METAL CONSTRUCTION ASSOCIATION

Metal Roof Installation Manual

Chapter 10: Roofing Design

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Chapter 10: Roofing Design

Chapter Contents

10. INTRODUCTION

This chapter introduces the installer to major roofing design concepts and shows how they relate to the actual work the installer must perform. An installer with a working knowledge of these topics will have three major advantages.

The first advantage is the understanding of *how* each part of the installation process relates to, and affects, these key design areas.

The second advantage is the understanding of *why* specific fasteners, materials, and methods must be used. This includes the spacing and quantity used, as well as the type, or style, specified in the installation.

Figure 10-1
The Use and Variety of Metal Roof Designs Are Appealing

The third advantage a knowledgeable installer will have is the ability to make informed decisions during an installation. Every installation has substitutions, modifications, and unique situations that must be addressed by an installer. Understanding these concepts will enable an installer to deal with each issue in a way that will not jeopardize the installation. The knowledgeable installer may make decisions which equal, or in some cases, exceed, the original design requirements. If a situation does arise that causes concern to an installer, he/she will have the understanding to knowledgeably communicate the issue in an effective manner. Such decisions often occur when there are difficult trim situations, stripped-out fasteners, repairs, or additional roof-mounted equipment to be installed. Additional situations are created when modifications are required by other trades, like plumbers, electricians, and HVAC tradesmen.

Chapter Design

Each design concept will be briefly presented, along with the key principles and general considerations a designer needs to follow in order to provide the customer with a roof which meets their specifications. Following the brief overview, installer-specific material will be presented which will show how the installer's work relates to this concept.

10.1 Features and Benefits of Metal Roofing

Metal has always been considered a premium roofing material. The extremely long life expectancy of metal roofs has always been a positive attribute, while high initial cost has been a major detractor. The weight advantage of a metal roof makes it an attractive option, either as a new or a replacement roof. The relatively light weight of the metal roof requires less structural support, reducing new build cost, and may eliminate the removal of an older roof, saving landfills, labor costs, and allowing the old roof to serve as insulation for the replacement metal roof.

Life cycle costs and environmental concerns have grown to become major factors in roofing decisions. As a result, the metal roof has grown in popularity in both residential and commercial applications. As seen in Figure 10-1, the use and variety of available styles and materials are appealing. Tax incentives, rebates, and energy cost savings have encouraged many building owners to make the change to a metal roof.

All these incentives, coupled with the growth of metal roof applications, are both a blessing and a challenge for today's installer: a blessing that the future looks bright as a career path, but a challenge because many of the advantages of a metal roof depend upon proper installation. Today's installer is challenged by an ever changing selection of tools, fasteners, sealants, adhesives, methods and procedures from a growing list of manufacturers. An understanding of basic roof design will enable an installer to evaluate these choices in timely manner and make an appropriate choice.

10.2 Uplift

Wind always produces stress on the roof system. Most of this stress is in the form of an upward pull or suction on the finished roof. This phenomenon is called wind uplift. It is the same effect which takes place on an airplane wing, and allows it to lift off the ground. This stress is dependent on wind speed, but varies at different areas of the roof. These are called wind zones and are identified in Figure 10-2. These areas represent the weakest areas of the roof structure affected by these stresses, and most likely the first to fail. Once these areas begin to breakdown as illustrated in Figure 10-3, significant damage is likely to follow.

A roof must not only be designed to sustain typical climate conditions, but also the likelihood of significant wind conditions. The designer uses historical climate data for the area, engineering formulas, and safety factors in calculating the stresses a roof is likely to experience. With this data, the designer will determine the proper fasteners, clips, spacing, and locations necessary for the installation.

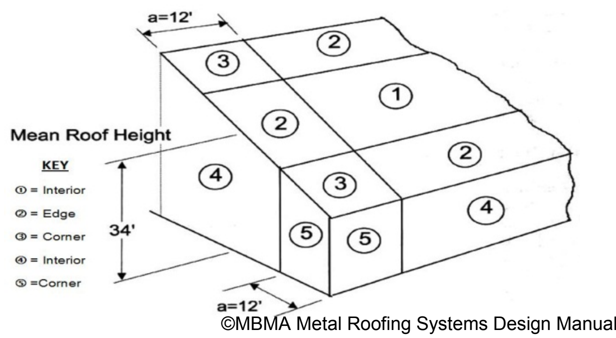

Figure 10-2
Wind Zone Locations of a Roof

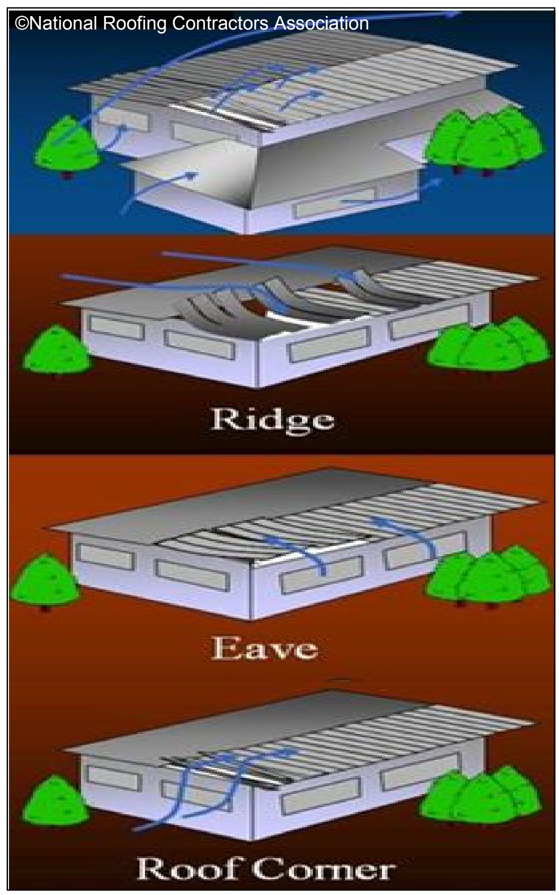

Figure 10-3
Potential Areas of Roof Wind Damage

Fasteners and clips are critical to the roof's ability to withstand the uplift forces, and are considered the weakest link. Fasteners are tested and evaluated on a pullover factor (where the panel material is pulled over the fastener) as well as pullout strength (the fastener pulls up and out of the material). These forces are illustrated in Figure 10-4. Clips are tested on their pull-up strength, and the strength of the portion of the clip which overlaps and secures the roof panel. This is why the proper size, quantity, and spacing of the fasteners and clips must always be used.

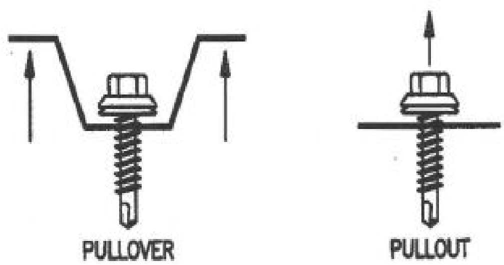

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Figure 10-4
Fastener Pullover and Pullout Factors

A well-designed metal roof system is better able to withstand extreme wind loads than any other roof system. Experience has shown that a properly designed and installed metal roof outlasts other roof products in severe wind conditions. It is the roof of choice in hurricane prone areas. Metal roofs can be constructed to meet the highest wind uplift ratings from UL (Underwriter Laboratories).

The life of a metal roof is literally "in the installer's hands" as fasteners, clips, sealant, and adhesive are applied. An installer needs to understand the various wind zones on a roof. These areas most likely will require additional fasteners and clips. The spacing of the fasteners may be different (typically closer) than the other roof areas and may require additional underlayment and sealant.

Other factors also control installation details. Government standards and requirements from federal, state, and local authorities may be different from the recommendations provided by the manufacturer. There are also designated "Special Wind Regions" (Figure 10-5) where additional special rules apply to all installations. This means an installation in one town may, indeed, need to be installed differently than a nearly identical job installed in a nearby location.

The effects of wind also vary with altitude, the distance off the ground. A 50 mile per hour wind on the ground will be much stronger several stories higher. Geographical features like mountains, coasts, and other conditions will also vary the wind loading of the roof and possibly require different installation requirements.

10.3 Energy Efficiency

A roof has a significant impact on the energy efficiency of a building. The roof could be considered a weak spot when a structure's energy efficiency is considered. Interior heat rises to the roof, while the roof, exposed to the sun, absorbs additional heat from solar energy. The roof must keep rain, wind, moisture, and outside material from entering the shelter, while allowing ventilation within the structure. A metal roof, however, can be a superior choice when considering the energy efficiency benefits of various roof materials.

The key concept behind any definition of energy efficiency is that of "doing more with less." When a metal roof is properly designed and installed, it becomes a key component of any energy efficient structure.

As a result, a term has been created to designate a roof which significantly impacts, in a positive way, the energy usage of a building. A roof of this type is called a “cool roof."

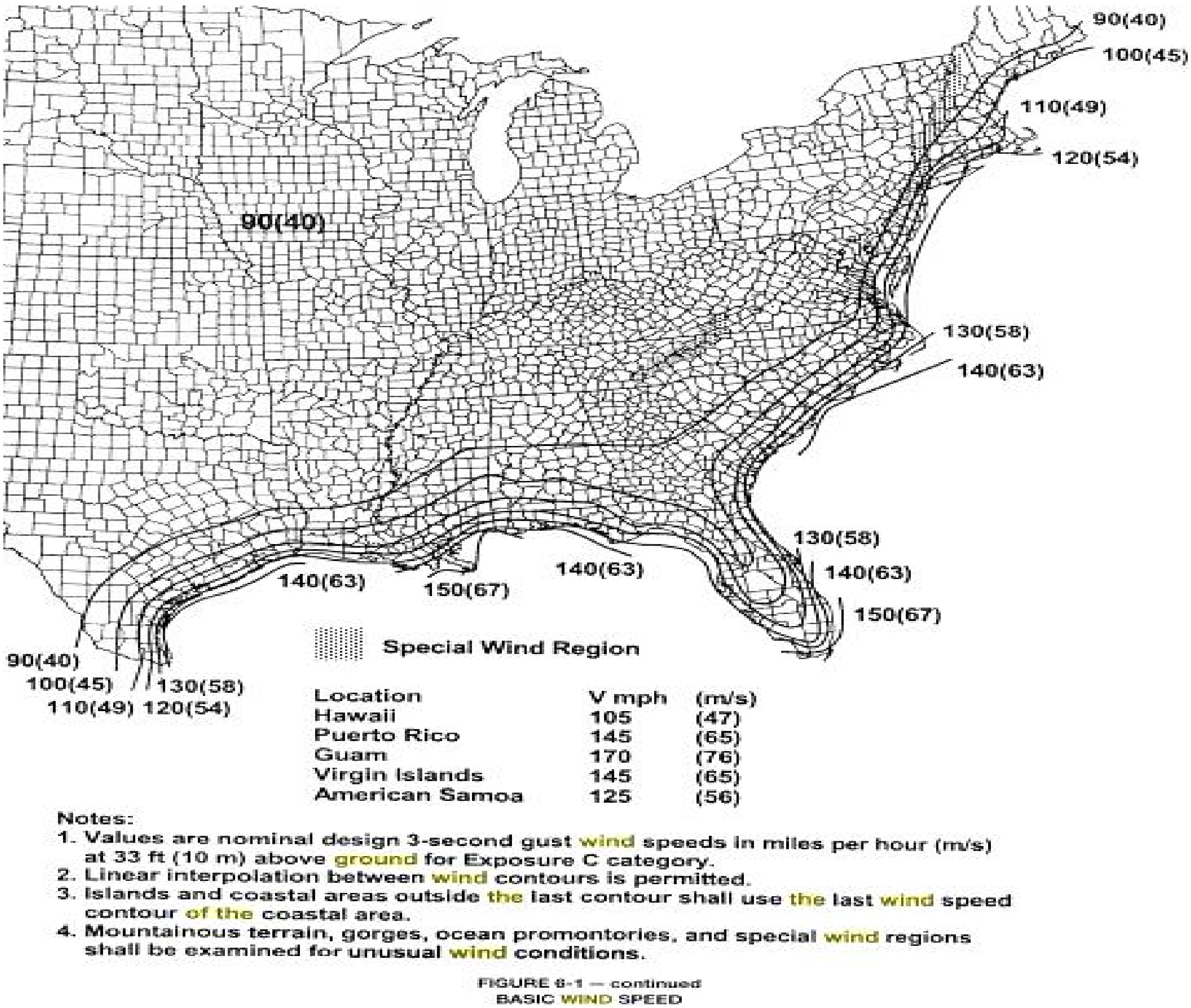


Figure 10-5
Example of Wind Zones

A cool roof is designed and installed to help avoid unwanted heat build-up inside the building and to help ensure maximum energy conservation.

Energy efficiency within a metal roof system is achieved through several design considerations. Selection of a "cool" color helps reflect thermal energy, reducing the cooling needs of the building. Ventilation and insulation of the roof system provide additional energy efficiencies and lower energy costs.

10.3.1 Cool Roof Colors

The color of a roof is a factor in determining the thermal characteristics of a roof. Darker colors tend to absorb more thermal energy (heat), while lighter colors tend to reflect more thermal energy and remain cooler. This becomes a design consideration for the ventilation and insulation required for the roof, but also has an effect on the life of the roofing material itself.

The term "cool roof" has to do with energy efficiency more so than appearance. An installer will benefit from a basic understanding of two properties related to cool roof performance: solar reflectance and thermal, or infrared, emittance.

Solar Reflectance

Solar reflectance, as illustrated in Figure 10-6, is defined as "the ratio of the reflected flux to the incident flux.[1]" In other words, the number given for the solar reflectance of a roof product will be a decimal number less than 1, which represents the fraction of thermal energy reflected off of the product. For example, a white painted metal roof is considered a "high" reflectance material and has a value around 0.70 (a.k.a. 70 percent) meaning that only 30 percent of the thermal energy from the sun is retained by the roof.

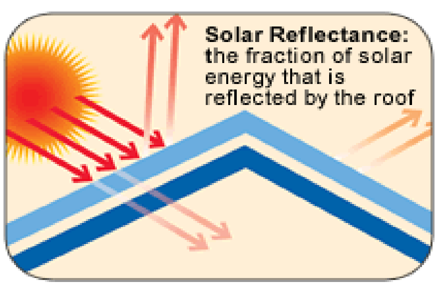


Figure 10-6
Solar Reflectance

The solar reflectance rating of the material is affected not only by the color of the material, but by other factors as well. One of those factors is the sheen, or luster, of the finish.

The "shinier" the finish, the more energy reflected; the "flatter" the finish, the more energy absorbed by the panel. Roof design, installation, and roof aging all affect the reflectance of roof material.

The U.S. Environmental Protection Agency (EPA) administers its ENERGY STAR Roof program under which manufacturers will be allowed to use the ENERGY STAR Label on reflective roof products which meet the EPA's strict performance requirements for solar reflectance. For example, to become ENERGY STAR qualified, low slope roofs (slopes of 2:12 or less) must have an initial solar reflectance equal to or greater than 0.65 (65%), a solar reflectance equal to or greater than 0.50 (50%) three years after installation (under normal conditions), and the manufacturer warranty for the reflective material must be equal in all respects to that offered for comparable non-reflective products. Refer to Table 10-1 for an example of a manufacturer's color chart showing solar reflectance values.

However, steep slope roofs (slopes greater than 2:12) must have an initial solar reflectance equal to or greater than 0.25 (25%), a solar reflectance equal to or greater than 0.15 (15%) three years after installation (under normal conditions), and the manufacturer warranty for the reflective material must still be equal in all respects to that offered for comparable non-reflective products.

Thermal Emittance

The concept of thermal emittance is illustrated in Figure 10-7. It is defined as "the ratio of the radiant heat flux emitted by

[1] According to the Cool Roof Rating Council (CRRC)

a sample, to that emitted by a black body radiator at the same temperature.[2]" In other words, the number given for the infrared emittance of a roof product is a decimal number less than 1, which represents the fraction of heat that is radiated *from a material* to its surroundings. For example, a low emittance product like unpainted Galvalume® has a value around 0.10 (10 percent).

