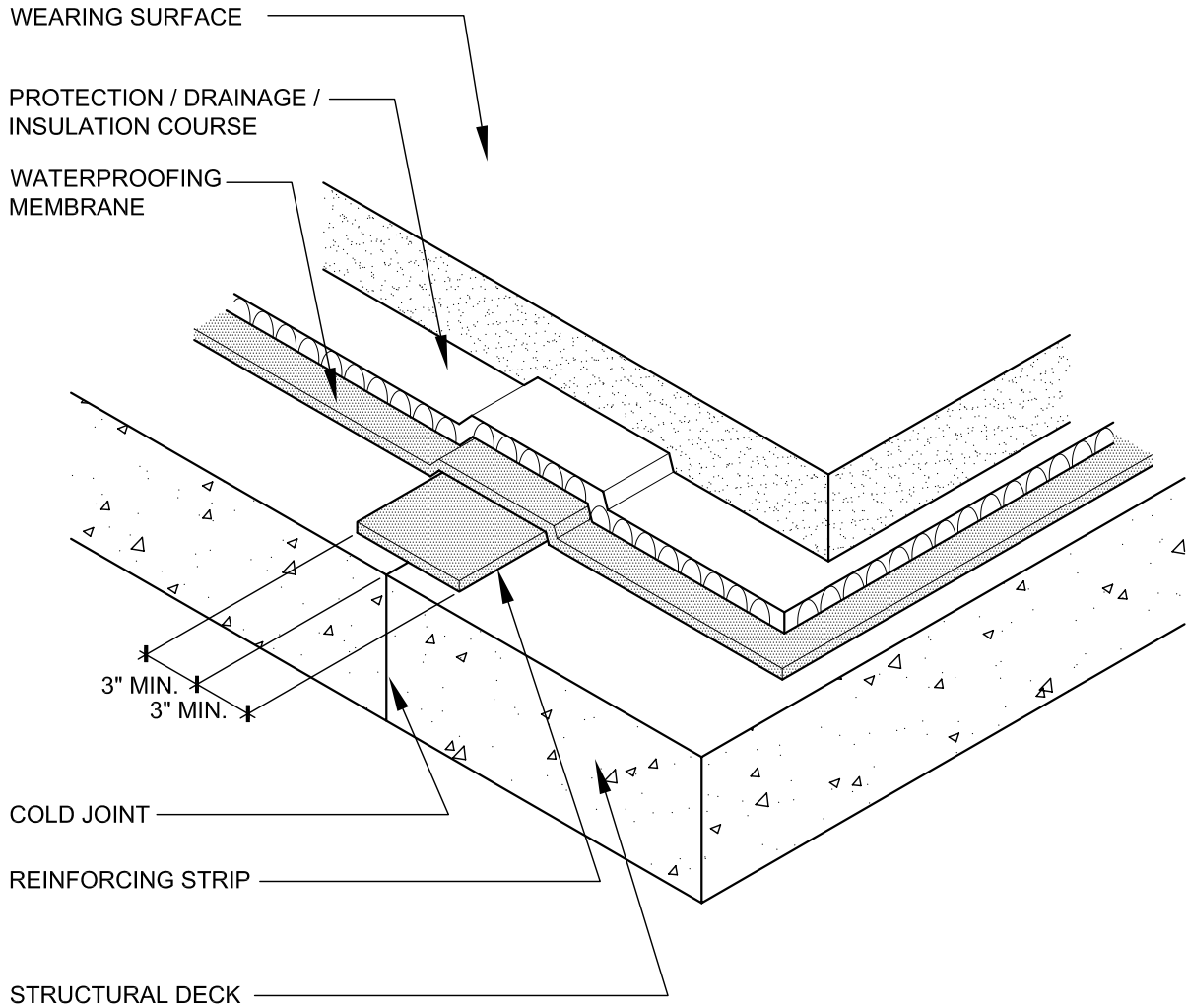


**PIPE PENETRATION THROUGH PLAZA DECK**

2005

NOT DRAWN TO SCALE

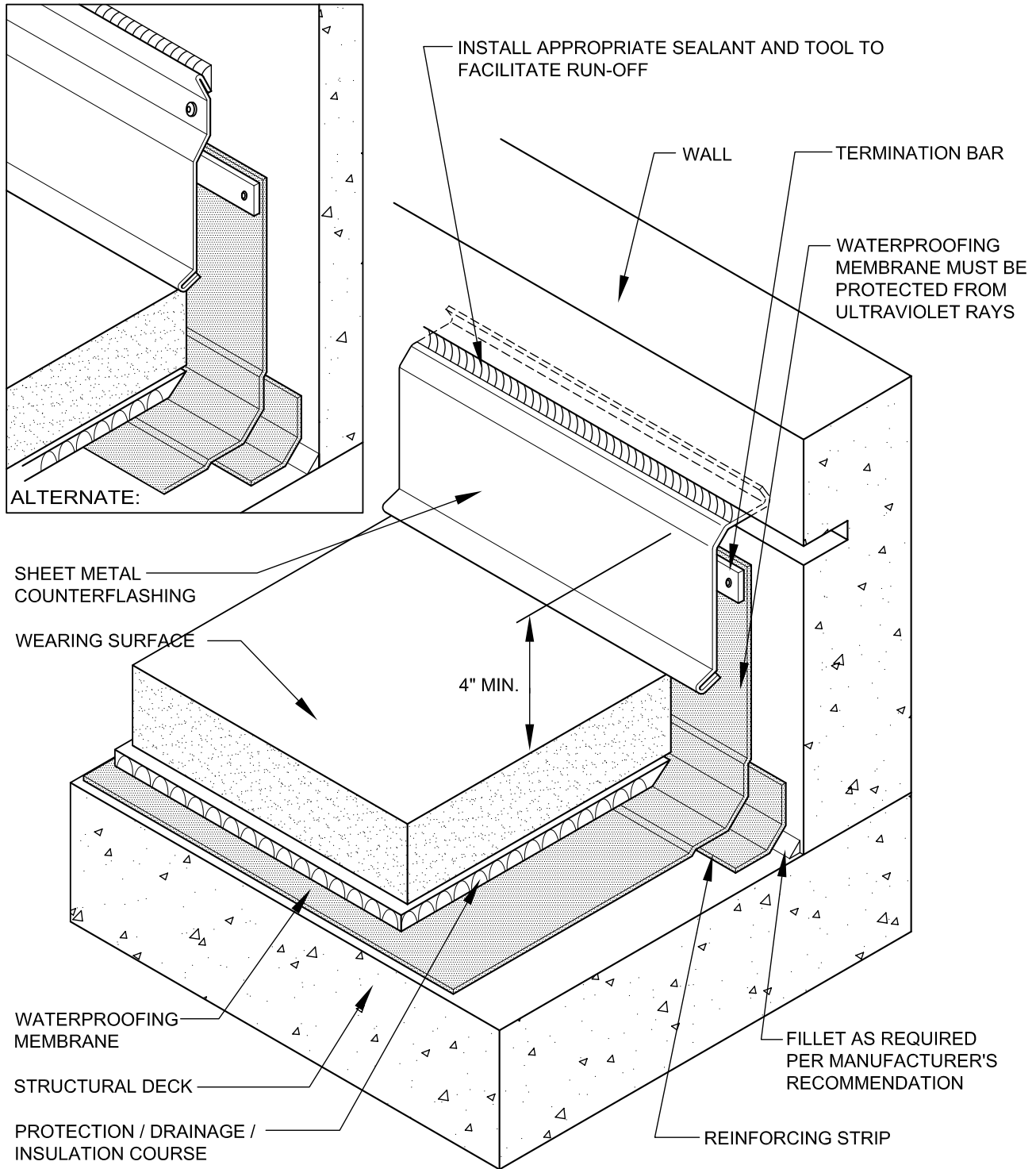
WP-25



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>NON-MOVING COLD JOINT AT CONCRETE DECK</b>
<b>2005</b>	NOT DRAWN TO SCALE	<b>WP-26</b>



**NOTES:**

1. MEMBRANE TERMINATION MAY NEED TO EXCEED 4" ABOVE TOP OF WEARING SLAB UNDER CERTAIN CLIMATIC CONDITIONS (E.G., SNOW).
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