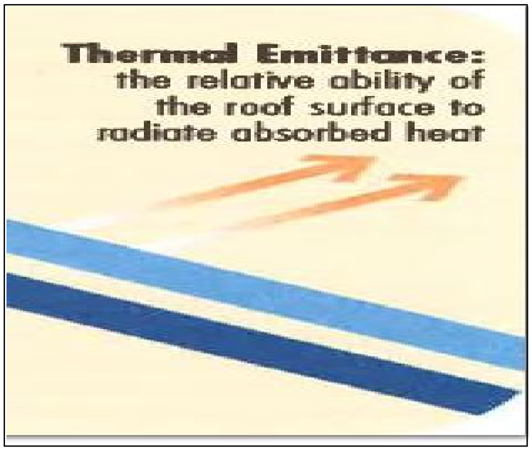


Figure 10-7
Thermal Emittance, Radiating Absorbed Heat

The emittance value is a critical measurement used around populated areas when evaluating the phenomenon known as the "Urban Heat Island" effect. This effect is used to explain how urban, populated, developed areas consistently tend to maintain warmer temperatures in comparison to rural undeveloped areas within the same geographic locale.

Table 10-1 lists an example of one manufacturer's color chart listing the solar reflectance and thermal emittance of various colors. Remember: the higher the number, the more the roof reflects and emits thermal energy.

[2] According to the Cool Roof Rating Council (CRRC)

SPECIFICATION CHART

The colors below are available in the listed materials and gauges.[1]

Color	Color #	Steel Gauge			Aluminum					Solar Reflectance	Thermal Emittance	Solar Reflectance Index
		29	24	22	0.032	0.040	0.050	0.063	0.080			
Classic Bronze	01		X	X	X	X	X	X	X	0.09	0.85	2
Black	02		X	O	X	X	X			0.06	0.85	-2
Medium Bronze	03		X	X	X	X	X	X		0.32	0.85	32
Chocolate Brown	04		X	O	X	X	X			0.27	0.85	25
Concord Cream	05		X	O	X	X	X			0.65	0.85	78
Sandstone	06		X	X	X	X	X	X		0.57	0.85	66
Redwood	07	X	X	O	X	X	X			0.21	0.85	18
Mission Red	08	X	X	O	X	X	X			0.32	0.87	33
Sierra Tan	09	X	X	O	X	X	X			0.35	0.87	37
Ascot White	10		X	O	X	X	X	X		0.70	0.88	85
Forest Green	11	X	X	X	X	X	X	X		0.30	0.87	31
Patina Green	12		X	O	X	X	X			0.43	0.85	47
Dove Grey	13		X	O	X	X	X	X		0.48	0.85	51
Siam Blue	14		X	O	X	X	X			0.34	0.85	35
Rawhide	15		X	O	X	X	X			0.55	0.85	64
Rocky Grey	16	X	X	O	X	X	X			0.29	0.88	30
Brite Red	17	X	X	O	X	X	X			0.51	0.85	58
Regal Blue	18		X	O	X	X	X			0.25	0.84	23
Teal	19		X	O	X	X	X			0.26	0.88	26
Slate Grey	20	X	X	X	X	X	X			0.36	0.87	39
Slate Blue	21		X	O	X	X	X			0.31	0.86	31
Mint Green	22		X	O	X	X	X			0.35	0.86	37
Boysenberry	25		X	O	X	X	X			0.28	0.85	27
Bone White	26	X	X	X	X	X	X	X	X	0.70	0.87	85
Hartford Green	27		X	O	X	X	X			0.25	0.85	23
Char Brown*	29	X								0.09	0.85	2
Hemlock Green	30		X	O			X			0.30	0.86	30
55% Al-Zn Coated Steel with Acrylic Coating	97		X	O						0.68	0.14	58
Mill Finish-Aluminum	99				X	X	X	X	X	--	--	--
Premium Finish												
Coppertone	23	X	X	O	X	X				0.50	0.86	57
Antique Patina	24		X	O	X	X				0.26	0.86	25
Silversmith	28		X	X	X	X				0.47	0.81	51
Champagne	31		X		X	X				0.55	0.79	62
Clear Anodized	70				X	X	X			0.77	0.70	92
Dark Bronze Anodized	71				X	X				0.15	0.77	6

X = Available Material and Thickness

O = Available with minimum quantities and lead time

*= Low Gloss Finish

Table 10-1
Example of Manufacturer Color Chart
Note - Solar Reflectance and Thermal Emittance Values

A common misconception in applying these terms is the assumption that the highest solar reflectance and the best infrared emittance ratings are the right selection for every project. This is simply NOT true. There are different climate zones, and not all will benefit from the high reflectance and emittance of some roofing materials. In fact, the high ratings may be detrimental if installed in certain climate areas. It is important that the specific needs of the building and the location be properly evaluated before specifying the material. This is a job typically done by an architect or design engineer.

10.3.2 Ventilation

Ventilation is the exchange of air, in, around, and throughout the roof system. Proper ventilation of the roof is necessary for meeting the design specifications of the roof, as well as maintaining and sustaining a long life to the roof system. Ventilation is very important to a metal roof system in order to minimize the effects of condensation. Ventilation items are discussed in Section 8.1, *Roof Vents-Types and Applications*, while condensation details are covered in more detail within Section 10.4 of this chapter. Additional purposes of roof ventilation will vary based on climate conditions.

In cold climates, the primary purpose of ventilation is to maintain a cold roof surface. This helps control the formation of ice dams from melting snow and also vents any moist air which escaped from the conditioned portion of the shelter to the roof and attic areas, to the outside, avoiding condensation on the metal roofing.

In hot climates, the purpose of ventilation is to expel solar heated air from the roof and attic area, reducing the cooling load of the structure.

The amount of ventilation required may be determined by applicable building codes or unique design considerations, such as high humidity, agricultural use, etc. Roof ventilation is typically provided through eave and ridge vents, as well as above sheath ventilation. This air flow is illustrated in Figure 10-8.

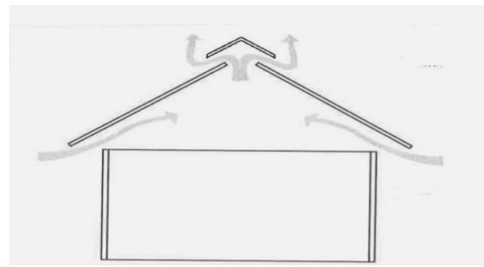


Figure 10-8
Typical Air Flow for Roof Ventilation

Eave

Ventilation along the eave area of the roof can be considered as intake, or incoming air. As outside air enters through the vent, it travels upward towards the ridge of the roof. Eave ventilation can be supplied in several ways:

- Entire "soffit style" panels with preformed vent openings.
- Pre-formed vent openings in eave trim molding.
- Separate vent covers which require a vent opening to be cut out and a vent cover secured over the opening.

Examples of eave vent styles are illustrated in Figure 10-9, but the exact quantity, style, and location of these vents will be determined by the designer.

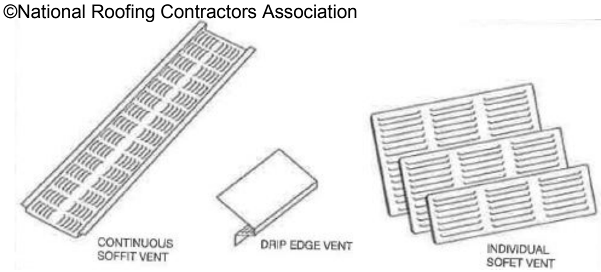


Figure 10-9
Eave and Soffit Vent Examples

Ridge

Ridge vents are considered exhausts, or outgoing air. Ridge vents have the advantage of momentum. Since heated interior air tends to rise; the ridge vent provides a convenient means for this heated air to escape.

Styles and types of ridge vents are too varied to show an example of each type, but several common ridge and gable vent types are illustrated in Figure 10-10. Common ridge vents include types which run the entire length of the roof, while other ridge vents are smaller, rectangular, or square units which mount near the ridge on either, or both sides, but not directly over the ridge crest. Ridge vents may use forced ventilation, or depend on the natural rise of the heated air through the other vents designed to bring in fresh air.

Above Sheathing Ventilation

Many metal roof profiles and installation methods automatically provide above sheathing ventilation. Ventilation channels naturally occur when a panel profile includes major and minor ribs, and side seaming methods involve some form of overlap joint. Although usually blocked at the eave to prevent birds, insects, and dirt from entering, these ventilation paths as illustrated in Figure 10-11 provide an air flow to the underside of the roof panels. This air flow reduces the formation of condensation and also provides a means of escape and evaporation for any condensation to evaporate and be removed.

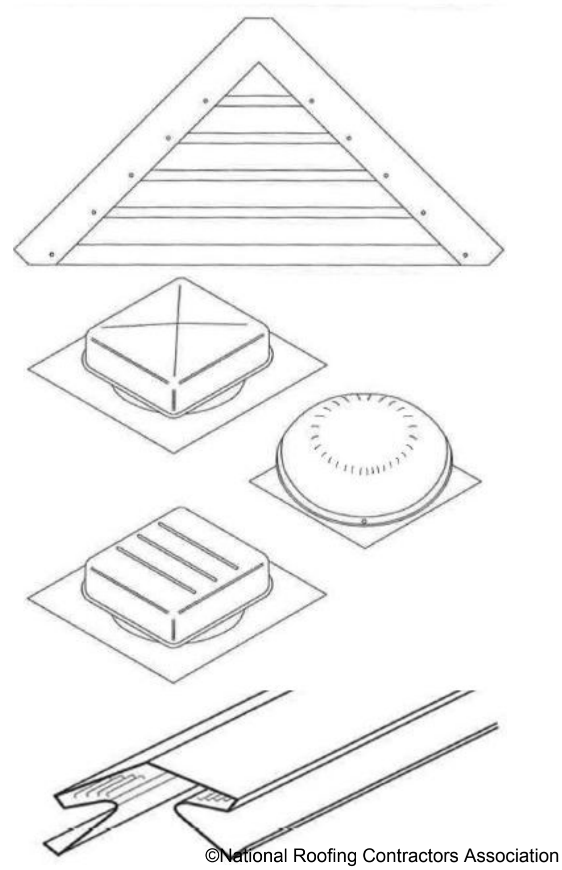


Figure 10-10
Examples of Common Ridge and Gable Vent Styles

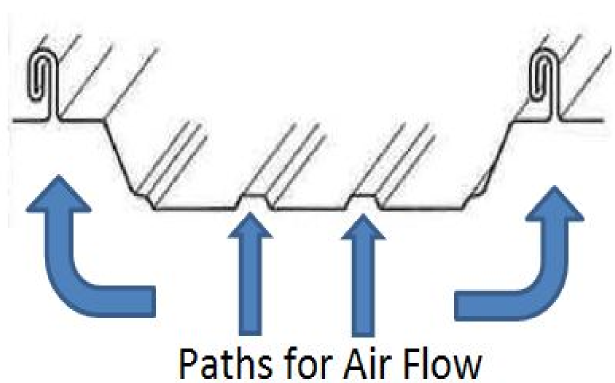


Figure 10-11
Ventilation Provided by Panel Profile

As shown in Figure 10-12, when installed over purlins, additional ventilation areas are formed.

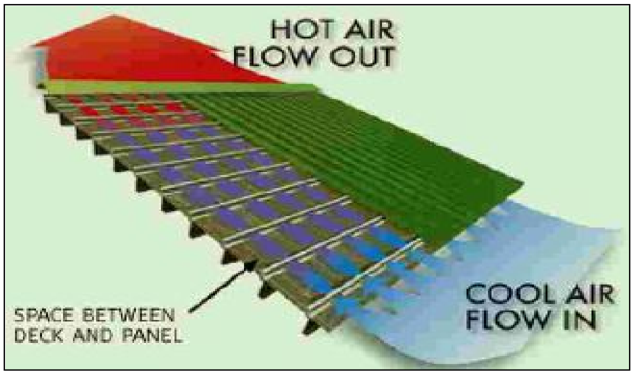


Figure 10-12
Additional Ventilation Areas Provided By Purlins

10.3.3 Insulation Requirements

One of the purposes of a roof is to isolate and protect the interior environment of a structure from temperature changes in the outside environment. This is usually accomplished by some form of insulation. This section will discuss two common types of insulation associated with metal roof systems: rigid and continuous. Discussion will begin with a description and the characteristics of the material, then provide typical installation guidelines.

Vapor retarders are not insulation, but are associated with insulation because they are installed at the same time and in direct contact with the insulation. Vapor retarders are often manufactured already attached to the insulating material itself. This is often the case in roll-type insulation (as noted in Figure 10-18). Vapor retarders are critical to the prevention of condensation. They are most effective when installed on the warm side of the building insulation. Vapor retarders are thin and easily torn. Often, when the vapor retarder is separate and installed independently of the insulation, special fasteners are used which provide more surface contact for securing the material.

If the installation requires a vapor retarder, keep the following key points in mind:

- Make sure the vapor retarder is installed on the correct side of the insulation, normally the warm side.
- Properly seal all side laps, end laps, and any penetrations to prevent the escape of warmer, moist air. This is usually done by taping.
- Vapor retarders are easily damaged, punctured, or torn. Any damage should be repaired when it occurs.

It should be noted that the ***amount*** of insulation required on any installation may vary. Code requirements, climate conditions, and structural use are all factors which are used to determine both the type ***and*** the amount of insulation necessary. Always make sure the correct material is on-hand and ready to use before beginning an installation.

Code Requirements

Code requirements are established to provide uniformity on minimum design and installation practices. Following "the code" avoids inconsistencies arising from differing approaches used by architects, builders, and installers. Some code requirements were developed through government legislation at federal, state, and local levels, while other codes and standards were established through the cooperative efforts of nationally recognized organizations like the MCA and others. Certain code requirements will be mandatory on an installation solely due to geographical location, structure use, funding requirements linked to construction details, or simply the customer's desire.

Installer Note on Fasteners

Whenever insulation is used as part of a metal roof installation, make sure the proper fasteners and clips are available and used.

Most insulation does ***not*** provide an adequate surface with enough strength for attaching the roof clips and fasteners. Depending on the installation, the following fastener differences may apply:

- **Longer fasteners** may be necessary to reach *through* the insulation and *into* the substrate.
- **Different fasteners** may be necessary if installing into additional supporting metal framework instead of substrate.
- **Fasteners of a different material** may be necessary if installing into treated wood support members.
- **Additional components,** such as bearing plates, battens, purlins, or channels, may be required.

Remember, code requirements are considered minimum standards; are mandatory; and may involve such things like the use, or non-use, of certain materials, the spacing of fasteners, and clearances. Also consider that, although adherence to a code may not be required in certain installations, many of the details within the code should voluntarily be obeyed in order to follow the best practices used within the industry.

Rigid

Rigid roof insulation can be installed over a continuous (solid) or closely spaced deck substrate. The type of insulation, and vapor retardant requirements, will depend on design and code requirements. The potential for condensation may also require a ventilation space and/or slip sheet.

Structural metal panels installed over a solid substrate commonly use a type of rigid insulation as shown in Figure 10-13. This rigid foam insulation is made from polyiso-cyanurate (Polyiso), extruded polystyrene, expanded polystyrene, or fiberglass insulation. There are several methods of attaching the metal roof panels over top of the rigid insulation.

One method uses purlins, metal hat channels, or wood nailers, as battens fastened to the solid deck. These additional pieces are installed perpendicular to the roof slope (parallel to the eave). The roof panel attaches to the purlins, channels, or nailers. The method illustrated in Figure 10-14 uses z-purlins for panel attachment.

Figure 10-13
Installation of Rigid Polyiso Insulation

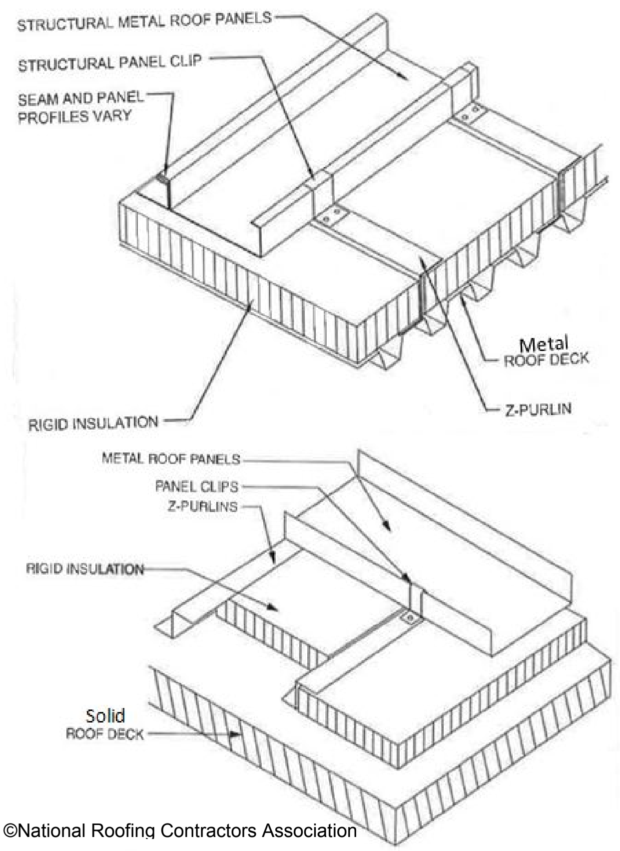


Figure 10-14
Insulation over Solid Deck with Purlins

The battens are the same thickness as the rigid insulation, or a bit thicker, to provide a ventilation cavity. The batten material used should have longevity similar to that of the metal roof being installed. Batten material should have a life expectancy of at least that of the roof material.

Where an increased R-Value is required, a second layer of insulation may be installed over the first layer. This second layer adds additional battens, installed perpendicularly to the first layer of battens, and a second layer of rigid insulation. This added insulation not only increases the overall thermal insulation of the roof, but reduces any thermal bridging which may have arisen from gaps and spaces in the first layer of insulation.

When installing this second layer of battens, the connection between the intersecting battens and the roof deck requires special attention. This intersection must be designed to withstand the designed wind-uplift load of the roof. Installation of the first layer of battens to the roof deck surface also requires adequate wind-uplift strength, especially where battens are spliced.

Another method (Figure 10-15) uses bearing plates to install roof panels over the rigid insulation. The bearing plate supports the clip, preventing it from cutting into the foam. There are two different methods of attaching the clip and bearing plate to the roof. One method uses fasteners which go through both the clip and the bearing plate, attaching into the deck surface. The other uses fasteners to attach the bearing plate to the deck surface, while separate fasteners attach the clip to the bearing plate.

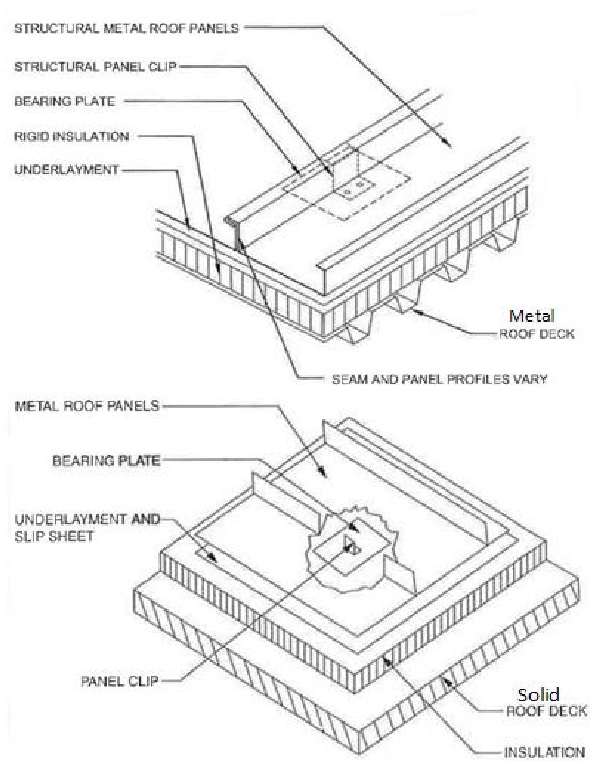


Figure 10-15
Rigid Foam with Bearing Plate and Solid Deck

The potential for condensation to occur between the metal roof panel and the rigid insulation should be addressed during the installation. An underlayment should be installed on top of the rigid roof insulation in a manner similar to that used on a solid deck and illustrated in Figure 10-16.

Continuous

Roll insulation is normally installed over open purlins or other spaced structural members. Typically made from glass-fiber, this insulation normally has a facer (as shown in Figure 10-19) on one side made from polypropylene, vinyl, or aluminum. The facer acts as a vapor retarder and, depending on the facer material, also provides an attractive finished appearance to the interior side of the roof surface.

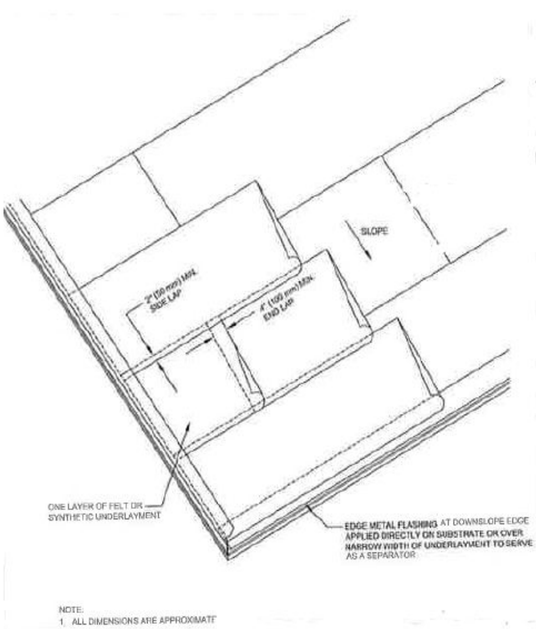


Figure 10-16
Underlayment over Rigid Insulation

There are four general methods of installing roll insulation over open framing. These methods apply for both through fastened as well as concealed fastener type systems.

Method 1 (Figure 10-17) - The insulation is rolled out, over the purlins and other structural members. The roof panel is then installed on top of the insulation. The insulation is compressed, especially where panel clips or fasteners are installed. This method can cause problems in cold climates. When compressed, the insulation value is decreased and may be reduced to the point where condensation can develop and cause dripping.

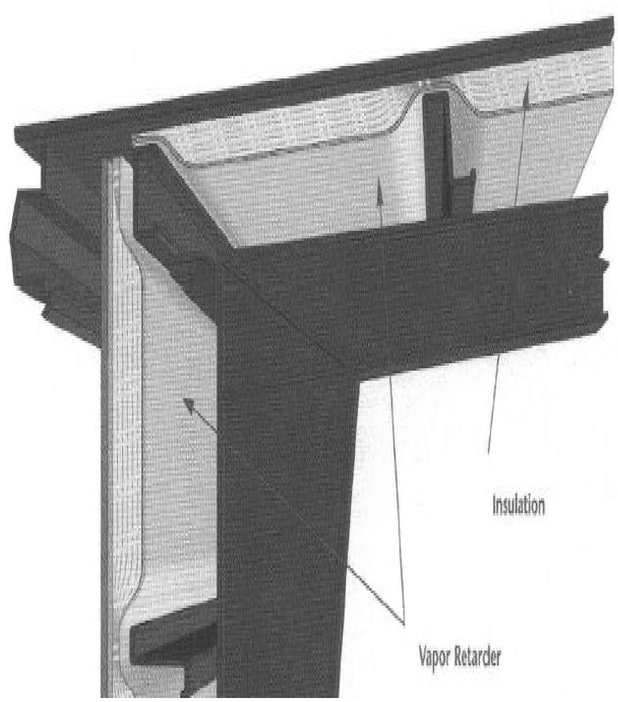


Figure 10-17
Roll Insulation over Purlins

Method 2 (Figure 10-18) - The insulation is installed <u>*between*</u> the purlins, from rake to rake, and the side tabs of the vapor retarder, if used, are overlapped and stapled or taped together for continuity. At purlins and other structural members, the vapor retarder tabs should be carried <u>*over*</u> the members, lapped and stapled or taped together. This method also creates reduced thermal insulation at the support members, and can cause condensation like the situation mentioned in Method 1.

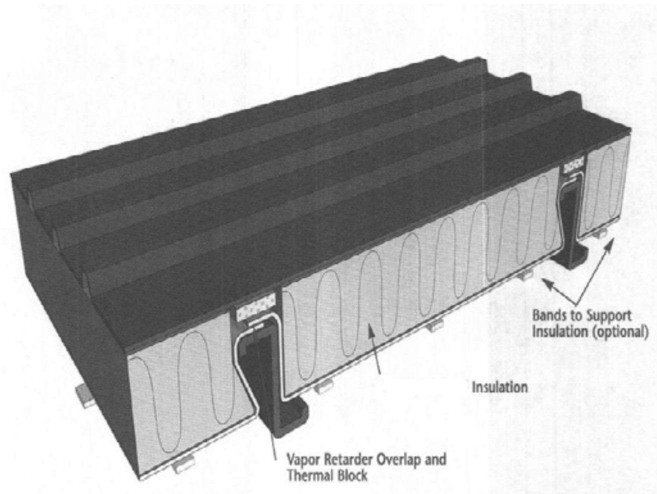


Figure 10-18
Roll Insulation Between Purlins

Method 3 (Figure 10-19) – The insulation passes over the purlins, or structural members, (as in Method 1) *and additional insulated thermal blocks* are placed at the purlin and structural member locations. The thermal blocks are placed between the metal roof panel and the insulation. These thermal blocks increase the insulating value in the compressed area, reducing the potential for condensation. They also serve a second purpose and act as a spacer block to prevent bulging of the roof panel where insulating material overlaps the members.

This is an improved version of Method 1. If additional insulation is required, a second, un-faced layer of insulation may be added. This second layer of insulation is typically installed perpendicularly to the roof slope or first layer of insulation.

Method 4 (Figure 10-20) – The insulation passes *between* the purlins, or structural members, *and additional insulated thermal blocks* are placed at the purlin and structural member locations. The thermal blocks are placed between the metal roof panel and the insulation. This is an improved version of Method 2.

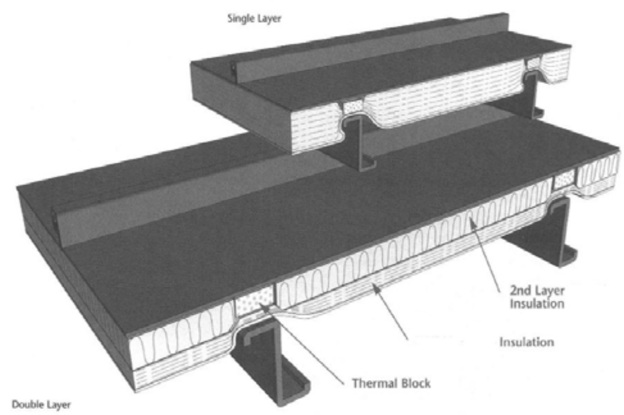


Figure 10-19
Roll Insulation over Purlins
Using Thermal Blocks

Different clips and fasteners may be necessary to adjust for the insulation and thermal block thicknesses. Through-fastened panels using thermal blocks and compressed insulation will have different fastener support characteristics than fasteners driven directly into the support member. The manufacturer of the roof system should be consulted to ensure the correct fasteners and clips are used.

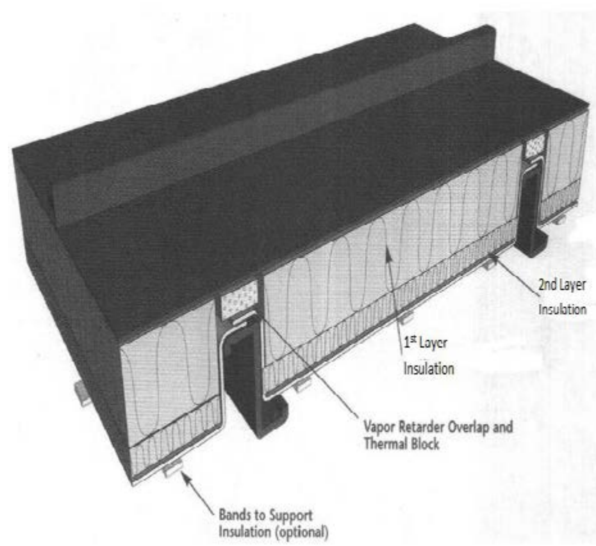


Figure 10-20
Roll Insulation Between Purlins
Using Thermal Blocks

10.4 Condensation Issues

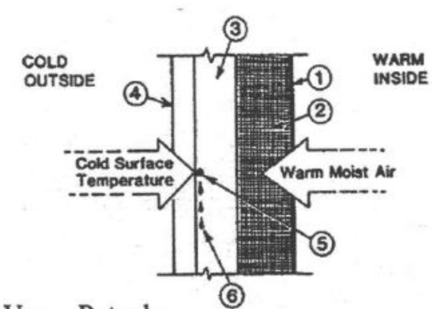
Condensation occurs when warmer, moist air comes in contact with cold surfaces, such as framing members and metal roof panels, or a colder region, such as an attic or crawl space. Warm air has the ability to hold more moisture than cold air. When this warm air comes in contact with cooler surfaces or areas, it loses much of this ability and drops of moisture (condensation) are formed. If this moisture collects on insulation, much of its insulating property is lost. Figure 10-21 illustrates this concept.

When installing any metal roof, the formation and removal of condensation needs to be addressed. Installation activities should focus on two condensation goals: to reduce and to prevent. *Reduce* the initial development of condensation and *prevent* any damage when condensation does occur.

Reduce the initial development of condensation

The major factor in eliminating and reducing the formation of condensation in the roof system is through proper ventilation. Ventilation is discussed in Sections 8.1 and 10.3.2. Refer to these sections for venting details. A related ventilation issue is controlling any warm moist air escaping into the colder areas or surfaces. Care should be taken to make sure that the correct type and amount of sealant is used, the proper type and amount of insulation installed, and that all joints are properly finished.

Vapor retarders are also critical in preventing the formation of condensation. They eliminate one of the key ingredients for condensation, warm moist air, from coming in contact with the cooler surface areas. Installers should note that vapor retarders are not used in all areas, and in some locations, may be detrimental in preventing condensation. Vapor retarders and their installation details were discussed in Section 10.3.3 along with insulation.



1. Vapor Retarder
2. Insulation
3. Cold (attic) region
4. Weather barrier (panel)
5. Dew point surface (Typical - can vary within wall cavity)
6. Condensation

Figure 10-21
The Formation of Condensation

Prevent damage from condensation

The major factor in achieving the second goal, preventing damage from any condensation which forms, comes from proper installation of appropriate roofing materials, specifically underlayments and slip sheets. This is especially important in leakage-prone areas like valleys, hips, and areas where penetrations to the roof are located, including roof jacks, flashings, and curbs.

10.5 Ice Dams

Icing conditions are never desired on a roof. Ice, icicles, and ice dams, as seen in Figure 10-22, present a danger to those below, and may potentially damage the roof. Ice dams also create pools of melted water.

Figure 10-22
Undesirable Ice, Icicles, and Ice Dams

This ponding often covers upslope portions of the roof, including joints, seams, and fasteners, which were not designed to withstand this condition. Ice can still form even when the roof temperature is above freezing. This is illustrated in Figure 10-23. Preparation for such events must take place during the installation of the roof.

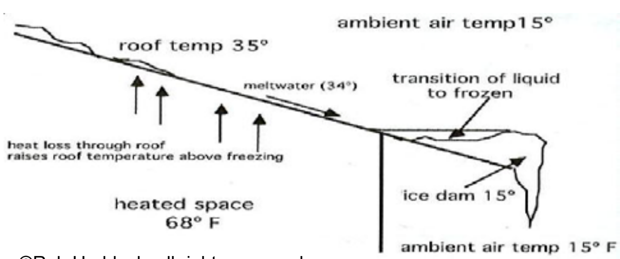


Figure 10-23
Ice Dam Formation on a Roof

In locations where the average temperature for January is 30º F or less (Figure 10-24), an ice-dam protection membrane should be installed. A typical ice-dam protection membrane uses a self-adhering polymer-modified bitumen membrane, in addition to standard underlayment and slip sheets.