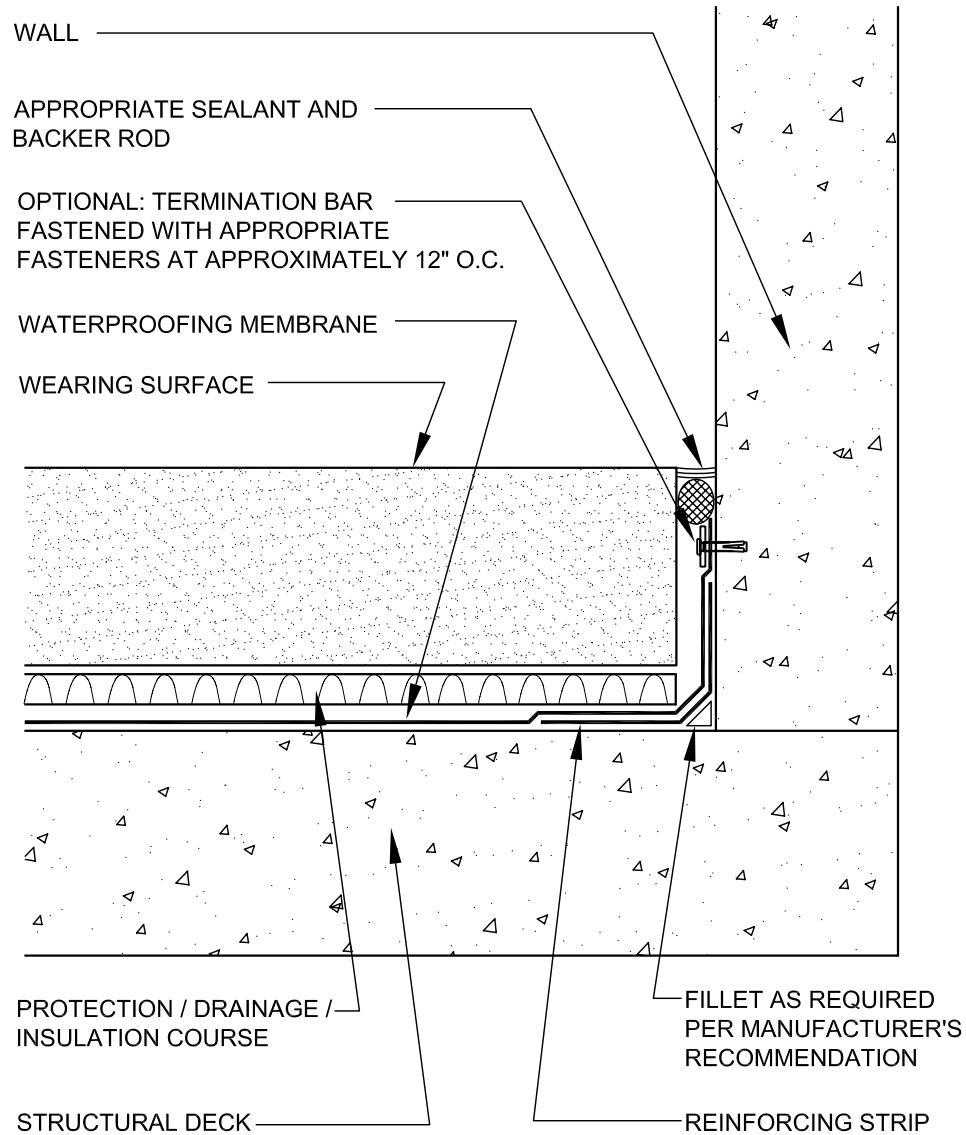


**PLAZA DECK-TO-WALL TERMINATION ABOVE WEARING SURFACE**

2005


NOT DRAWN TO SCALE

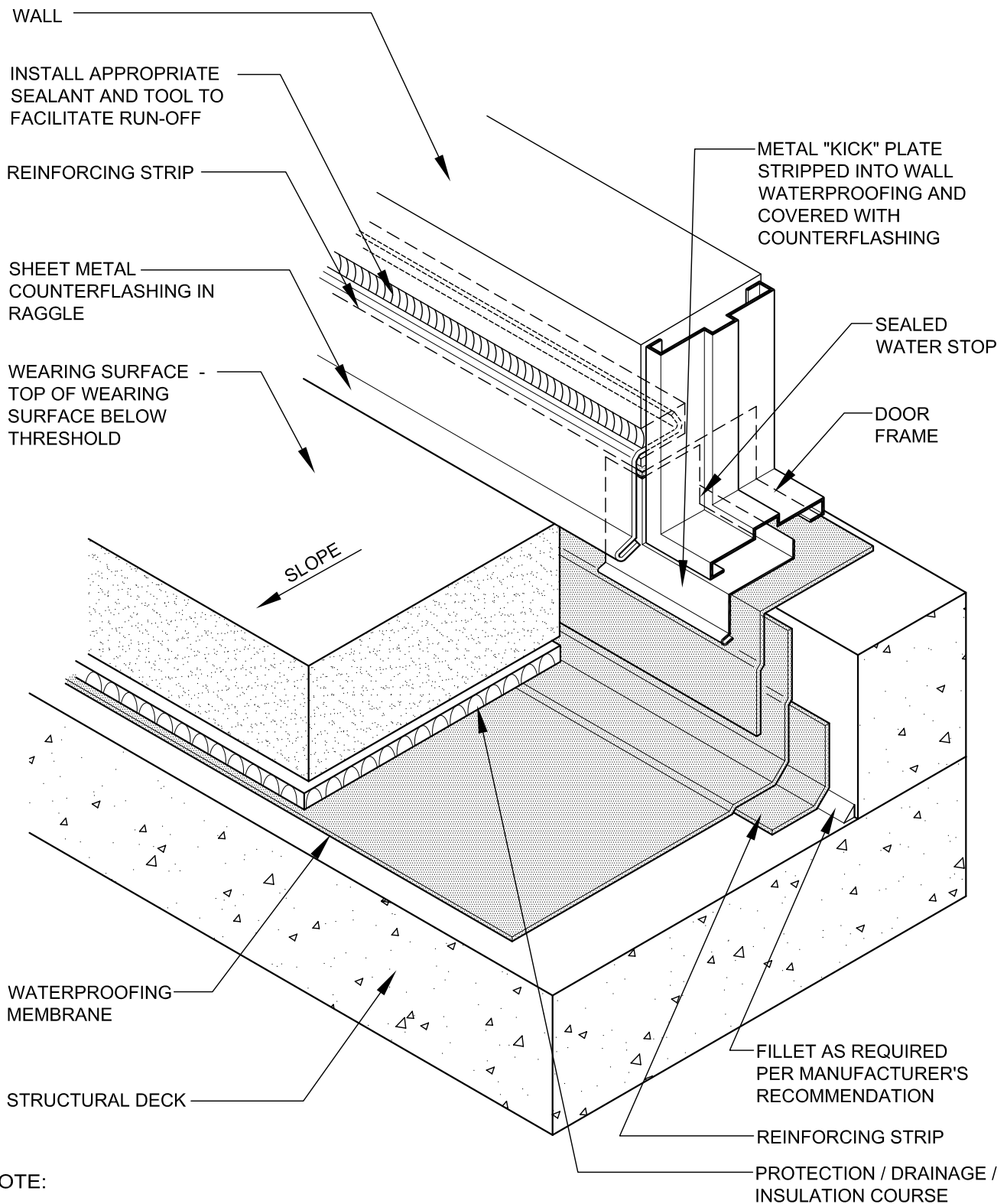
WP-27



**NOTES:**

1. PENETRATIONS TO BE SPACED 12" MIN. APART AND 12" MIN. FROM WALLS AND CURBS.
2. THIS DETAIL IS ONLY USED WHERE IT IS NOT POSSIBLE OR PRACTICAL TO TERMINATE THE WATERPROOFING MEMBRANE ABOVE THE FINISHED WEARING SURFACE.
3. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PLAZA DECK-TO-WALL TERMINATION AT WEARING SURFACE</b></p> <p><b>2005</b></p> <p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-28</b></p>
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**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



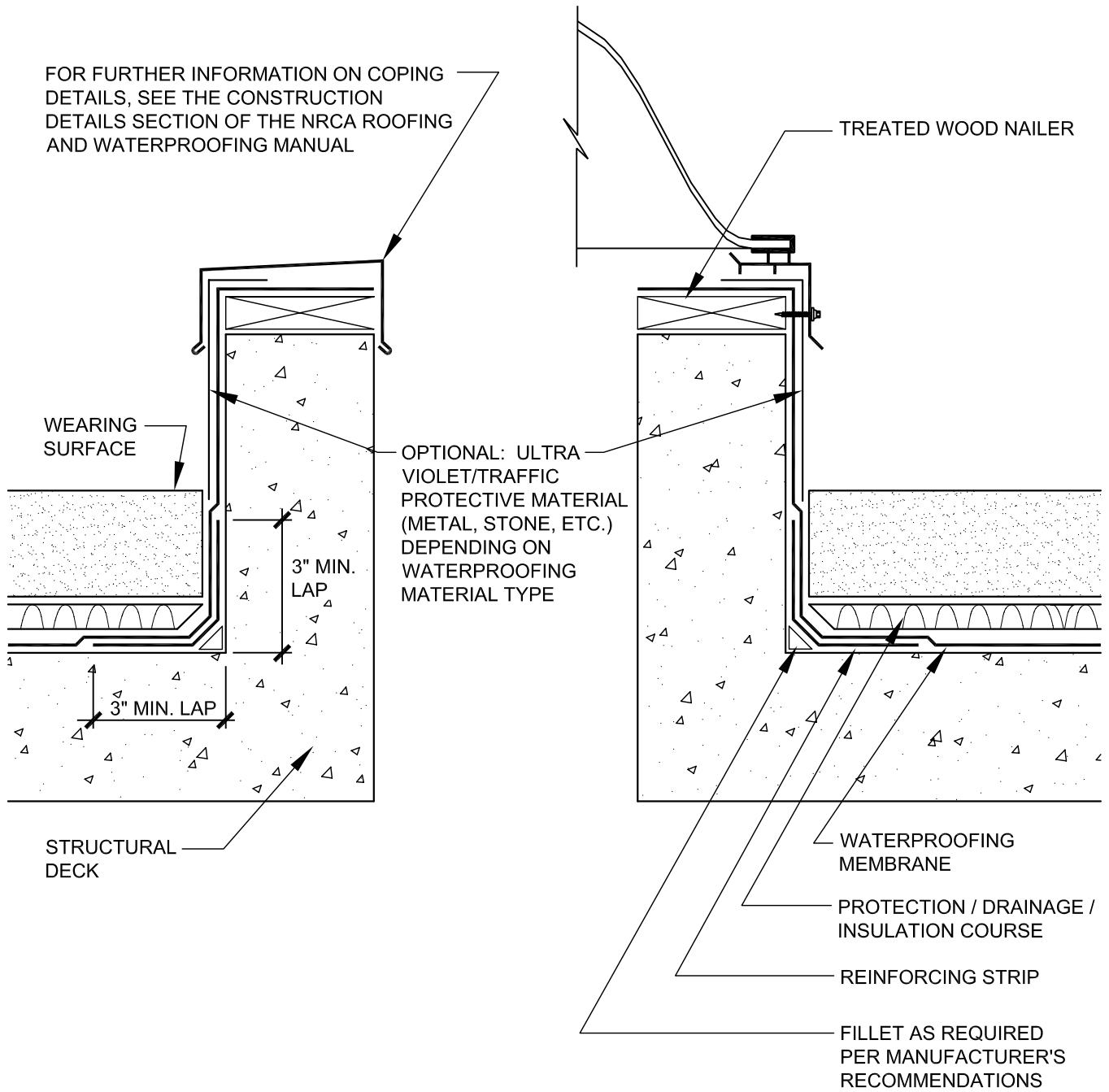
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**PLAZA DOOR THRESHOLD**

**2005**

NOT DRAWN TO SCALE

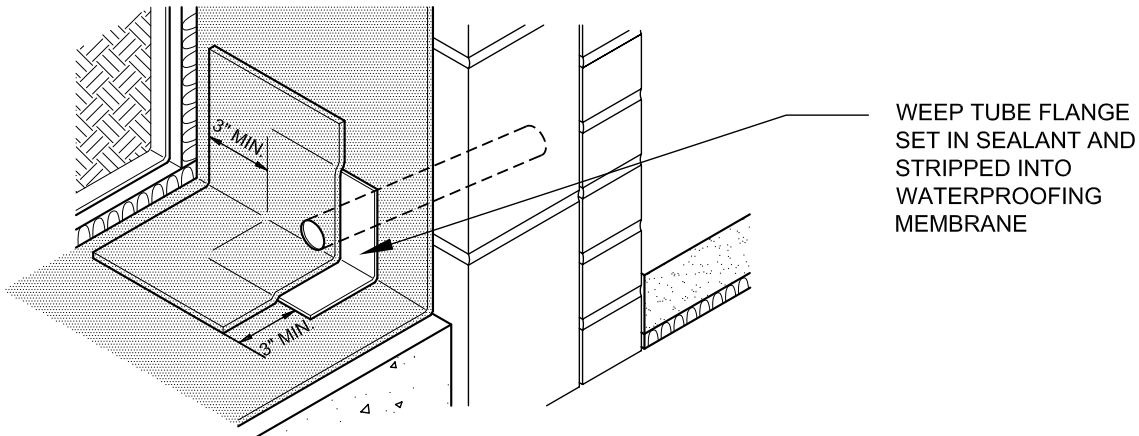
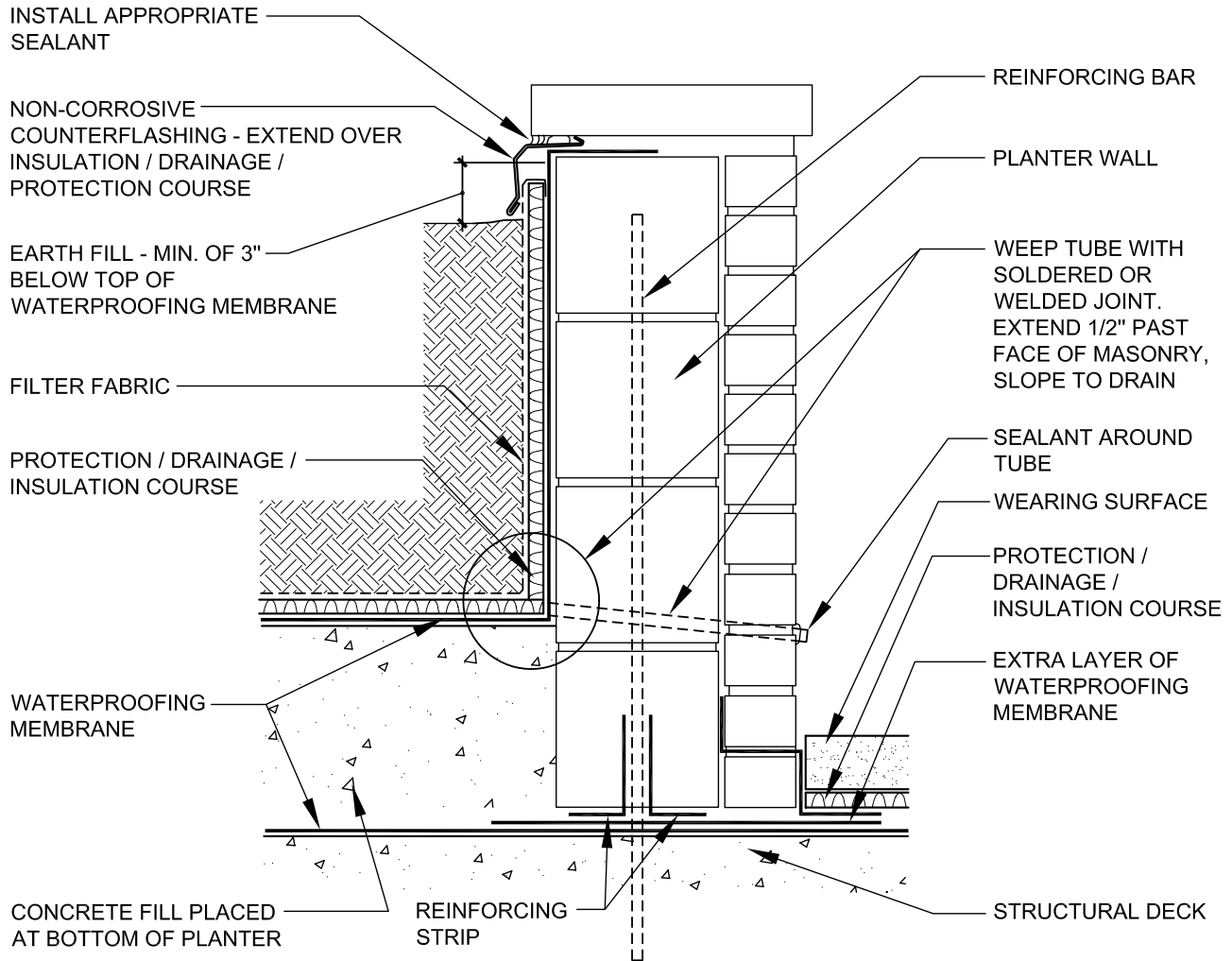
**WP-29**