Figure 10-24
Example of North America Temperature Chart
January Temperatures 30° F or Less

The ice-dam protection membrane should be applied starting at a roof's eaves and extending upslope a minimum of 24 inches *from the exterior wall line of a building*. For slopes less than 4:12 (18 degrees), a minimum of 36 inches is recommended. A typical ice dam membrane installation over an eave is illustrated in Figure 10-25.

Local code requirements, or locations where severe ice damming may occur, may require additional ice-dam protection. Examples of double layer applications are shown in Figure 10-26. Note the additional use of asphalt roofing cement or cold adhesive in the ice dam area.

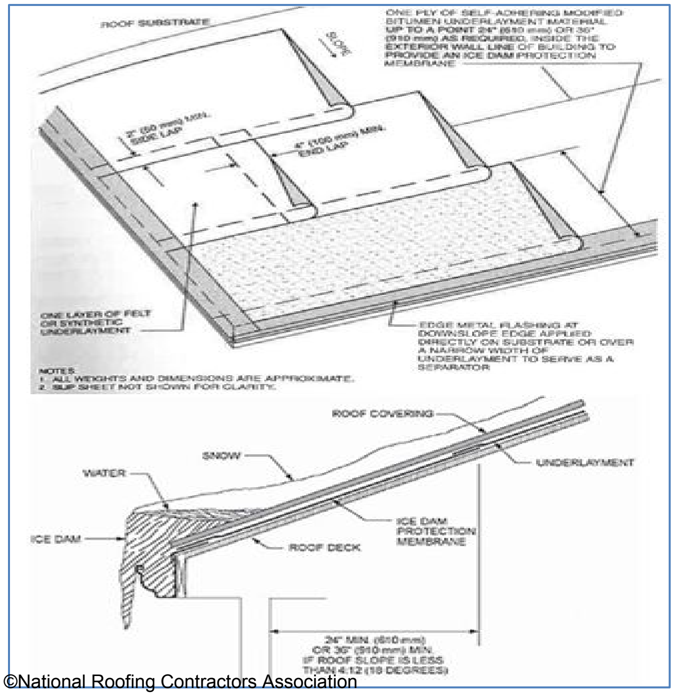


Figure 10-25
Typical Ice Dam Membrane Installation

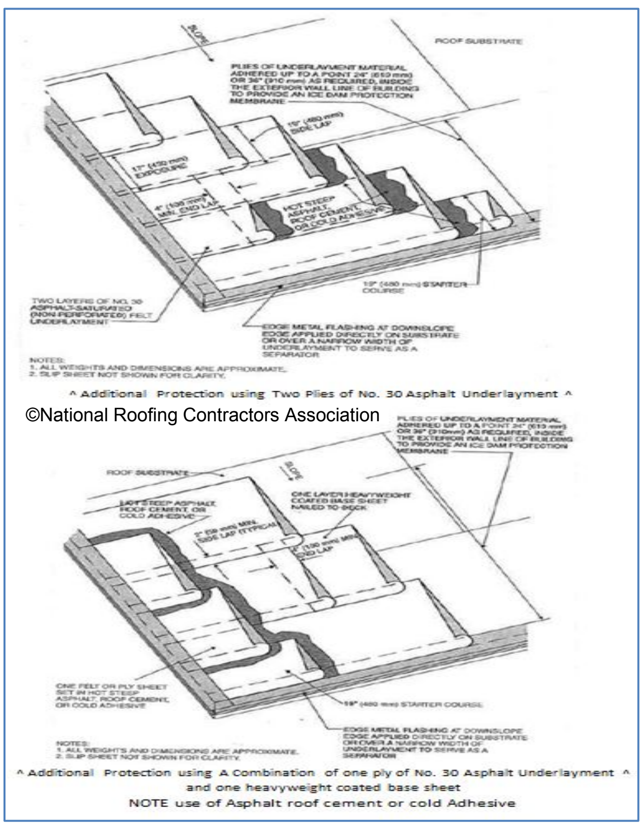


Figure 10-26
Additional Ice Dam Membrane Protection

10.6 Roof Underlayments

Underlayment (or "felt paper" as it is frequently called) is installed over the roof deck before the application of a metal roof system. An underlayment performs several primary functions: it provides temporary weather protection until the metal roof system is installed, acts as a separation between the roof membrane and the roof substrate, and serves as a secondary weatherproofing barrier if moisture infiltrates the metal roof panels.

For metal panel roof systems, metal shingles and metal shingle panels, a minimum of one layer of No. 30 asphalt-saturated felt should be applied horizontally in shingle fashion on roof decks having a slope of 4:12 (18 degrees) or more (Figure 10-27).

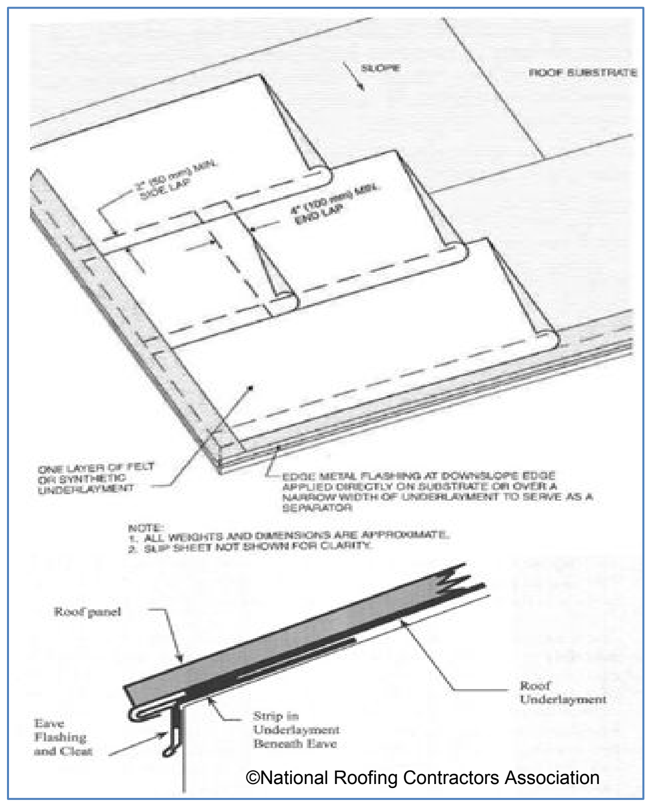


Figure 10-27
Typical Single Layer Underlayment Installation

For roof decks having slopes of 3:12 (14 degrees) up to 4:12 (18 degrees), a minimum of two layers of No. 30 asphalt-saturated underlayment should be applied horizontally in shingle fashion. Installers should note that alternative underlayment materials meeting ASTM requirements are a growing trend within the industry. A typical double-layer underlayment installation is illustrated in Figure 10-28.

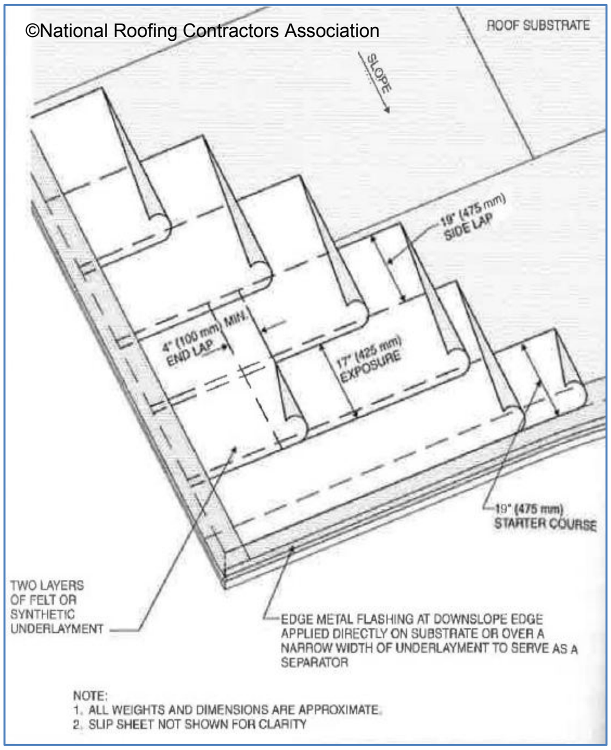


Figure 10-28
Double-Layer Underlayment Installation

Underlayments typically are not used with structural metal panel roof systems when intermittent supports are used to carry the roof systems. However, a continuous or closely spaced roof deck may use an underlayment.

Since underlayments serve as a temporary roof surface, fastening should be adequate to retain felts in place until panels are installed. Roofing nails are preferred over staples for attachment of underlayment. Because common organic felt will not completely seal nail holes, it is recommended that nailing patterns be performed using a minimal number of exposed fasteners, while still achieving the temporary function of holding felts in place until metal panels are installed.

For the same reason, one-inch synthetic cap nails, which increase the temporary wind resistance of felt, are preferred over increased nailing frequency. Commonly used underlayment fasteners are shown in Figure 10-29.

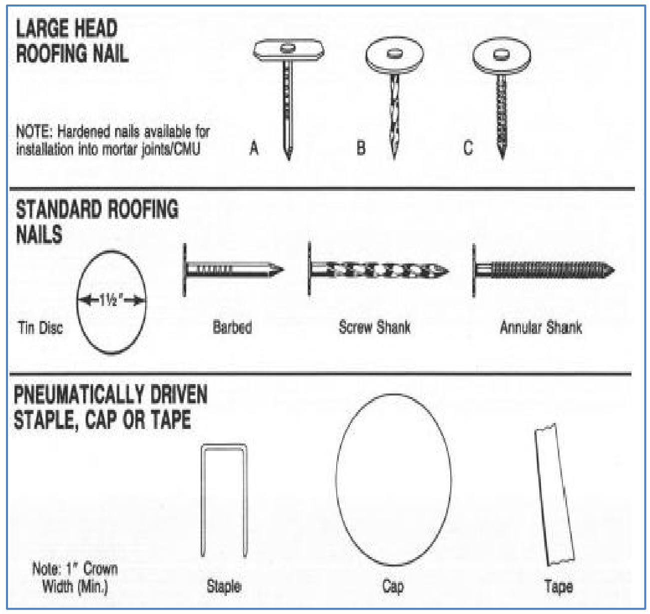


Figure 10-29
Underlayment Fasteners

A slip sheet may be installed over asphalt saturated underlayments for metal panel roof systems. Its purpose is to protect the underlayment from damage, and allow thermal movement of the panels. The slip sheet can be seen in Figure 10-30.

As the roof surface heats up, metal panels tend to stick to the softened asphalt underlayment. This results in the possible ripping and tearing of the underlayment material as the panels expand and contract due to temperature variation.

Figure 10-30
Slip Sheets Prevent Metal Roof Panels from Sticking to Underlayment, Preventing Rips and Tears

10.7 Thermal Movement

No matter how well designed, engineered, or attractive a metal roof appears, if it is not installed properly with respect to thermal movement, poor performance and damage will quickly occur. The important scientific facts are well known:

- When heated, materials expand.
- When cooled, materials shrink.
- Different materials expand and contract at different rates, and by different amounts.

Taking these scientific facts and applying them to metal roof installation results in several key points an installer needs to remember when installing a metal roof:

- The longer the panel, the more it will expand and contract.
- Different roof materials used on the same system will expand and contract differently.
- Every metal roof experiences large temperature swings. Typically, northern climates experience greater temperature swings than southern climates, often over 100° F.
- Panels should only be "pinned" in one location to allow for thermal movement.

In order to properly install a metal roof which allows for full and proper thermal movement, three factors need to be considered during the installation. The expected **amount of thermal movement**, the **point of fixity**, and **trim installation** are factors in determining the steps an installer must perform during the installation.

10.7.1 Calculating Amount of Thermal Movement

The amount of thermal movement a panel experiences depends on three factors:

- The material (C^e) (refer to Table 10-2)
- The length of the panel (L)
- The change in temperature (ΔT)

Metal Type	Coefficient of Thermal Expansion	Increase in 10 Foot Lengths per 100° F Temperature Change
Galvanized Steel	0.0000067 in./in./°F	.080 in.
Steel	0.0000067 in./in./°F	.080 in.
Terne	0.0000067 in./in./°F	.080 in.
Wrought Iron	0.0000067 in./in./°F	.080 in.
Monel	0.0000078 in./in./°F	.094 in.
Copper	0.0000094 in./in./°F	.113 in.
Stainless Steel	0.0000096 in./in./°F	.115 in.
Bronze	0.0000101 in./in./°F	.121 in.
Brass	0.0000104 in./in./°F	.125 in.
Aluminum	0.0000129 in./in./°F	.155 in.
Lead	0.0000151 in./in./°F	.193 in.
Zinc	0.0000174 in./in./°F	.209 in.

Table 10-2
Thermal Expansion of Materials (C^e)

The actual amount of change in panel length (ΔL) can be determined using the following formula:

$$\Delta L = L \times \Delta T \times C^e$$

(Δ means change)

Figure 10-31 illustrates this formula and other important considerations. The term ∆T ("delta T") means the change (∆ "delta") in temperature (T) the panel will experience. It is found by subtracting the lowest temperature from the highest temperature ($T_{high} – T_{low}$).

It is important to note that these temperatures are **NOT** the ambient, or air temperature, but rather the actual surface temperature of the panel. Actual roof temperature is always hotter than the ambient temperature during the day. The maximum high-end temperature (T_{high}) will be affected by the color of the panel and its solar absorption characteristics (lighter colors and high gloss finishes will be cooler than dark colors and low gloss finishes). A dark colored panel with low gloss at right angles to the summer sun can approach temperatures of 200° F!

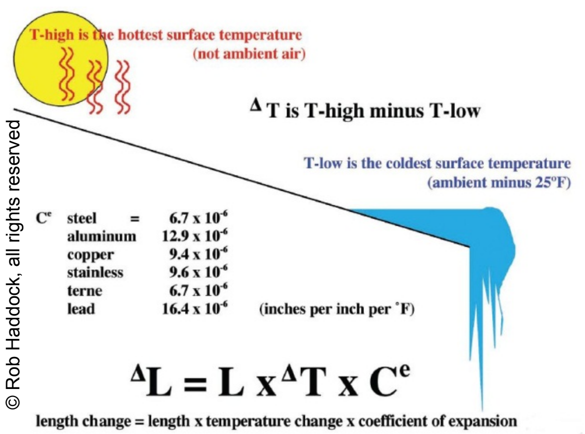


Figure 10-31
Thermal Movement of Common Roof Materials

The maximum low-end temperature (T_{low}) is also affected, especially with metal roof panels. In cold, winter, and night-time scenarios, the low extremes of surface temperature (T_{low}) can actually dip 25 to 30° F below ambient air. This is due to the principals of radiant energy. Skyward facing objects radiate heat energy towards the night sky. As this energy transfer occurs, the material loses heat reducing its temperature. It is this same effect that results in dew or frost forming on the ground, roof, or windshield of a car. It is a combination of these factors that can result in ΔT figures of close to 250° F on a metal roof. Even cold northern climates can experience a ∆T in well over 100° F!

This amount of movement is complicated by the fact that not all areas of the roof experience the same conditions at the same time. Some areas are shaded by trees, chimneys, and other structures, while others may be faded, dirty, or covered with debris.

The installer must remember that the roof will move with changes in temperature, and that any errors during installation may jeopardize the integrity of the system. Such errors may be panels out of alignment with the substructure, roof runs which are not straight, or excessive insulation between the panels and substructure. Thermal movement is addressed during the installation process by the proper use of clips, correctly fixing the panel to the substrate, and allowing for this movement when attaching trim and accessories.

10.7.2 Point of Fixity

One-piece and two-piece clips, like the ones shown in Figure 10-32, are used in most concealed fastener installations and allow for thermal movement of the panels.

While these clips perform well for thermal movement and uplift forces, each panel needs additional support and a point of solid attachment to the roof structure. This pinning, or "point of fixity," is necessary to withstand the gravity, and "drag loads" every roof experiences. Gravity attempts to "pull the panels off the roof," while drag loads, like snow, ice, and foot traffic on the roof panels, tend to "pull or slide" the panels downslope. Figure 10-33 shows the results of improper fixing, or pinning, of roof panels.

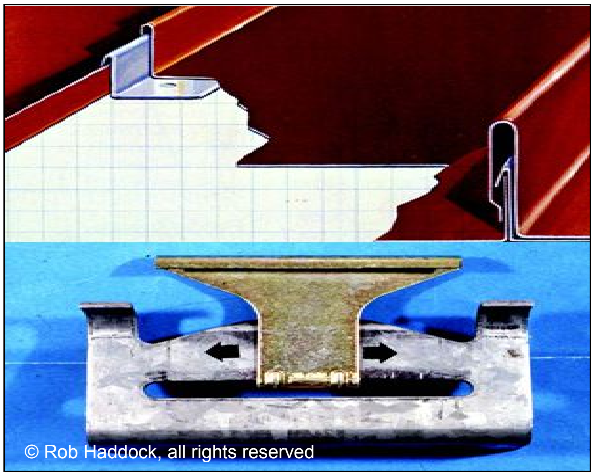


Figure 10-32
Concealed Clips Allow for Thermal Movement

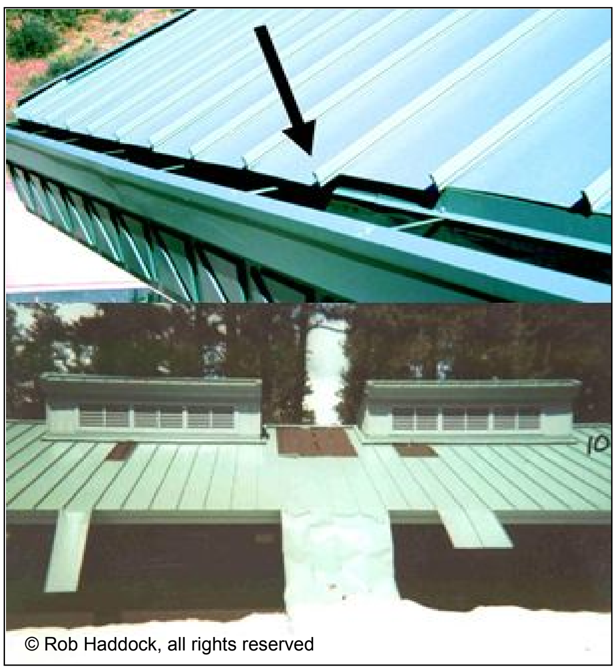


Figure 10-33
Roof Failure Caused by
Improper Fixing, or Pinning, of Panels

All the weight of these drag loads is transferred to the fixed pinning point of the panel. Three critical factors, plus additional safety factors determine the fastener required to fix the panels:

1. Roof slope (steeper slope = more stress)
2. Snow load (<u>design</u> load <u>*not*</u> <u>ground</u> snow)
3. Roof length, eave to ridge (longer = more stress)

The fasteners used to pin the panel often must withstand thousands of pounds of force.

Panel fixity can be accomplished by using one or more “fixed clips,” or by some method of direct panel fastening. With some panel designs, it is not possible to use a fixed clip, and traditional fasteners will be used, normally in an area of the panel which will be covered with trim or flashing material.

Using the correct <u>*fastener*</u> is critical to the safety and success of the installation. In addition, the panels must be pinned at the correct <u>*location*</u> for the design. The pinning, or fixing, of the panel is done at only *one* of three possible locations on the panel: the ridge, the eave, or mid-point. Figure 10-34 illustrates the three locations.

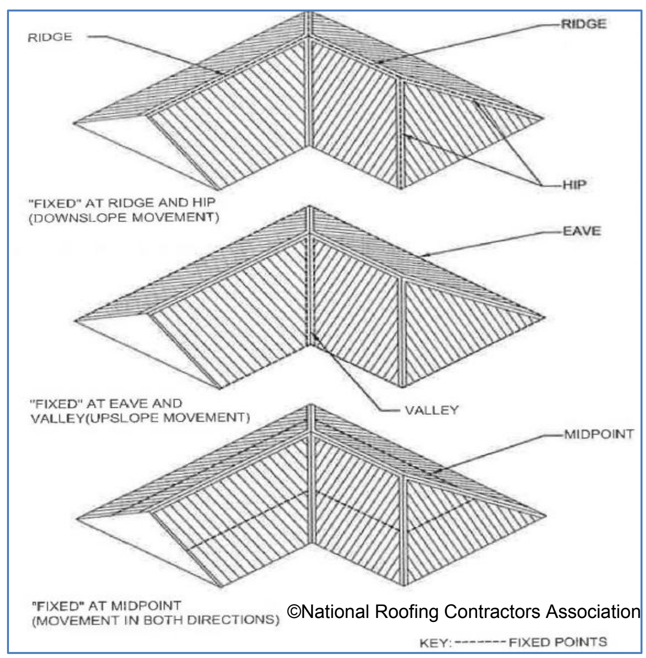


Figure 10-34
Panel Pinning Locations

It is important that the installer understand the differences between these three areas and why different installations may require pinning at different panel locations.

For steeply sloped roofs, the location of choice for fixity is at the ridge. At this location, exposed fasteners can be hidden beneath a ridge cover and accumulated thermal movement will be at the eave end. For most steep sloped roofs, water runoff is carried away by a gutter and drainage system.

Conversely, the popular point of fixity for low slope systems is at the eave. The primary reason for this preference is that such systems are often hydrostatic by design, and it is much easier to waterproof a joint that is stationary rather than one that must move. Such a system will then accumulate thermal movement to the ridge where a "bellows" style ridge flashing can accommodate differential movement of the two opposing roof planes while maintaining a hydrostatic seal.

These statements are not meant to be all-inclusive, and there are exceptions in both cases. On occasion, by design, the panel may be fixed at a third location, its midpoint. Figure 10-35 shows how pinning at the mid-point has the advantage of dividing thermal movement in half by sending it in both directions rather than one. Major dis-advantages are that mid-point fasteners are the through-fastened type, which carry the possibility of leakage, and are normally visible after the installation.

10.7.3 Trim Attachment

Having chosen a point of fixity for the metal panel system, it then becomes critical to ensure that such a point is singular. In other words, the panel should not be pinned inadvertently at any other point along its

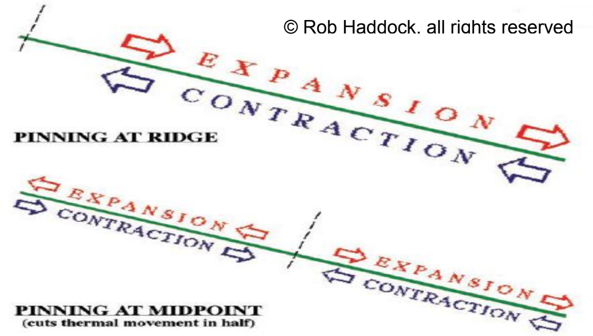
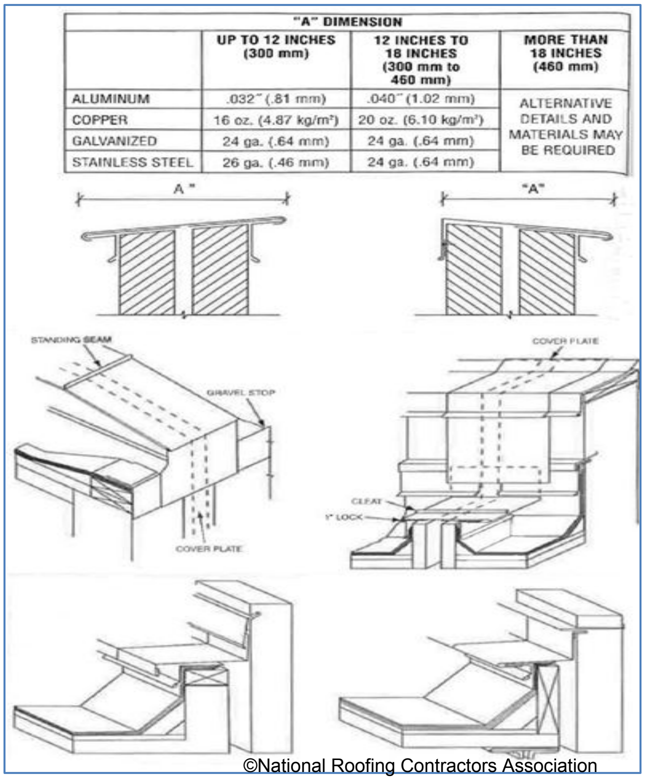


Figure 10-35
Pinning at Midpoint Cuts Thermal Movement in Half

length. To do so will likely produce a failure of some sort. An installer needs to be mindful of this concept wherever gaps, transitions, or accessories are located within a roof system. On larger structures, 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. For new construction, it is the designer's responsibility to account for any building movement, the placement of the expansion joint, and the design details. Several expansion joint examples are shown in Figure 10-36. It is the installer's responsibility to ensure that the installation is performed properly.

As previously mentioned and demonstrated in Chapter 8, *Common Roof Accessories*, on occasion the thermal movement integrity of a roof system is violated because some construction detail or roof accessory mounting did not preserve this characteristic. Figure 10-37 illustrates how accessories can inadvertently pin the panel to the substrate, and a method of avoiding this accidental pinning.



	"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/m²)	20 oz. (6.10 kg/m²)	
GALVANIZED	24 ga. (.64 mm)	24 ga. (.64 mm)	
STAINLESS STEEL	26 ga. (.46 mm)	24 ga. (.64 mm)	

Figure 10-36
Expansion Joint Examples

> **Installer Note**
>
> Design and as-built construction should be scrutinized by the installer for point of fixity. A fascia break detail, for example, fixes the panel at the point of the break. To fix it again at its opposite end would constitute double pinning.
>
> Many times the accidental double-pinning of a panel occurs by other trades, and even by the customer or maintenance personnel. It may also take place after the initial installation of the roof system.

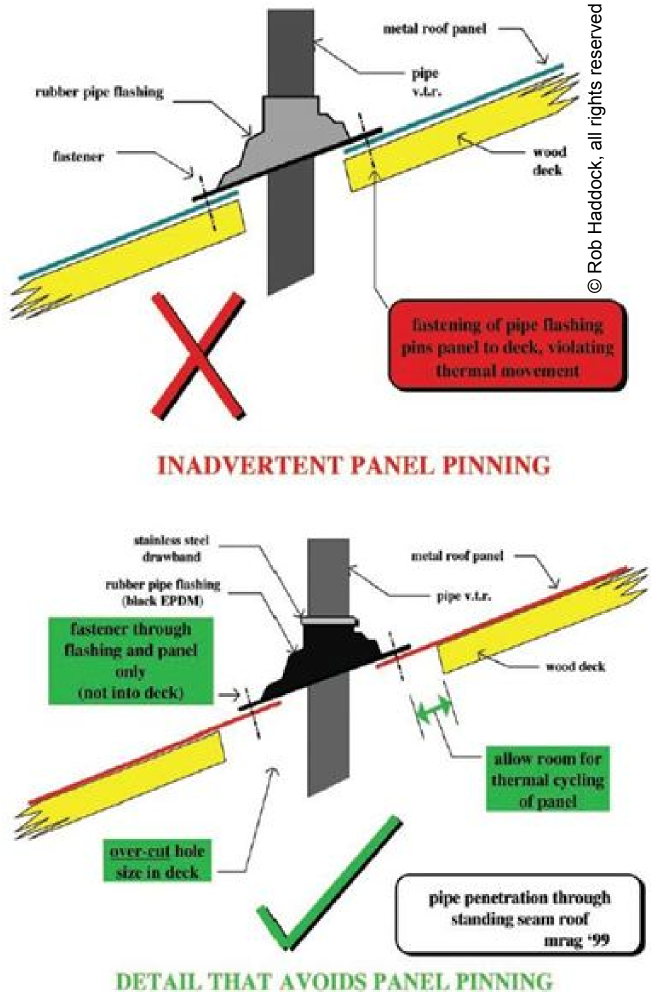


Figure 10-37
Pinning Around Accessories

10.8 Oil Canning (Surface Distortion)

Oil-canning is prevalent in light gauge, cold-formed metal products, especially those with wide, flat, pan areas. Oil canning is not a performance issue but an aesthetic issue.

10.8.1 Definition

Oil-canning refers to physical distortions in the *flatness* of the metal. This distortion can be clearly shown in Figure 10-38. It should be remembered that this condition does not have any adverse effect on the structural integrity or the weatherproofing capability of the panel.

10.8.2 Causes

There are a number of potential causes of oil-canning; however, all of them are attributable to residual stresses within the roof panel. These residual stresses may have been added during production of the metal coil, the roll-forming of the panel, or during installation of the roof panel. Panel finishes can draw attention to an oil canning issue.

Figure 10-38
Oil Canning of a Metal Roof

Some paint finishes, clear coats, and metals are highly reflective and bright. These can cause distortions in the panel to be quite obvious and visually distracting. Additionally, the visual effects of oil-canning can be made to look much worse by changing or varying light conditions.

The installer has no control over stresses coming from the manufacture of the metal coil, or the forming of the metal roof panel (assuming the panels were not rolled on-site). However, there are several actions an installer can perform which will reduce the stresses added to the roof panel and minimize oil-canning during the installation process. Attention to the following issues during installation will reduce the effects of oil canning:

- **Alignment of support members**
- **Engagement of panels**
- **Installation of fasteners**
- **Expansion longitudinally**
- **Movement of primary structure**
- **Handling panels**

Alignment of support members within the structural system that are produced, fabricated, and installed within "allowable tolerances" can create "non-flat," or contoured, bearing surfaces. The stresses induced while forcing panels to conform to this surface can contribute to oil canning. Installing these panels over uneven solid decking or debris on a solid deck surface, also adds distortion and may cause oil canning.

Most panels accommodate transverse (side to side) thermal expansion by the flexing of ribs, webs, and **engagement of the panel** side joints. When panels are *over-engaged*, the added stresses either hinder, or eliminate, these relief features. In extreme cases, the over engagement process itself can generate waviness. Either cause contributes to oil canning.

Installation of the fasteners contributes to oil canning when fasteners are over driven, like the one in Figure 10-39. This operation distorts and creates stresses in the panel which provides a "reading line" along the fastener alignment.

Expansion longitudinally is adjusted through proper clip design and installation. Waviness may be amplified when there is uneven fastener restraint along the panel. This sometimes occurs when sealant accidently interferes with designed movement of a clip, or clips become bent or damaged during installation. Such restraint is common on "concealed fastener" systems having fasteners along one edge and an interlock along the other. Waviness caused by thermal forces differs from the other forms of oil canning in that waves can appear and disappear daily as the sun moves across the sky.

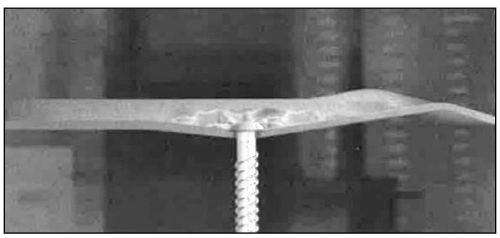


Figure 10-39
Over-Driven Fastener

Movement of the primary structure can cause noticeable waviness within panel flats. Depending on the cause of the movement, this distortion can be temporary or sustained.

Handling panels in the flat orientation or twisting panels can induce a wavy appearance to a previously flat panel. Twisting can occur if one corner of a panel is used to lift a panel or to remove the panel from a bundle. Thin panels are easily stressed and deformed by what appear to be slight handling, twisting, and lifting. Proper panel handling is covered in detail is Section 9.3.3, *Handling Materials*, and Section 11.3, *Unloading, Receiving, and Storing Materials*. Refer to Figure 10-40 for an illustration of the improper and the proper way to handle and carry long panels.

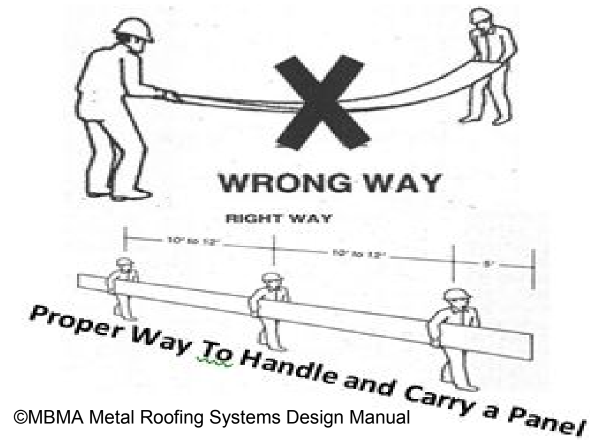


Figure 10-40
Proper Carrying of Longer Panels

An installer **does** have control over these installation and handling issues. Instructions to additional labor, erection, and roofing crew members regarding proper handling, spacing, and fastening should be presented based on the manufacturers' material.