**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

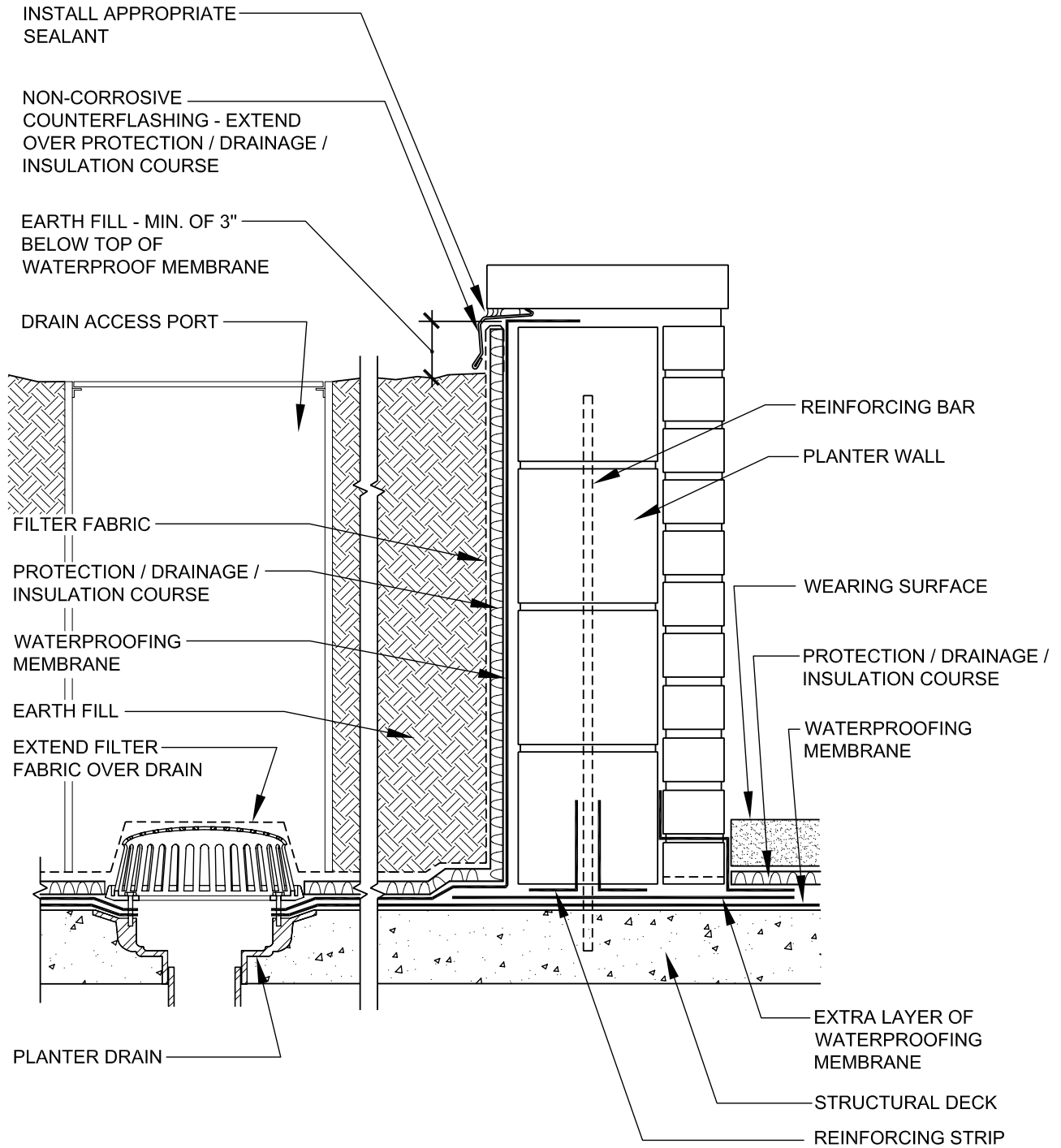
	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PLAZA DECK CURB / OPENING</b></p>	<p><b>2005</b></p>	<p>NOT DRAWN TO SCALE</p>	<p><b>WP-30</b></p>
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**NOTES:**


1. WEEP TUBE AND SPACING DETERMINED BY PLANTER SIZE AND LOCATION (BY OTHERS).
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

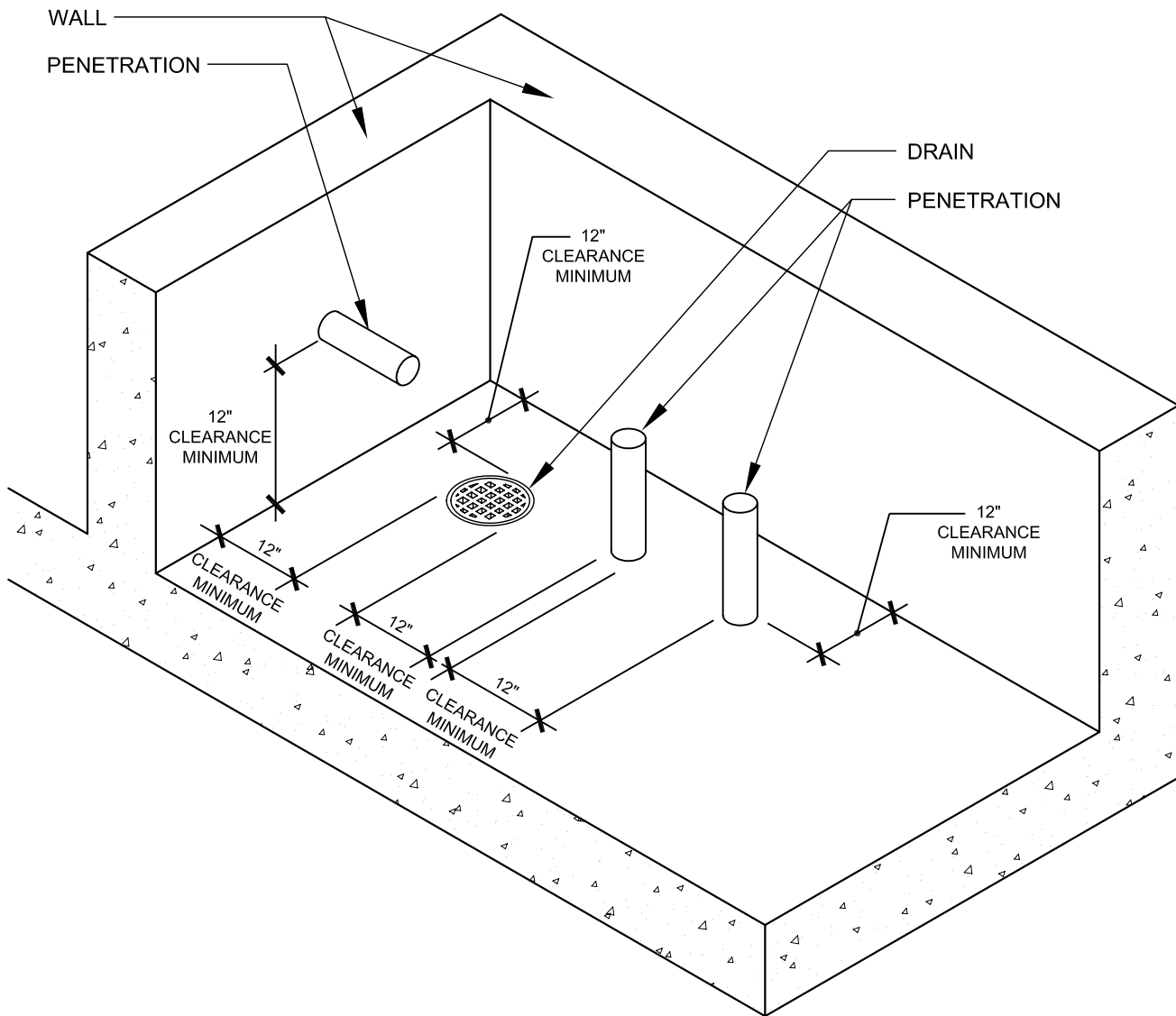
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>BUILT-IN PLANTER WITH WEEP DRAINAGE</b></p> <p>2005</p>	<p>NOT DRAWN TO SCALE</p> <p><b>WP-31</b></p>
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NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

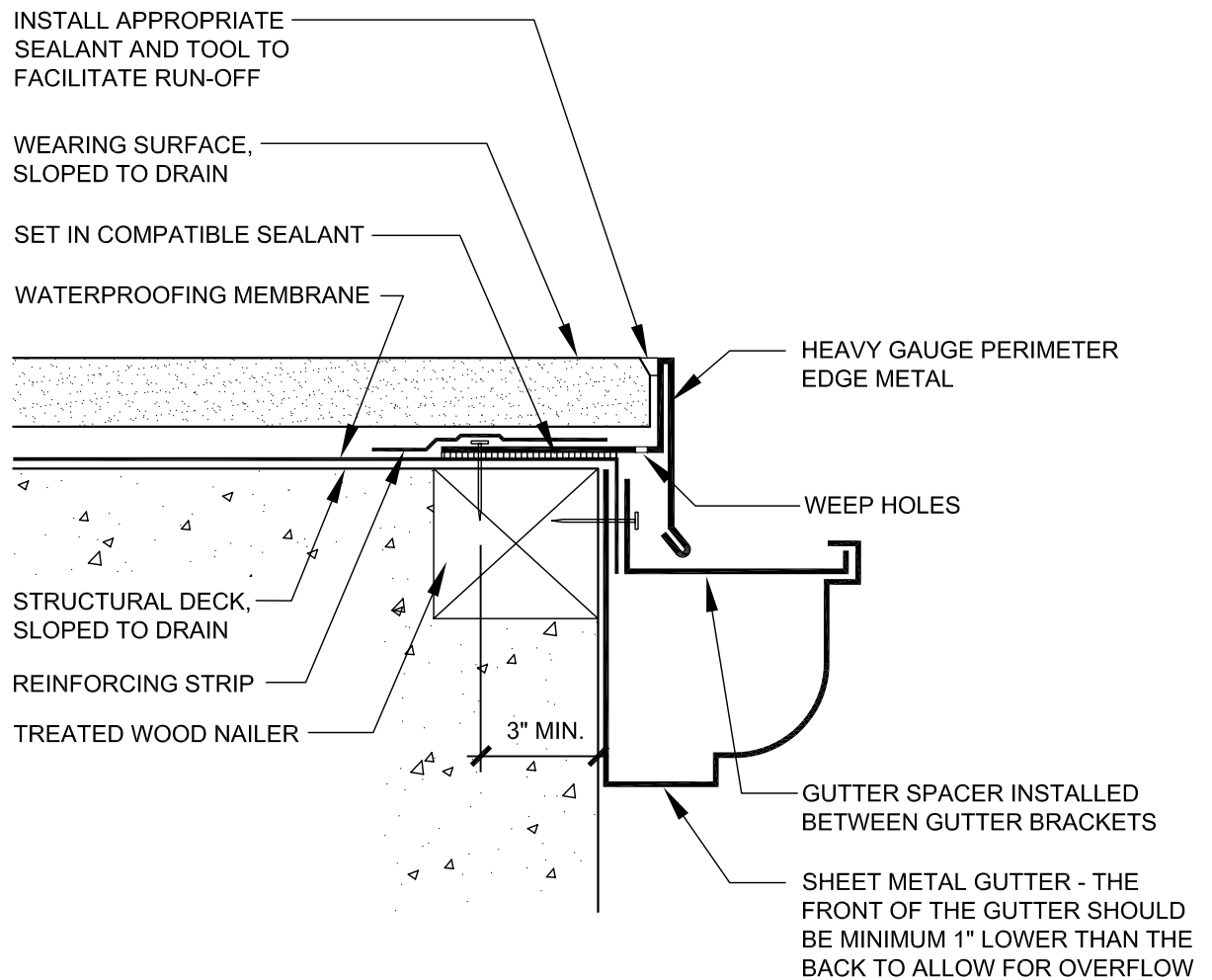
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PLANTER WALL WITH INTERIOR DRAINAGE</b></p>	<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-32</b></p>
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**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