Since proper panel handling is so important, attention should also be given to informing and training all those involved in production, transportation, and delivery activities.

10.8.3 Mitigation

Many metal roof manufacturers issue disclaimers regarding oil-canning. This means any oil canning which develops is *<u>not</u>* a warranty issue and *<u>not</u>* covered; nevertheless, oil canning can become a customer-acceptance issue and one the roofing team must be aware may happen on some installations.

Unless specific tolerances have been incorporated into the contract documents, accepted by both the panel provider and the panel manufacturer, *<u>and</u>* if reasonable precautions have been taken, oil canning is *<u>not</u>* grounds for panel rejection. Corrective measures may include the addition of shims under clips, backer rods, or the use of similar types of materials.

10.9 Corrosion Issues

To corrode means to destroy or damage by chemical action, and examples of corrosion are shown in Figure 10-41. Any corrosion will shorten the actual working life of the metal roof, not just mar the appearance. While corrosion involves a chemical action, there are also conditions which accelerate corrosion and provide ideal situations for corrosion to develop.

Moisture, dampness, and water, in addition to the interaction between different materials, are key ingredients necessary for corrosion. Whenever possible, the installer should look for, correct (where possible), and avoid creating such conditions. This requires using proper material selection and avoiding certain procedures, while closely following others. It can also be as simple as making sure the work area is clean and that extra materials are removed from the area.

Figure 10-41
Corrosion Damage to a Metal Roof

10.9.1 Ponding Water

Corrosion requires water as an ingredient. Ponding on a metal roof provides an ample supply of water to encourage the process. Remember that some roof designs, especially low-sloped roofs, are designed to withstand and handle periods of ponded water in certain areas. The goal, however, is to minimize the amount of liquid, the length of time such events last, and how often they occur. It is also important that these ponded areas are able to drain and dry promptly.

Each roof installation presents its own set of challenges. Figure 10-42 shows completed installations which had several challenges. This picture shows everything done right. A special panel is wide enough to carry all the water off of the roof without creating a water head. The special panels are under the upper roof panels. And an endlap was created at the valley termination point.

Figure 10-42
Proper Planning and Installation
Avoids Ponding Issues

10.9.2 Debris

Debris is not part of the roof system. It is, however, a problem which can begin at installation. There are several habits which an installer can establish that will help relieve this debris accumulation.

One way to avoid debris accumulation is to always clean the work area, before, during and after the installation process. Unfortunately, this may also include having to clean up items which are not a direct part of the installer's work. Items left lying around can find their way under panels, containers may spill, and even the slightest item could become a trip or slip hazard, or damage a panel or trim material.

Figure 10-43 shows how quickly common debris, like plywood, pipes, and dirt, can cause corrosion and damage a roof.

Another source of accumulated roof debris comes from trees and other foliage in the area. It should be noted that leaves, seed pods, flower remnants, and broken stems and branches have the potential to create areas of corrosion and even damage the roof membrane.

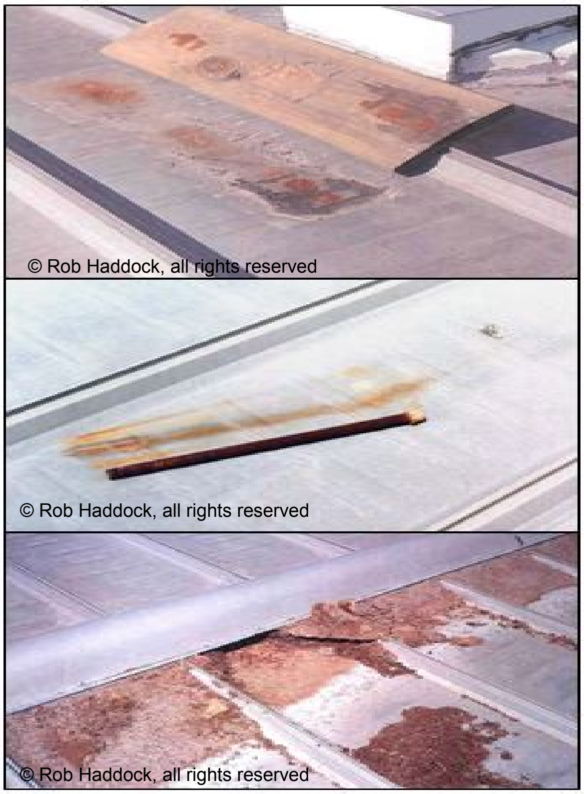


Figure 10-43
Common Debris Can Quickly Damage a Metal Roof

Sharp edges, protrusions, and burrs on fasteners and panels, like those shown in Figure 10-44, not only present a safety hazard, but also tend to snag wind-blown debris. Once snagged, this debris will gather moisture and additional debris. Eventually this "dam" of debris will retain and pond water and corrosion occurs. Good workmanship habits by each individual installer will eliminate this risk. Properly installed fasteners do not have burrs or sharp edges. Cut edges and corners should be properly finished with burrs removed.

10.9.3 Dissimilar Metals

There are certain basics of metal chemistry and corrosion which should be understood by the installer in order to have the foresight to avoid potential corrosive situations. Ignorance of these basics by other trades may result in the violation of some very basic material guidelines and common knowledge within the metal roofing trade. The installer is closest to the work, even when performed by other trades, and can alert the appropriate parties if something that may have a harmful corrosive effect on the metal roof is discovered.

Figure 10-44
Burrs and Sharp Edges Snag Debris

Note that paints which are typically used on coated steel and aluminum panels do little to change or improve the corrosive mechanisms discussed below. The total film thicknesses typically used within the industry are below one mil (.001"), and therefore, moisture permeable. Because of this fact, the same corrosive mechanisms will act upon painted panels as on unpainted panels, even though the corrosion may be somewhat retarded.

The common metals used in construction are zinc, aluminum, carbon steel, nickel stainless steel, copper, and lead. Some of these metals are compatible with each other and others are not.

- Generally, stainless steel gets along well with anything.
- Copper gets along with lead or stainless, but nothing else. In fact, copper has a very severe corrosive reaction with steel, aluminum, and zinc.
- Care must be used when using aluminum panels and contact with zinc should be avoided. Aluminum ancillary items such as fasteners, roof curbs, and clamps are reasonably compatible with Galvalume®, galvanized metal and steel.

Refer to Table 10-3 as the relationship between metals in the galvanic series is explained. When dissimilar metals are in contact and water is present, the more noble metal (lower on the list) will induce corrosion of the less noble (higher on the list). Since steel, aluminum and zinc are high on the galvanic scale; they are usually the metals that suffer the corrosion.

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

Table 10-3
Galvanic Series of Metals

It is of critical importance to the installer, and anyone involved in the metal roofing trade, to note the following important dangers. First, the most noble metal on the list, graphite, is the primary metal called "lead" in the common pencil. When this is used on any metal panel, trim, or other material, corrosive activity begins when moisture is present. As shown in Figure 10-45, common installer markings rapidly become points of corrosion. Permanent markers should be used instead of pencils.

Figure 10-45
Corrosion Caused by Graphite Pencil

Secondly, other than stainless steel, all other common roofing metals are higher than copper on the galvanic chart. Extreme caution must be used by installers and other tradesmen to avoid exposing the metal roof to copper. This also includes exposure to treated wood and runoff from copper plumbing, HVAC equipment, and other copper-based products. A high concentration of copper-based chemicals is applied to most pressure treated wood within the construction industry. This copper will quickly stain and corrode the roof surface as shown in Figure 10-46.

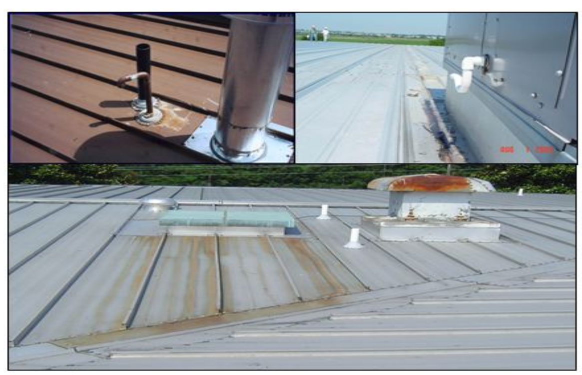


Figure 10-46
Staining and Corrosion from Copper Runoff

Some aspects of electrolytic behavior make certain combinations either more, or less, aggressive. One aspect is the frequency of wetting. Since electrolytic corrosion only occurs when the roof surface is wet, an obviously relevant point is: "How frequently, and for how long, does the surface stay wet?" All other factors being equal, a surface which is wet more frequently will corrode faster than one that is not. It is expected that corrosion of gutters will happen before ridges. If dissimilar metals are used in gutter construction, the effect will be more accelerated than if it occurs elsewhere on the roof. Another characteristic is the formation of oxide layers. For instance, although lead is very dissimilar from zinc, it forms an oxide layer that prevents electrolytic contact from occurring. Figure 10-47 illustrates how zinc sacrificially protects and prevents corrosion of steel. (This characteristic is discussed in more detail in Section 3.3.5.1, *Galvanized*)

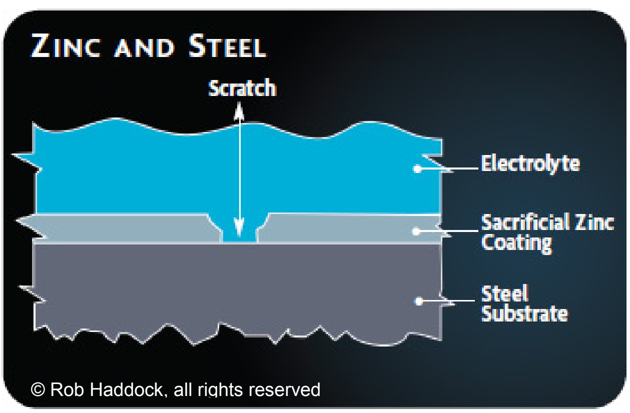


Figure 10-47
"Sacrificial" Oxide Formation

Another factor in corrosion is the specific nature of the electrolyte (the fluid which couples the two metal surfaces). Electrolytic corrosion is greatly accelerated by an acidic electrolyte. The significance here is that galvanic corrosion will occur more rapidly where there are chemicals dissolved in the water. This happens when water drains off of other metals, such as copper pipes, as well as contained in rain water. There are geographic pockets of the country, like the Northeastern United States, where rainfall is particularly acidic.

Exposed Fastener Selection

A typical metal roof installation will use thousands of individual fasteners and clips. However, proportionally, it is a small portion when compared to the surface area of the metal panels and trim. Electrolytic behavior is affected by surface areas. For instance, it was already stated that zinc and aluminum are quite compatible. However, the aluminum is slightly more noble in behavior than zinc, hence the zinc will corrode rather than the aluminum. For this installation, it would be prudent, therefore, to use aluminum rivets in galvanized roofing. The galvanizing will corrode, but not measurably due to the extreme proportion of zinc surface to aluminum. The reciprocal - galvanized rivets in aluminum roofing panels would not be prudent, because now the weaker metal is in minute proportion to the stronger. The rivets will corrode rapidly. This premature corrosion can easily be seen in Figure 10-48 where fasteners made from incorrect material were used.

Figure 10-48
Incorrect Fastener Material

These same principles are true when using stainless steel, which is normally compatible with everything, as a fastener, rivet, or other attachment hardware for panels of other metals. The opposite however, is not true. When attaching stainless panels, stainless fasteners must be used. Galvanized or aluminum fasteners will corrode rapidly when in contact with stainless in this scenario, again due to the proportions of surface areas.

10.9.4 Cement, Mortar and Other Alkalis

Aluminum and metallic coatings used on steel sheet that contain aluminum, (Galvalume®, Zincalume®, Aluminized) have a severe sensitivity to strong alkalis. Sometimes, highly alkaline cleansers are used in the cleaning of certain rooftop HVAC equipment. This should be avoided on such roofs. Cementious materials are also very alkaline, including concrete, brick and block mortar, and stucco. As shown in Figure 10-49, these mortars pose a very severe threat to the above metals when wet. Corrosion caused by these alkalis will be made apparent by a conspicuous black stain on the panel surface. When dry, and freely draining, cement mortars do not seem to be a chemical problem, but they *are* highly abrasive and can scratch, mar, and damage the metal roof surface.

Construction trades should be sequenced so that adjacent masonry work is complete before roof materials are put in place. If this is not possible, the roof surface must be thoroughly protected, which is almost a practical impossibility. If a spill occurs, it must be immediately removed and thoroughly cleaned and rinsed with clean water to prevent damage.

Figure 10-49
Cement, Mortar, and Related Products Can Damage Metal Roofs

10.10 Integration with Gutter System

The gutter system is designed to control drainage from the roof system. Integration of the metal roof system with the designed gutter system should provide effective water transfer with minimum splash-over of the gutter and minimum back-up of water trying to enter the gutter system. There are two types of gutters: hanging (externally attached) and built-in. The gutter design and installation must ensure adequate drainage and strength, including any ice and snow loading during colder condition. It must do all this and still remain leak free. These considerations require attention to the gutter size, style, attachment, location, and spacing of fasteners and other items.

10.10.1 Drip Edge

The drip edge is defined as a metal flashing or other overhanging component with an outward projecting lower edge, intended to control the direction of dripping water and help protect underlying building components. The drip edge is part of the roof system and is made in several styles. Both low-slope and steep-slope roof systems commonly use "L" and "T" shaped profiles, illustrated in Figure 10-50, when interfacing with a gutter system.

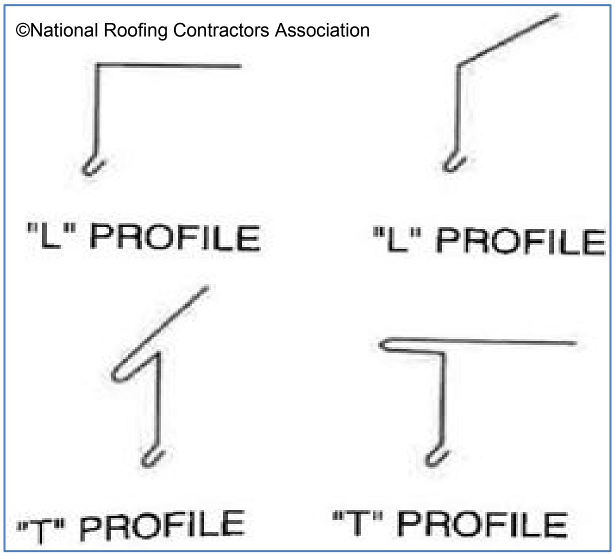


Figure 10-50
L and T style Drip Edge Profiles

In steep-slope roof applications, either "L"-type or "T"-type profiles may be installed at the roof's eave and/or rake. In a typical application, the edge metal is fastened to the deck, if it can be nailed. Succeeding pieces are installed by overlapping the next piece (Figure 10-51), or by using overlapping (Figure 10-52) or concealed (Figure 10-53) joint plates.

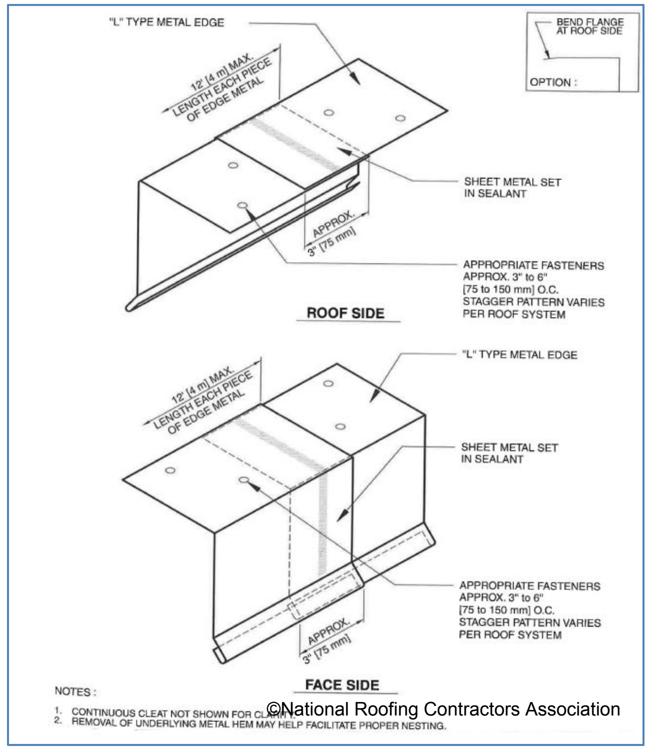


Figure 10-51
Overlapping of Drip Edge Material

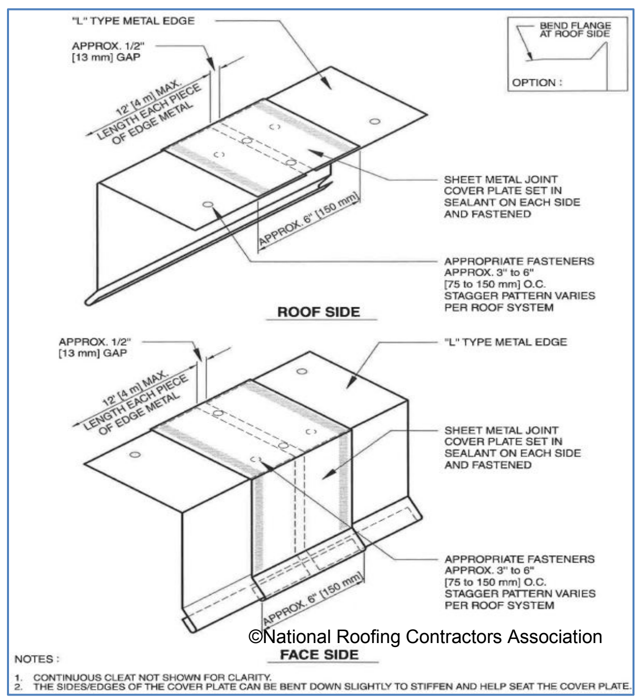


Figure 10-52
Drip Edge with Overlapping Joint Plate

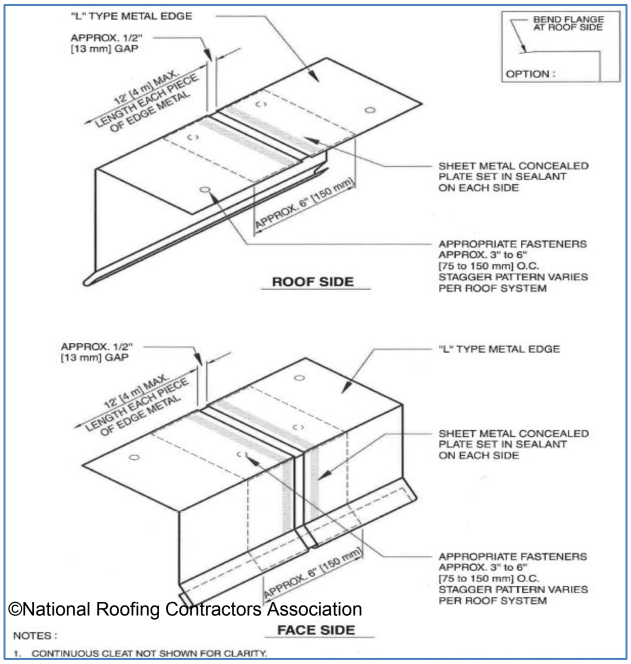
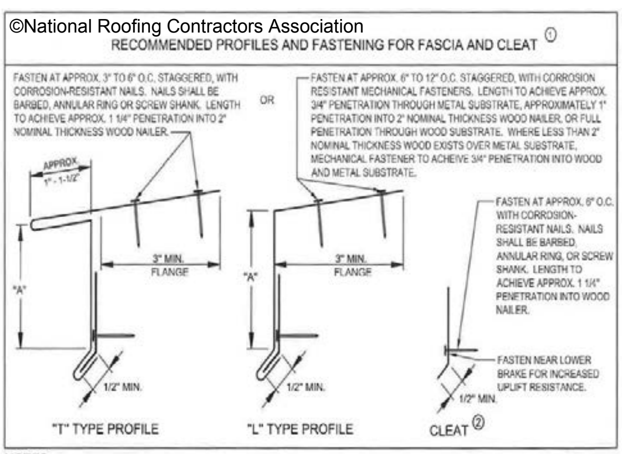


Figure 10-53
Drip Edge with Concealed Joint Plate

It is common that the end joints and corner pieces are not sealed, soldered, or welded. Only the flange of the edge metal is fastened to the deck when used in a steep-slope roof system, the lower edge is normally held in place with a cleat. Cleat details are illustrated in Figure 10-54.



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.

Figure 10-54
Fascia and Cleat Installation Details

If an open, or unnailable, deck is used, the installation may require wooden nailers, cleats, or some other method of securing the edge metal, similar to the method shown in Figure 10-55.

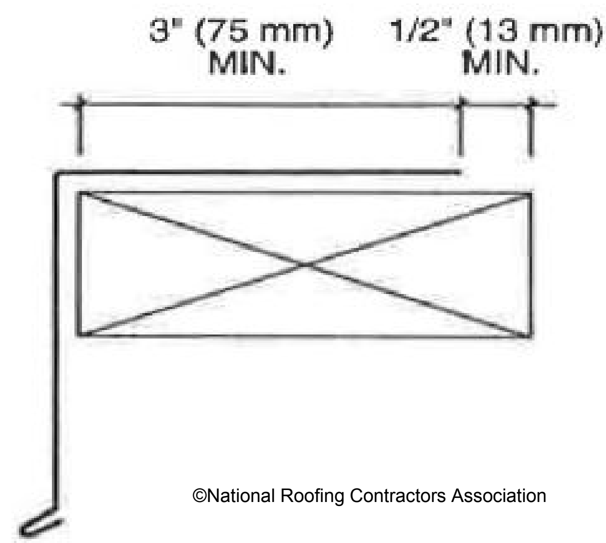


Figure 10-55
Nailer Details for Drip Edge Material

In some installations, 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. The "T" profile edge metal is typically secured at its lower edge with a cleat, and the roof flange is fastened to the deck. Typical installation details are illustrated in Figure 10-63, while trim joints are illustrated in Figure 10-56.

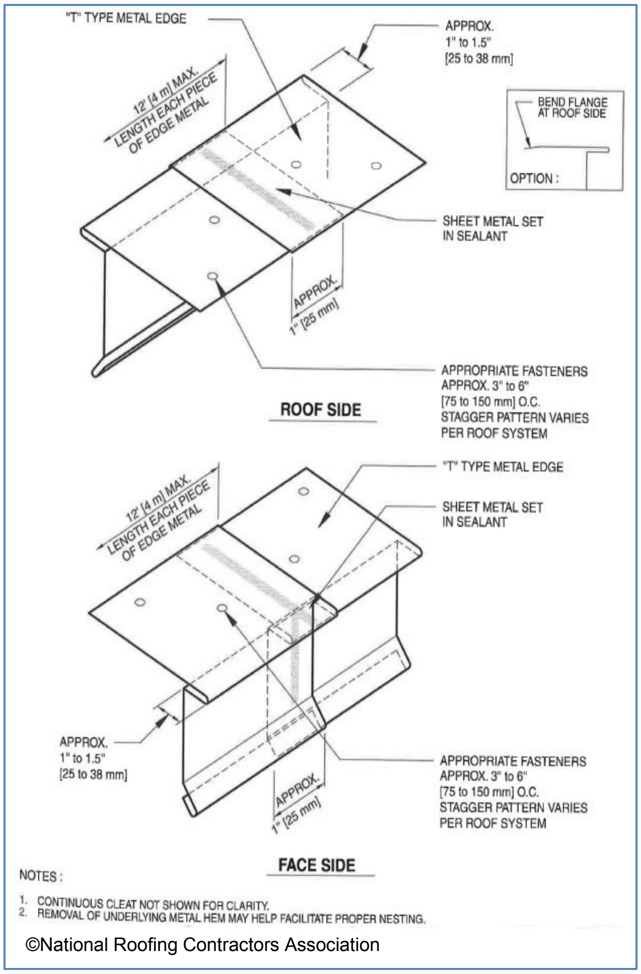


Figure 10-56
"T" Style Drip Edge

10.10.2 Gutter Sizing

Gutter size is determined by the roof slope area and the anticipated amount of rain an area historically receives. While gutter sizes will vary, common profiles are used and illustrated in Figure 10-57 for built-in gutters, and Figure 10-58 for external, hanging gutters. A good gutter design will have a front face lower than the back face to allow excess water to spill over in a heavy downpour, or in situations where the gutter or downspout is clogged. The lengths of the gutters will also vary. Some are pre-formed and ordered from the manufacturer in standard lengths, while others may be roll-formed to length on-site.

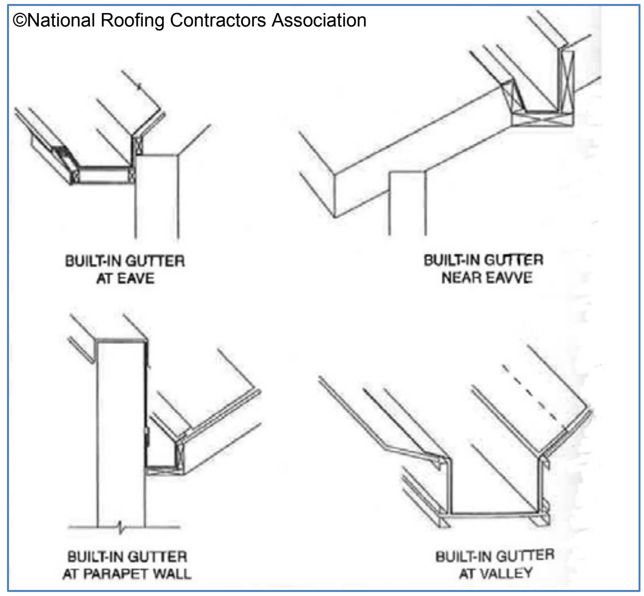


Figure 10-57
Typical Built-In Gutter Profiles

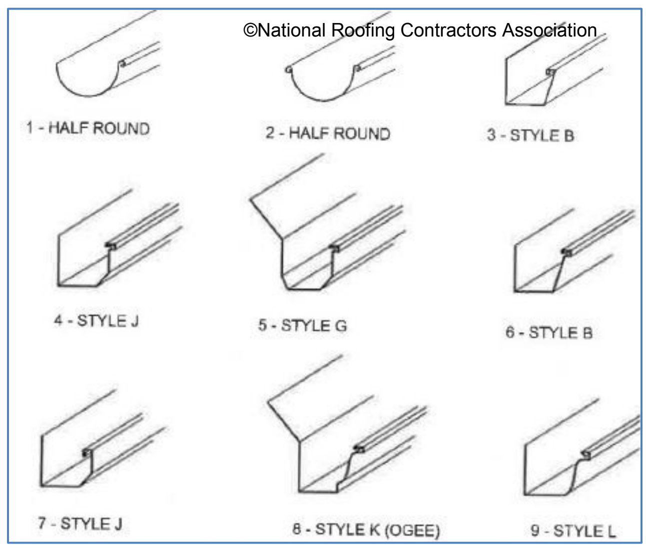


Figure 10-58
Typical Hanging Gutter Profiles

Built-in Gutter Systems

Interfacing with built-in gutters will vary by the location of the gutter. Built-in gutters located on eaves will be similar to externally hung gutters. A built-in gutter is often discouraged due to complexities of waterproofing requirements. For built-in gutters:

- Underlayments should be used and should consist of a minimum of one layer of No. 30 asphalt saturated roofing felt. Self-adhering modified bitumen membranes may also be used with isolation/protection sheets beneath soldered joints. A slip sheet over the underlayment is suggested, to allow for thermal movement of the gutter.

- Weathertight seaming and joining is critical to performance.

- Metal types must be compatible between gutter, flashing, and roofing materials. Incompatible materials will cause both visual and performance problems as seen in Figure 10-59.

Figure 10-59
Incompatible Gutter, Flashing, and Roof Material

- 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 rates of thermal expansion, such as aluminum and zinc, should be avoided. Be mindful of not double-pinning gutter material.

Hanging Gutter Systems

Interfacing with hanging gutters normally takes place at the eaves of the roof. The gutter size and profile will be factors in determining the method used to mount the gutter system. Three common support systems are:

1. Straps.
2. Brackets.
3. Brackets and straps.

Hanging gutter systems may use "L" or "T"-type drip edge material, and may be used with architectural or structural style panels. Installation details are shown in several figures as follows:

"L"-type drip edge installations are shown in:

- Figure 10-60, "L"-Type Downslope
- Figure 10-61, "L"-Type Downslope with Gutter and Brackets
- Figure 10-62, "L"-Type Downslope with Gutter and Brackets and Straps

"T"-type drip edge installations are shown in:

- Figure 10-63, "T"-Type Downslope
- Figure 10-64, "T"-Type Downslope with Gutter
- Figure 10-65, "T"-Type Downslope with Gutter and Brackets

The illustrated examples are for general information purposes only. Always use the manufacturer's recommended materials, and follow the manufacturer's suggested methods and procedures.