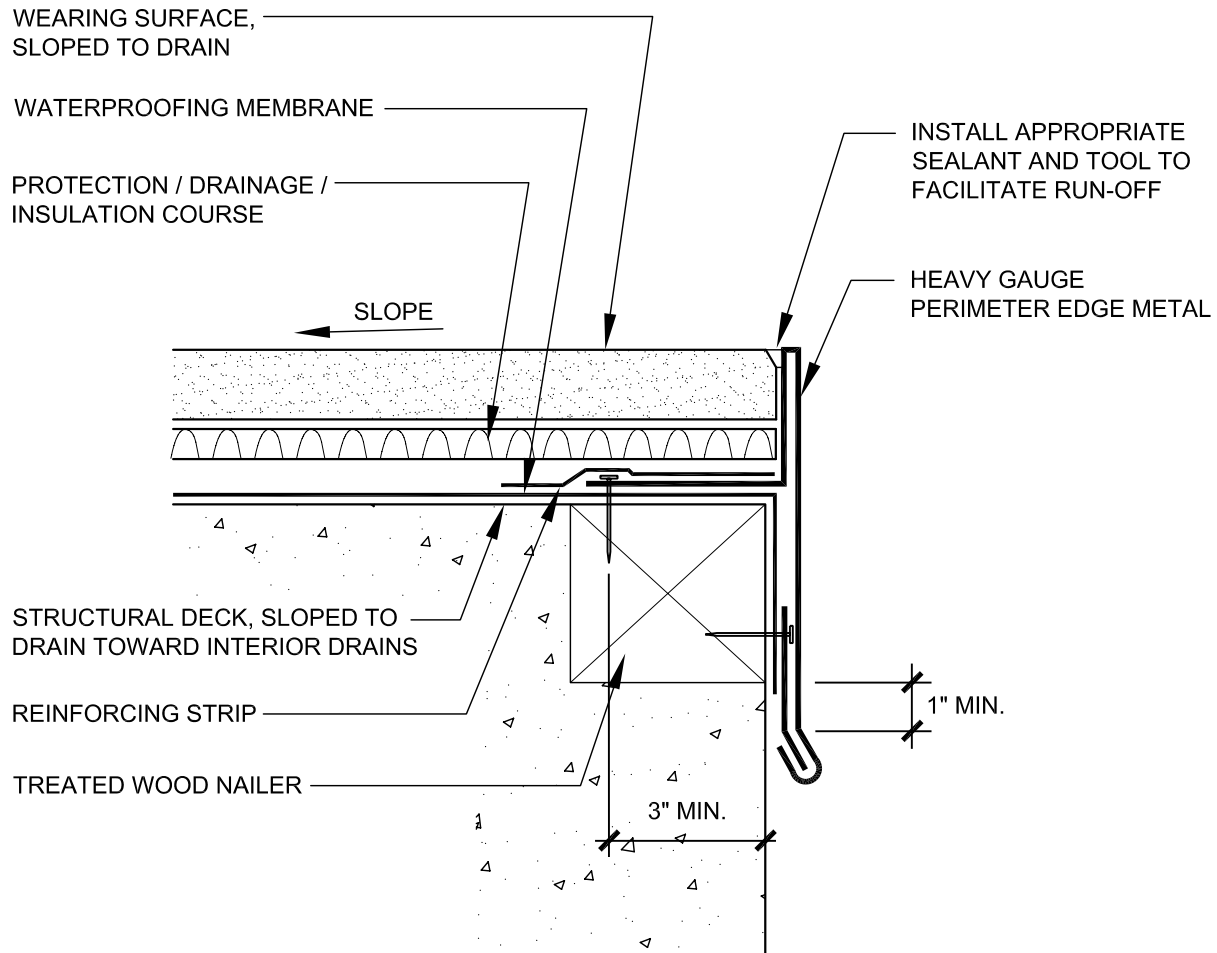
	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>CLEARANCE FOR PENETRATIONS AND WALLS FOR PLANTERS</b>
<b>2005</b>	<i>NOT DRAWN TO SCALE</i>	<b>WP-33</b>



**NOTE:**

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>OPEN EDGE PERIMETER DETAIL WITH EDGE DRAINAGE</b></p>	<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-34</b></p>
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NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



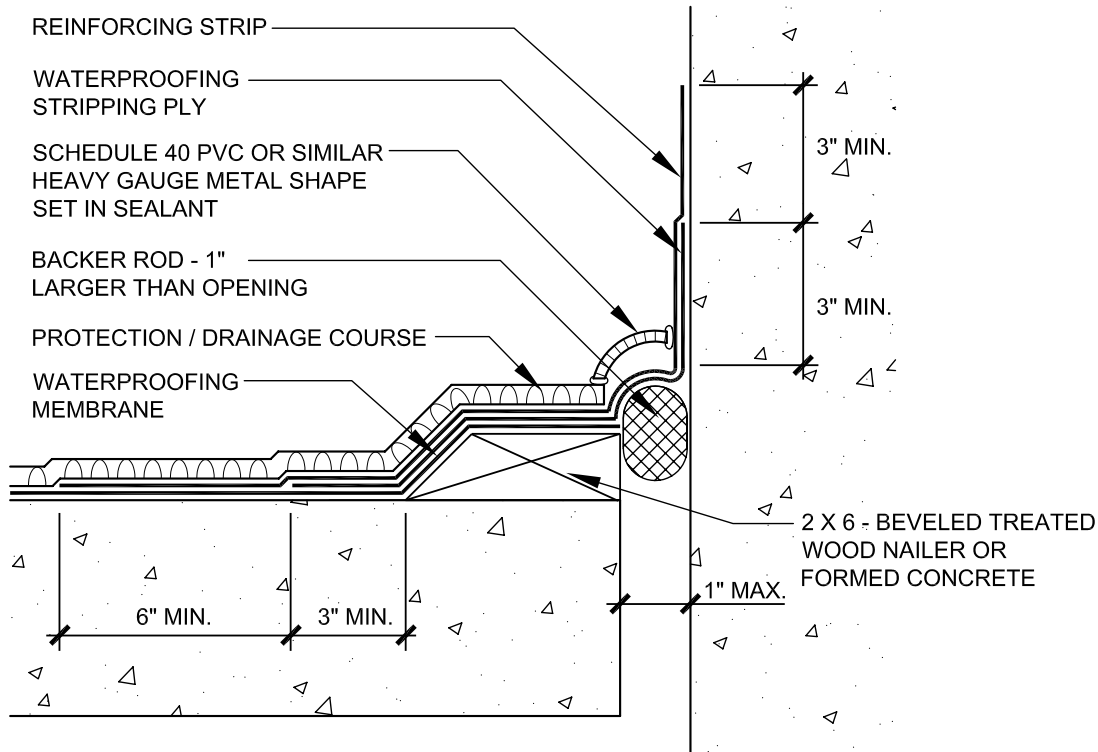
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**OPEN EDGE PERIMETER DETAIL WITH INTERIOR  
DRAINAGE**

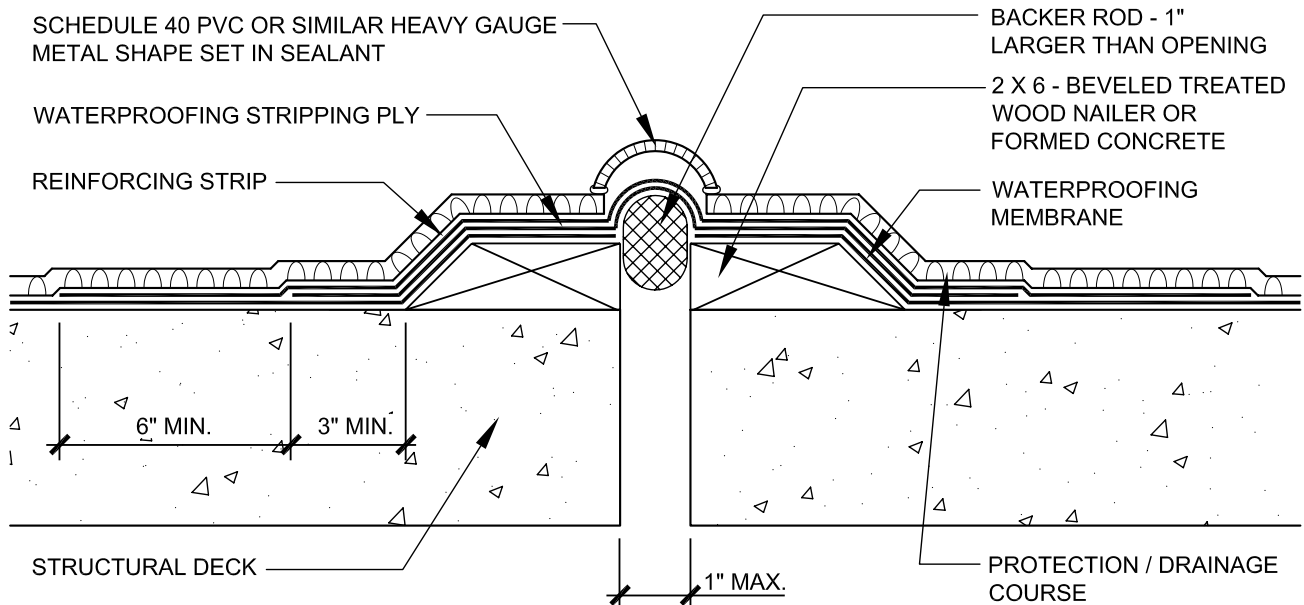
**2005**

NOT DRAWN TO SCALE

**WP-35**



**DECK-TO-WALL ELEVATED EXPANSION JOINT DETAIL**



**NOTES:**

1. STRIPPING PLY IS NOT ADHERED TO THE BACKER ROD.
2. DRAINAGE SHOULD BE AWAY FROM THE EXPANSION JOINT.
3. THIS DETAIL IS FOR USE WHERE THE HEIGHT OF THE EXPANSION JOINT DOES NOT AFFECT THE WEARING SURFACE. WEARING SURFACE NOT SHOWN.
4. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

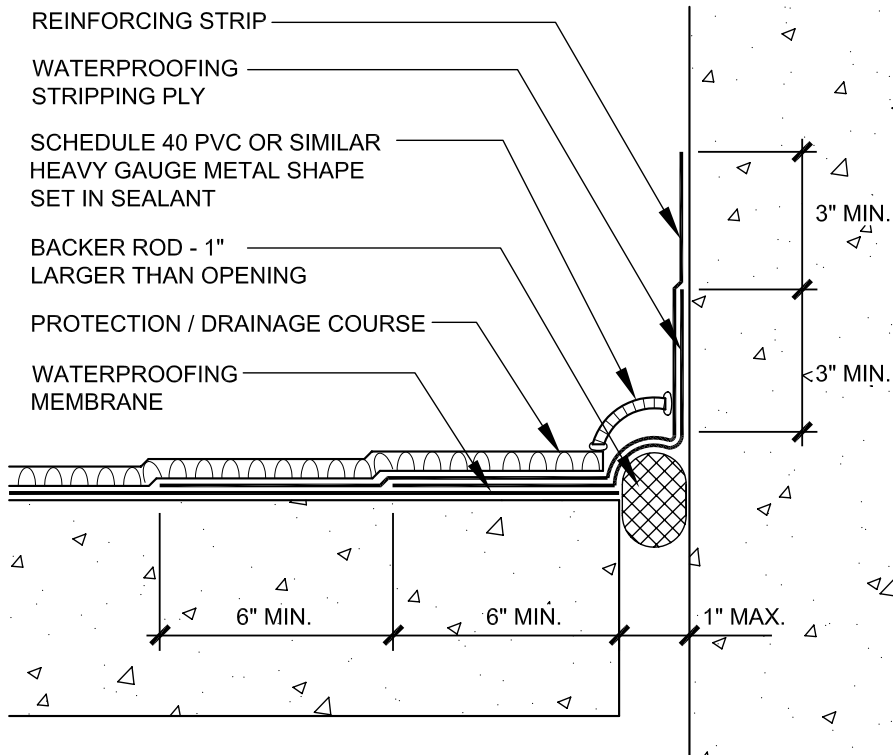


**ELEVATED EXPANSION JOINT**

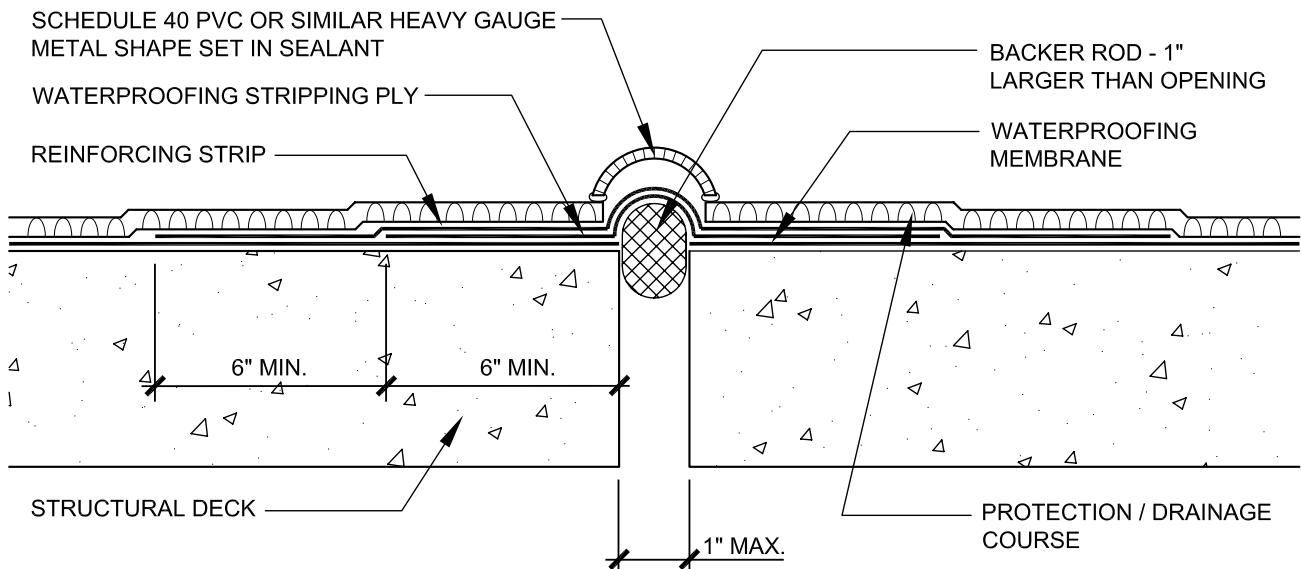
2005

NOT DRAWN TO SCALE

WP-36



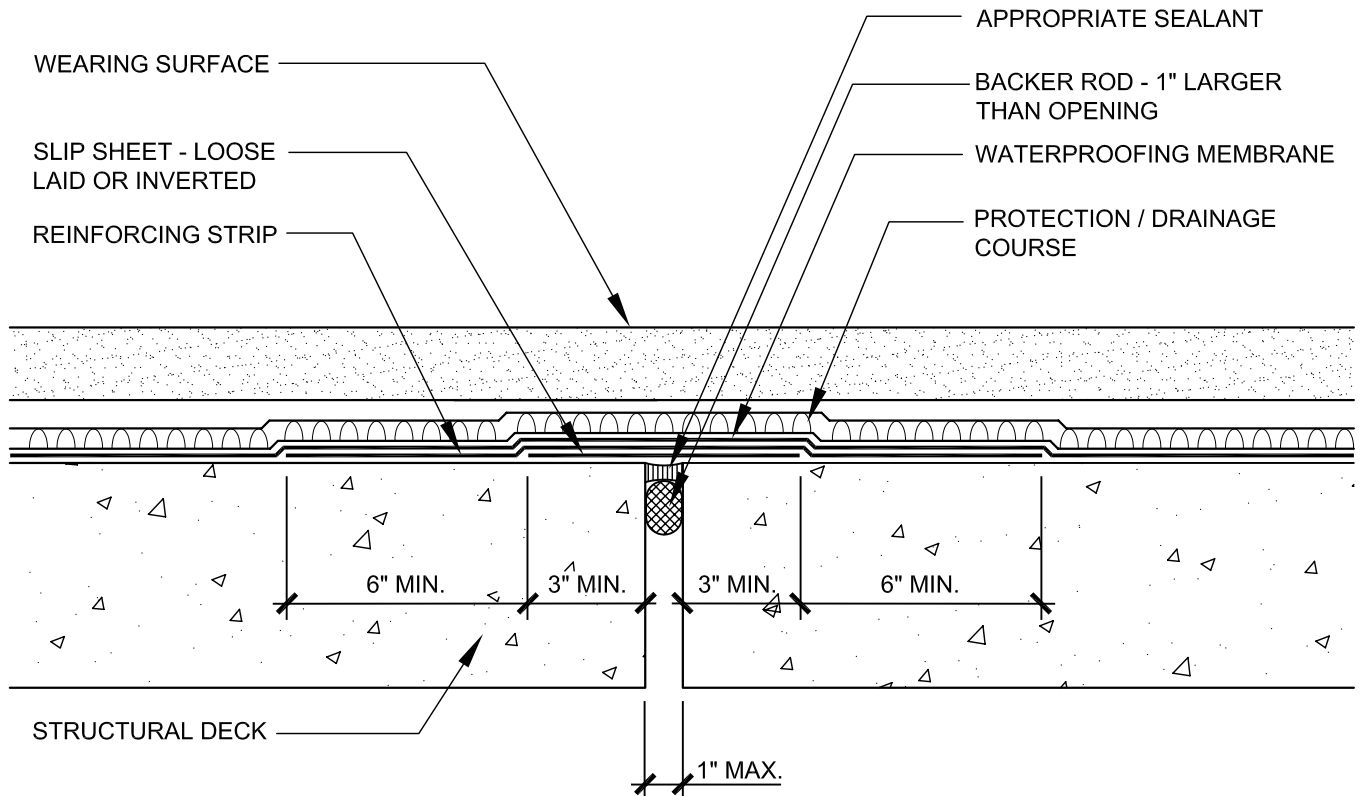
**DECK-TO-WALL LOW-PROFILE EXPANSION JOINT DETAIL**



**NOTES:**

1. STRIPPING PLY IS NOT ADHERED TO THE BACKER ROD.
2. DRAINAGE SHOULD BE AWAY FROM THE EXPANSION JOINT.
3. THIS DETAIL IS FOR USE WHERE THE HEIGHT OF THE EXPANSION JOINT IS CRITICAL TO THE WEARING SURFACE. WEARING SURFACE NOT SHOWN.
4. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

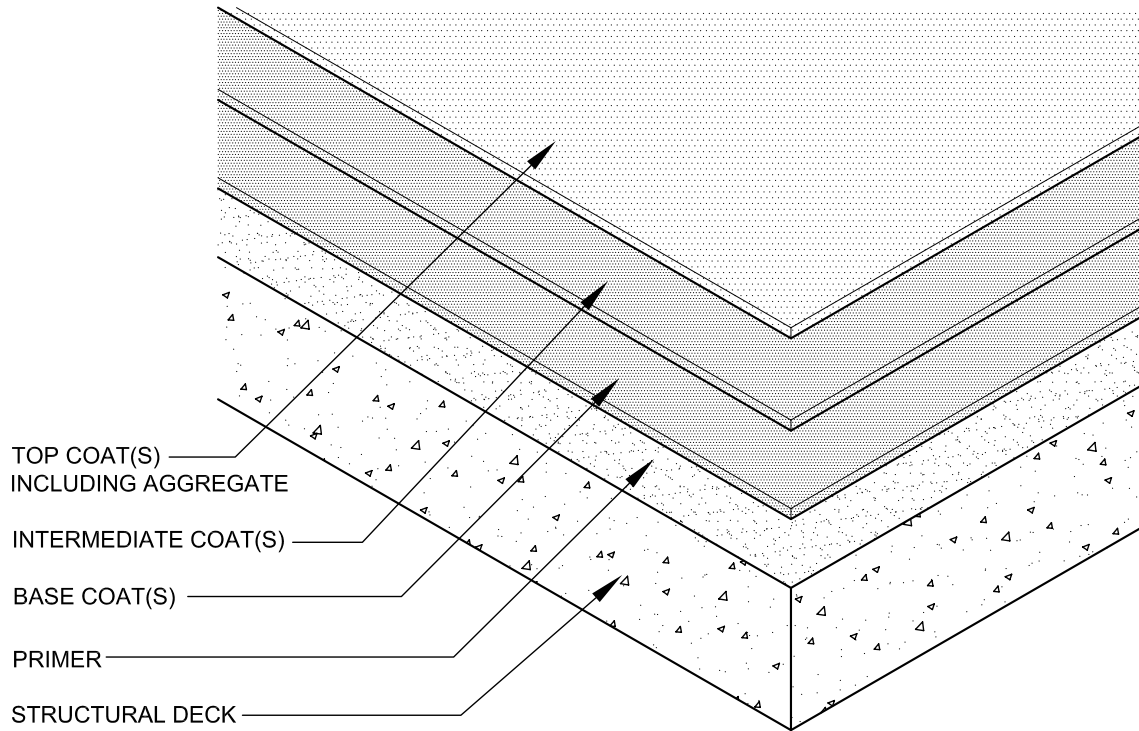
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>LOW-PROFILE EXPANSION JOINT</b></p> <p>2005</p>	<p>NOT DRAWN TO SCALE</p> <p><b>WP-37</b></p>
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**NOTES:**

1. THIS DETAIL SHOULD BE USED WHERE DRAINAGE CANNOT BE DIVERTED AWAY FROM THE EXPANSION JOINT.
2. THIS DETAIL IS FOR USE WHERE THE HEIGHT OF THE EXPANSION JOINT IS CRITICAL TO THE WEARING SURFACE.
3. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.
4. LEVEL SURFACE EXPANSION JOINTS ARE NOT THE PREFERRED METHOD AT EXPANSION JOINTS. SEE DETAILS WP-36 AND WP-37 FOR THE PREFERRED METHODS.

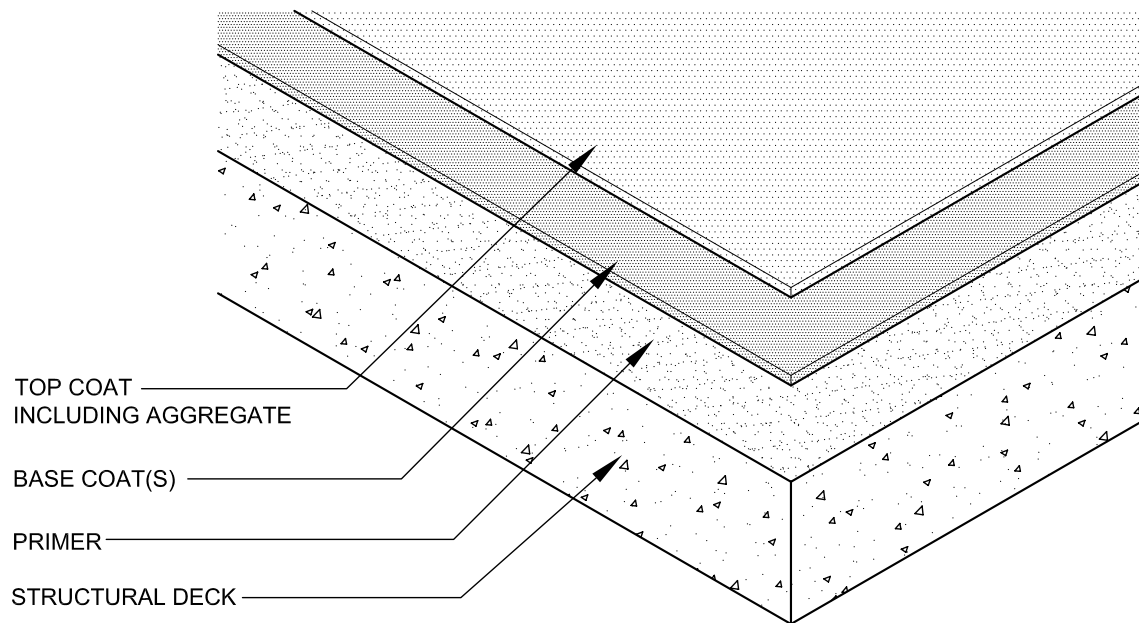
 <p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>LEVEL SURFACE EXPANSION JOINT</b></p> <p>2005</p> <p>NOT DRAWN TO SCALE</p>	<p><b>WP-38</b></p>
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**NOTE:**

1. IN HIGH TRAFFIC AREAS, AT RAMPS AND AT TURN AREAS, AN EXTRA COAT IS REQUIRED. CHECK WITH MANUFACTURER FOR RECOMMENDATIONS.

VEHICULAR



**NOTE:**

PEDESTRIAN

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



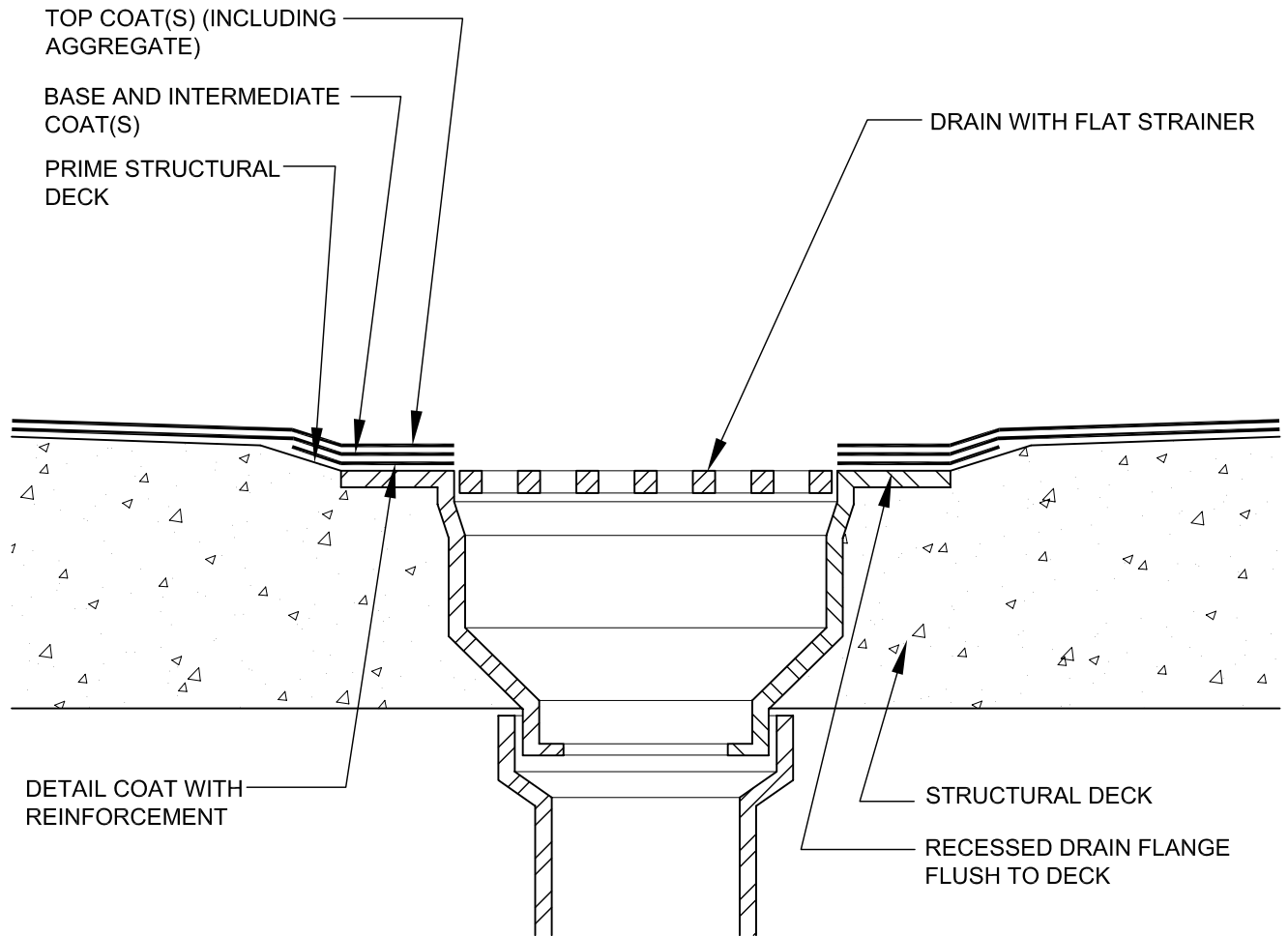
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**TRAFFIC-BEARING WATERPROOFING MEMBRANE**

**2005**

NOT DRAWN TO SCALE

**WP-39**



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

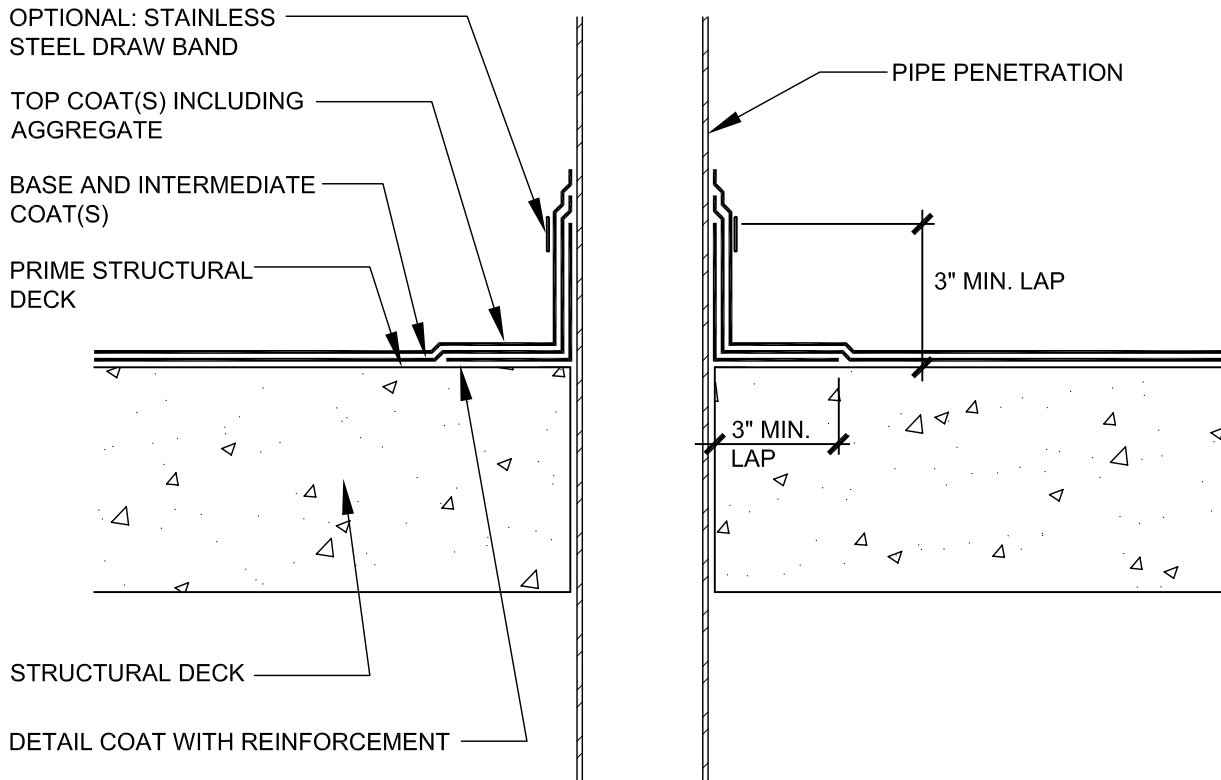


**TRAFFIC-BEARING WATERPROOFING MEMBRANE -  
DRAIN DETAIL**

2005

NOT DRAWN TO SCALE

**WP-40**



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



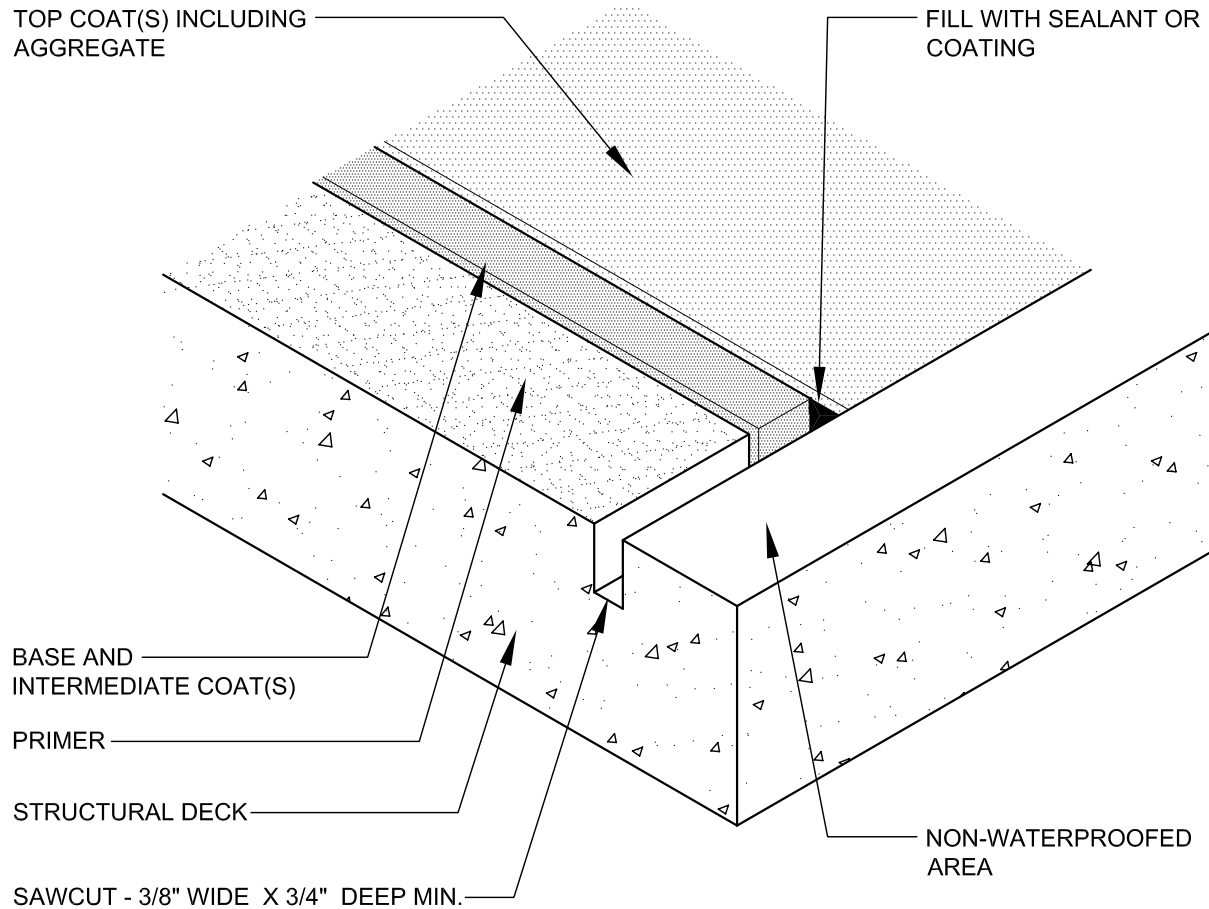
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**TRAFFIC-BEARING WATERPROOFING MEMBRANE -  
PIPE PENETRATION DETAIL**

**2005**

*NOT DRAWN TO SCALE*

**WP-41**



NOTES:

1. THIS DETAIL ONLY TO BE USED WHEN NON-HABITABLE SPACE IS BENEATH.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

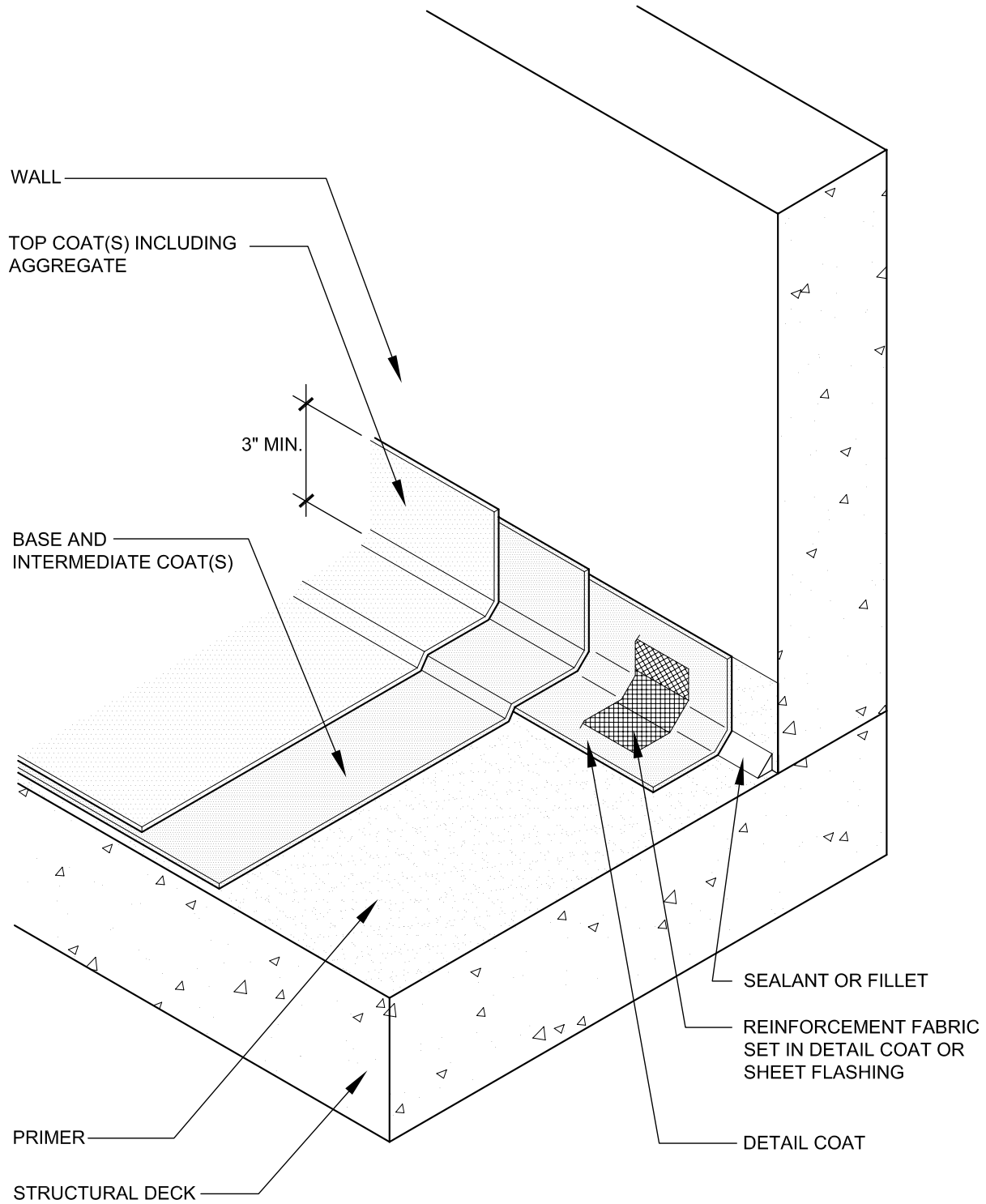


**TRAFFIC-BEARING WATERPROOFING MEMBRANE -  
HORIZONTAL TERMINATION DETAIL**

2005

NOT DRAWN TO SCALE

WP-42



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.



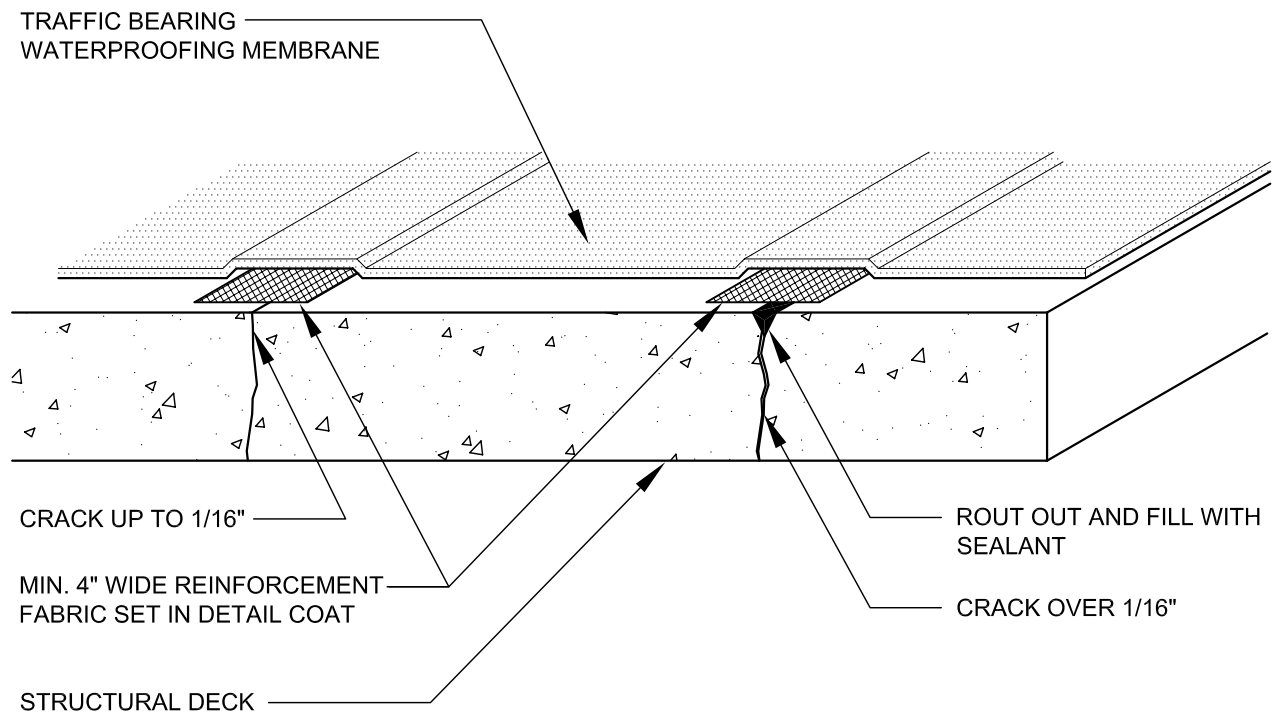
**NATIONAL  
ROOFING  
CONTRACTORS  
ASSOCIATION**

**TRAFFIC-BEARING WATERPROOFING MEMBRANE -  
BASE FLASHING DETAIL**

**2005**

*NOT DRAWN TO SCALE*

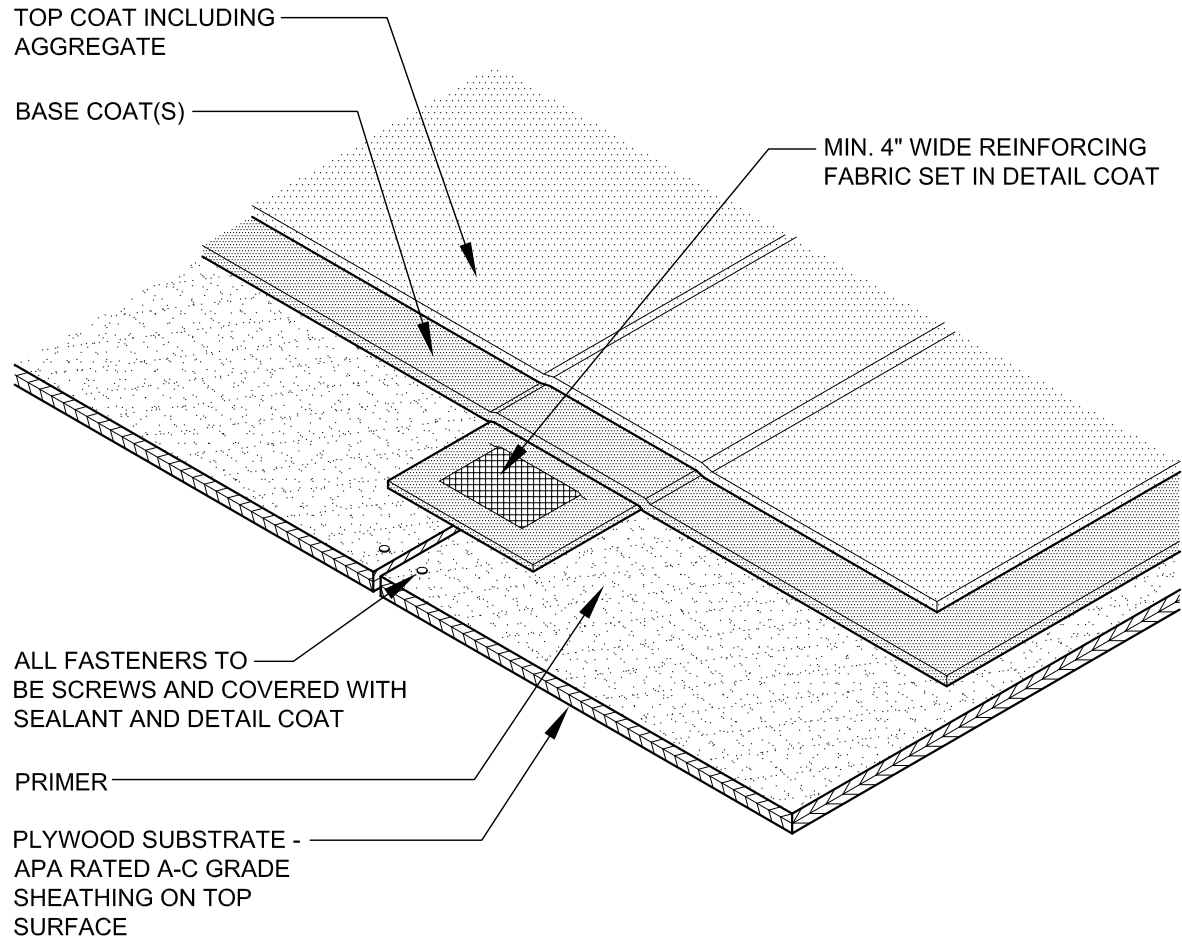
**WP-43**



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>TRAFFIC-BEARING WATERPROOFING MEMBRANE - CRACK PREPARATION DETAIL</b>
2005	NOT DRAWN TO SCALE	<b>WP-44</b>



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

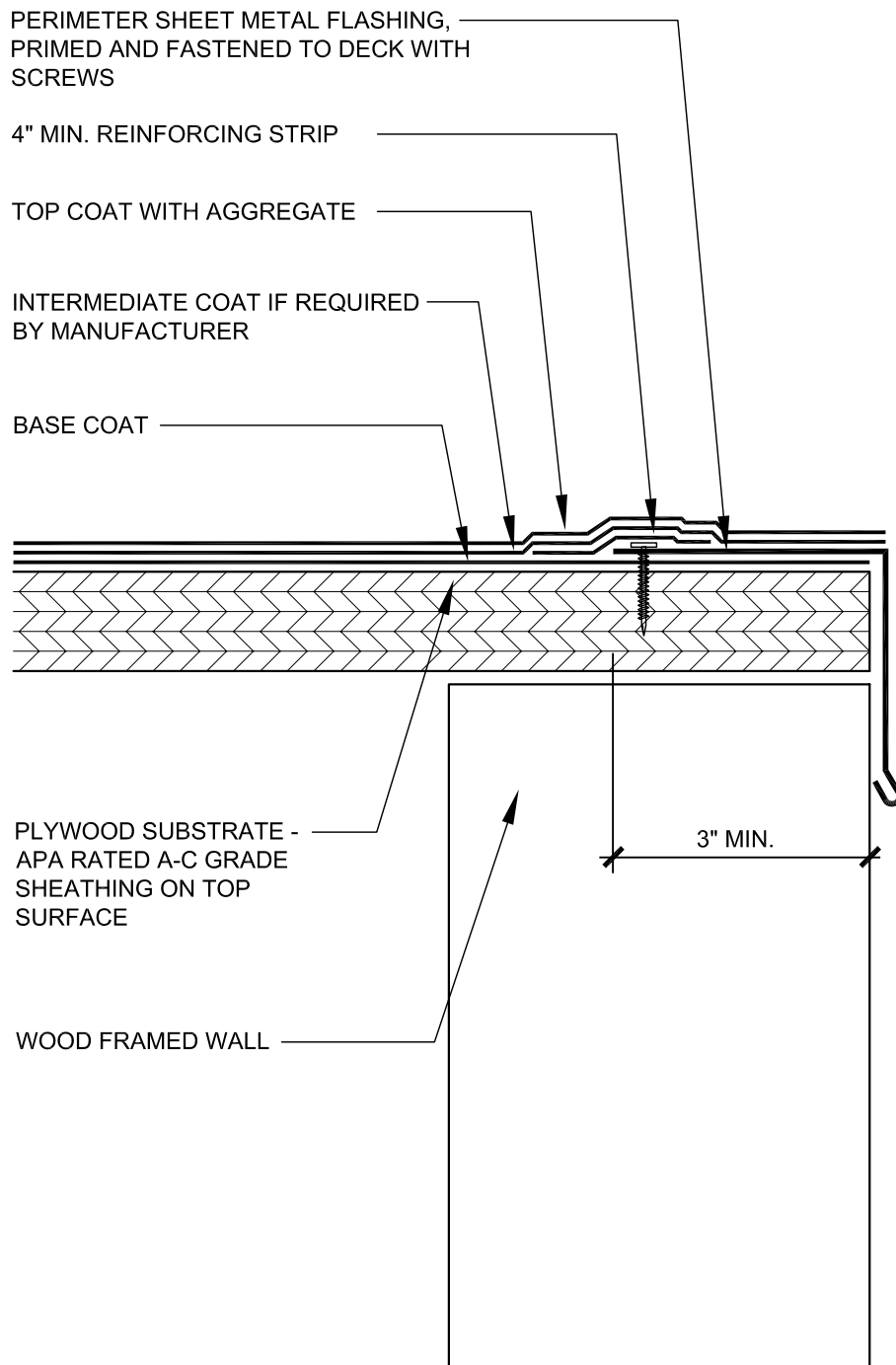


**PEDESTRIAN-TRAFFIC-BEARING WATERPROOFING MEMBRANE - PLYWOOD JOINT TREATMENT**

2005

NOT DRAWN TO SCALE

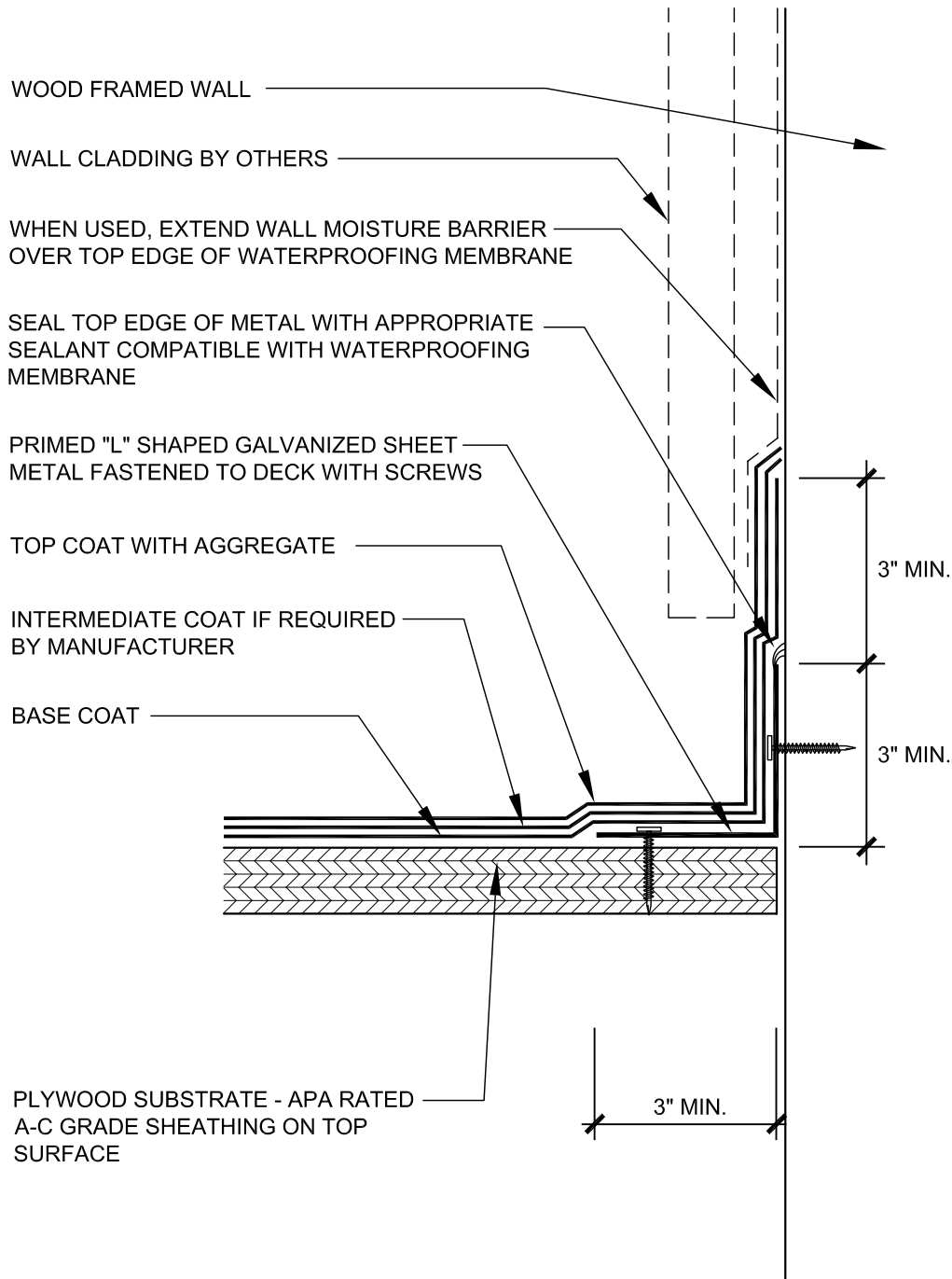
WP-45



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

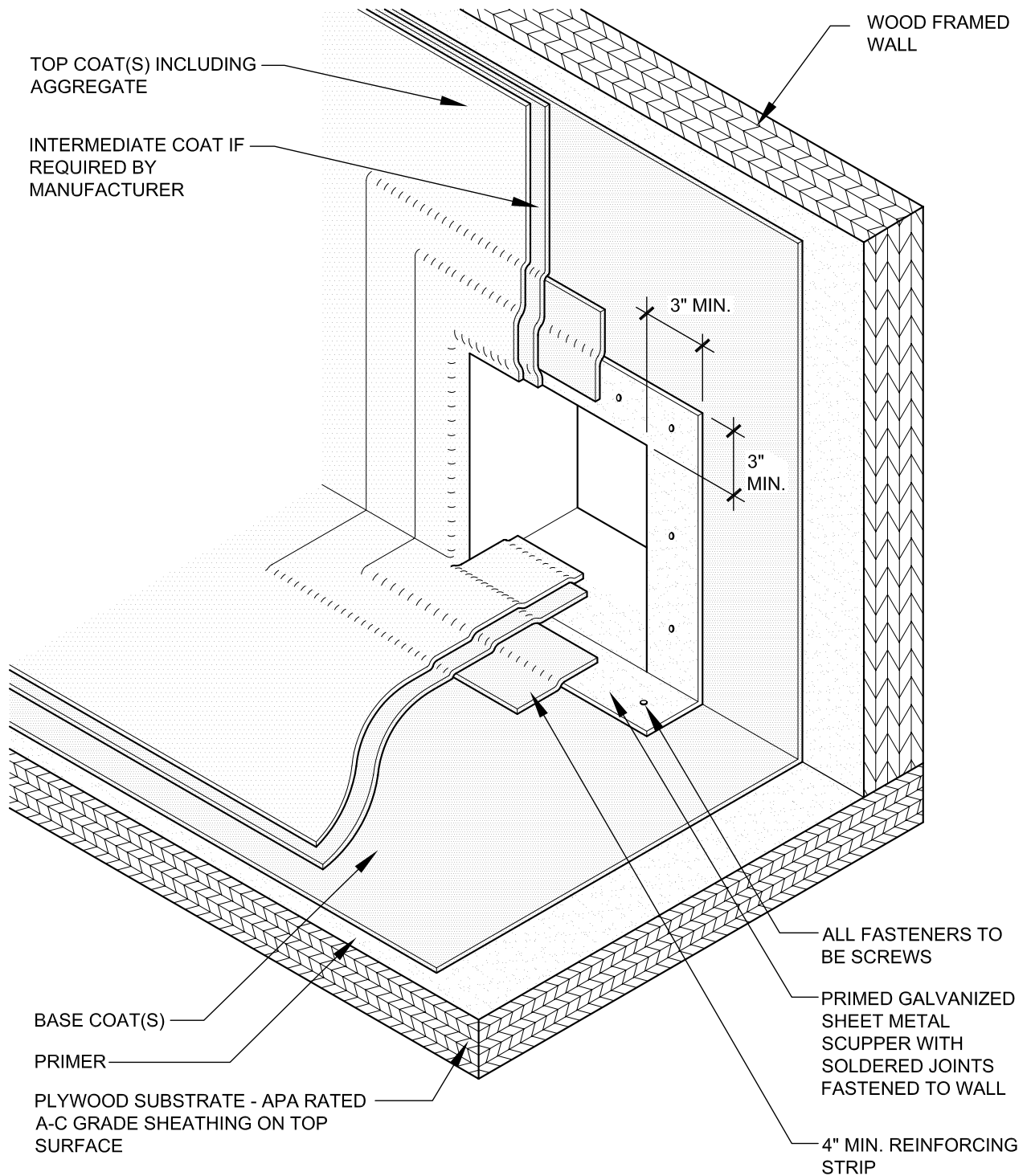
	<b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b>	<b>PEDESTRIAN-TRAFFIC-BEARING WATERPROOFING MEMBRANE - PERIMETER EDGE</b>
2005	NOT DRAWN TO SCALE	<b>WP-46</b>



NOTE:

1. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PEDESTRIAN-TRAFFIC-BEARING WATERPROOFING MEMBRANE - FLASHING AT WALL</b></p>
<p><b>2005</b></p>		<p>NOT DRAWN TO SCALE</p>
		<p><b>WP-47</b></p>



**NOTES:**

1. BASE, INTERMEDIATE AND TOP COATS EXTEND INTO THE SCUPPER BOTTOM.
2. SEE INTRODUCTION TO THE WATERPROOFING CONSTRUCTION DETAILS FOR ADDITIONAL INFORMATION.

	<p><b>NATIONAL ROOFING CONTRACTORS ASSOCIATION</b></p>	<p><b>PEDESTRIAN-TRAFFIC-BEARING WATERPROOFING MEMBRANE - SCUPPER DETAIL</b></p>
<p><b>2005</b></p>	<p><i>NOT DRAWN TO SCALE</i></p>	<p><b>WP-48</b></p>

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