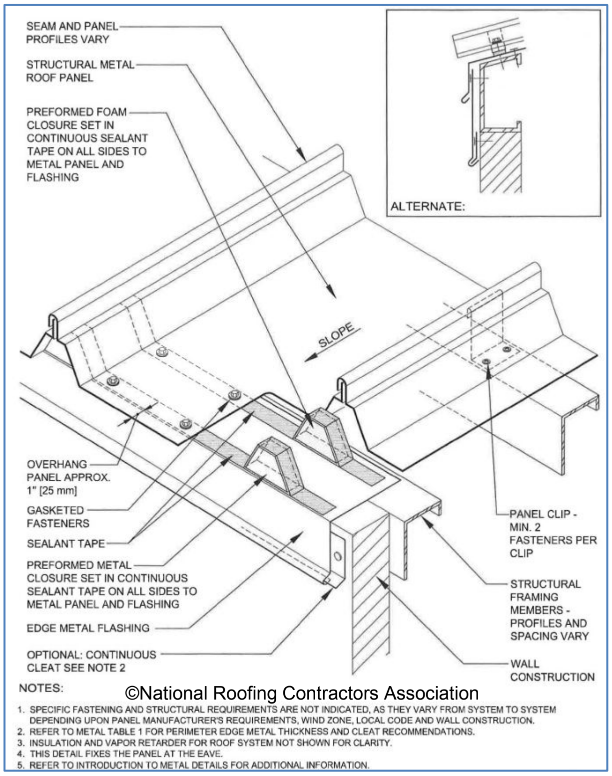


Figure 10-60
"L"-Type Downslope

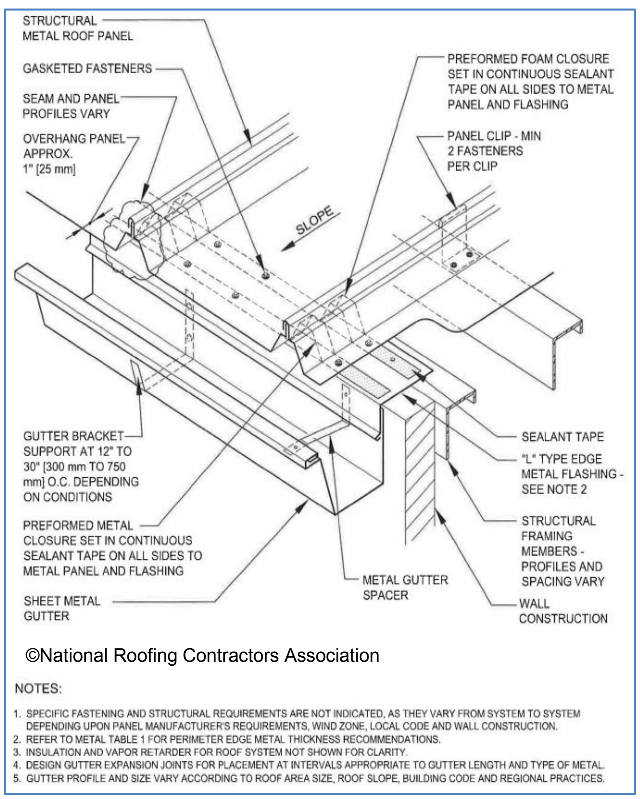


Figure 10-61
"L"-Type Downslope with Gutter and Brackets

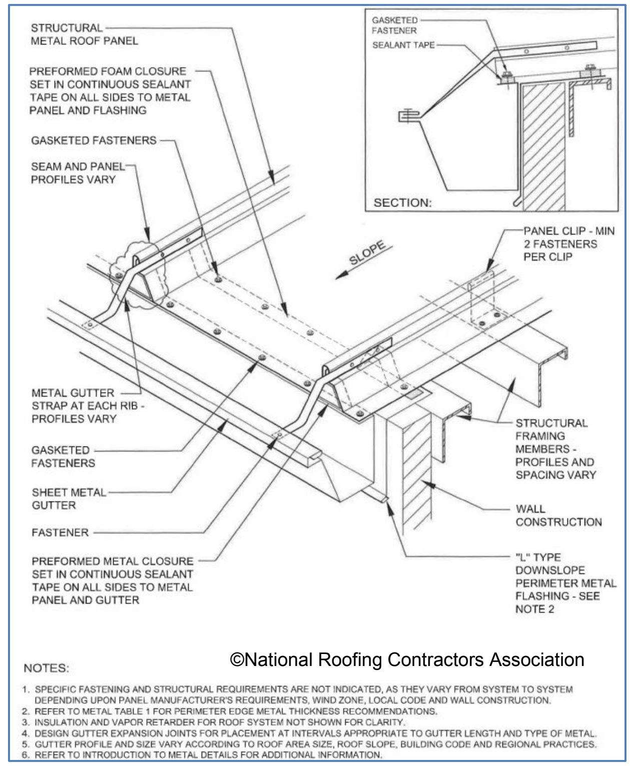


Figure 10-62
"L"-Type Downslope with Gutter & Straps

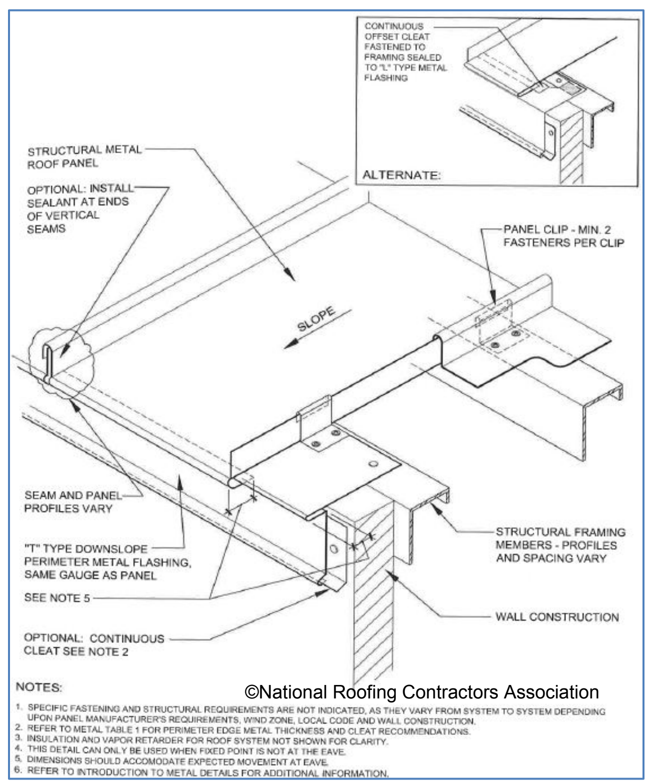


Figure 10-63
"T"-Type Downslope

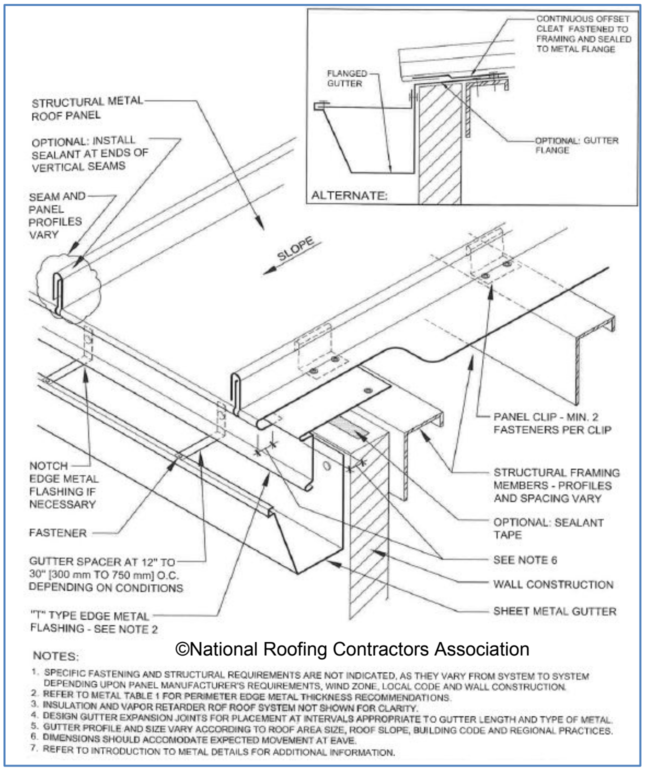


Figure 10-64
"T"-Type Downslope with Gutter

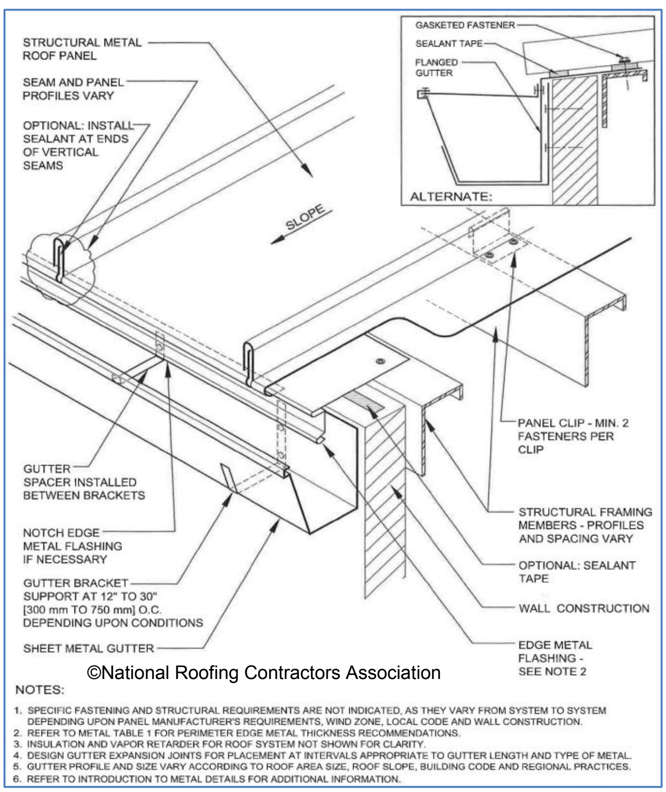


Figure 10-65
"T"-Type Downslope with Gutter and Brackets

10.10.3 Apron

Apron flashing, illustrated in Figure 10-66, is a term used for a flashing that is located at the juncture of the top of a sloped roof and a vertical wall, chimney or steeper-sloped roof.

Any apron flashing should be securely, and appropriately, sealed against the chimney, wall, or barrier. The apron should also be secured along the roof membrane surface but allow for thermal movement.

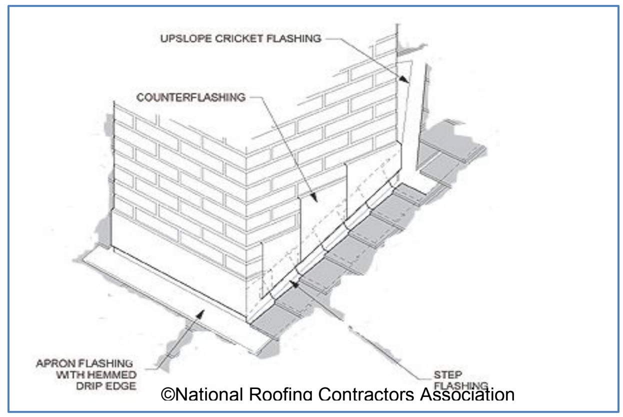


Figure 10-66
Apron Flashing Around a Chimney

10.11 Water Shedding and Weathertightness Theory

The primary purpose of a roof system is to prevent the infiltration of water and the outside environment. Metal is the ideal material for this purpose. Metal does not leak. Infiltrated water can only enter a metal roof system where there is a puncture or a joint. With this in mind, there are certain areas requiring special attention during a typical installation. Those areas include:

- Back water laps
- Obstructions to quick water egress
- Valley sizing
- Sealant placement
- Proper seating of fasteners

10.11.1 Back Water Laps

A back water lap is a lap joint which is exposed to water flow in the opposite direction. This opposing direction, coupled with the pressure of the water flow, forces water through against seam, joint or opening.

10.11.2 Obstructions to Quick Water Egress from Roof

A properly designed roof and drainage system will plan for occasional obstructions in the primary drainage path. A secondary draining method should be incorporated into the installation. An obstruction is a physical disruption or a blocking of the discharge. Common obstructions are caused by dirt, debris, and structural damage which block gutters, downspouts, and scuppers, or divert the flow of runoff to those components. Obstructions may also occur when accessories or roof mounted items are installed with inadequate analysis of the impact the additional installation will create as shown in Figure 10-67.

Figure 10-67
Improperly Installed Pipe Blocking Water Flow

10.11.3 Valley Sizing

Valley installation details will vary from job to job and roof system to roof system. The differences are due to the size and slope of the roof; the type and size of the panel being installed, and even the manufacturer. Other geographic, climatic, and engineering factors may affect the requirements of each valley installation. There are still several general guidelines an installer should follow and consider whenever installing a valley.

Even under normal conditions, the valley area of the roof will experience significantly more water exposure than other portions of the roof. The valley, by its nature, tends to collect and accumulate leaves, foliage, and debris which may disrupt flow and cause other problems.

Most manufacturers produce specific valley material for use with the roof panels being installed. This valley material typically has a "W" shaped profile, and is available in several widths for design requirements. A typical installation with panel clips is shown in Figure 10-68.

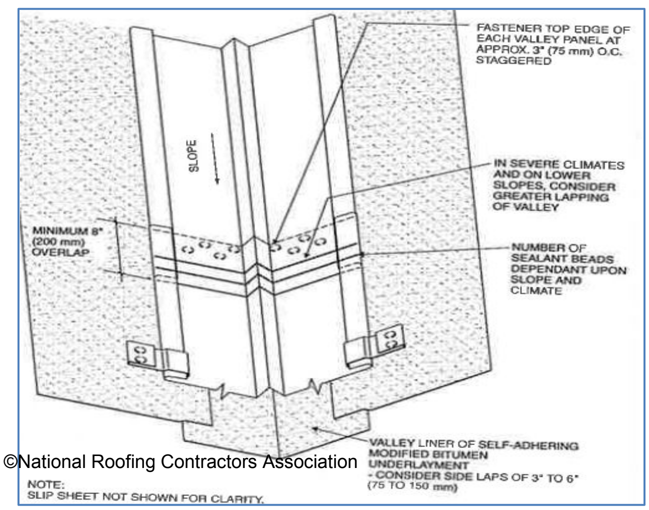


Figure 10-68
Typical Valley Installation

Consider 36" of 30# underlayment, 18" on each side of center a minimum requirement, plus a slip sheet as necessary. However, most installations will require additional material. All material should extend past the width of the valley flashing and be adequately covered by other underlayment. Often "peel and stick" polymer-modified bitumen replaces or supplements the asphalt underlayment. Some methods use additional strips of "peel and stick" bitumen on hidden edges. This is called stripping and is illustrated in Figure 10-69 and Figure 10-70 for both nailed and clip-installed valley material.

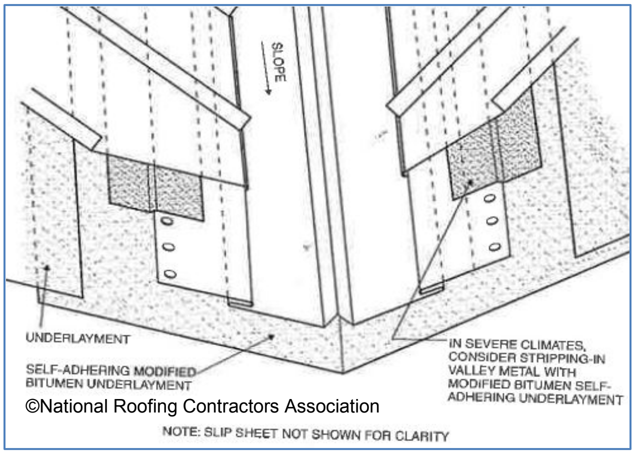


Figure 10-69
Stripping of Nailed Valley Trim

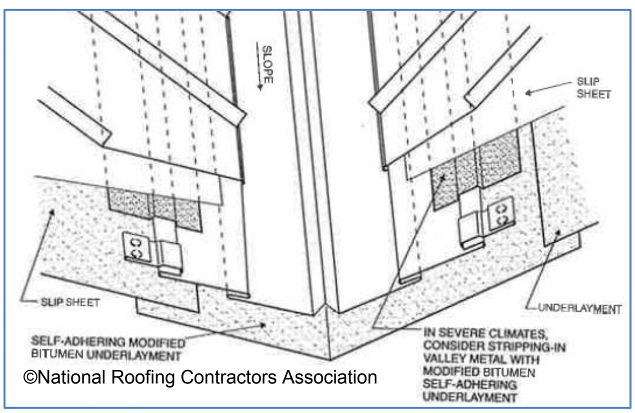


Figure 10-70
Stripping of Clip-Installed Valley Trim

Care should be used whenever installing additional underlayment and sealants, especially some rubber-modified asphalt materials. Some materials may melt and run during periods of warmer temperatures. Geographic and climatic conditions and material characteristics should be considered before installation. High temperature products are recommended.

Panel edges ending at the valley must be properly fastened and sealed. Closures must be installed properly and sealed.

10.11.4 Sealant Placement

Sealant types, compatibility, and application details will be discussed in Chapter 13, *Sealants*. However, it is important to mention several key points when working with sealants of any kind with respect to water and weather.

Sealant locations and procedures are described in each manufacturer's installation manual, and may vary. Both are critical, and must be followed. Some of the usual areas for critical sealant applications include:

Eave (Figure 10-71):

- Panel-to-eave flashing or gutter
- Panel rib closure-to-eave flashing or gutter
- Panel-to-rib closure
- Panel seam end

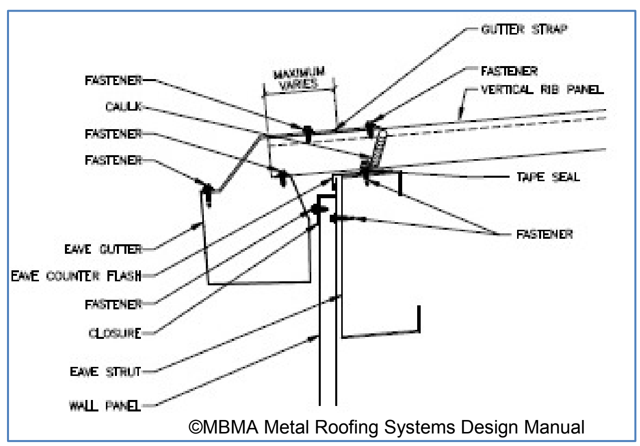


Figure 10-71
Eave Sealant Locations

Endlap (Figure 10-72):

- Panel flat to panel flat
- Panel rib-area to panel rib-area (and into seam)

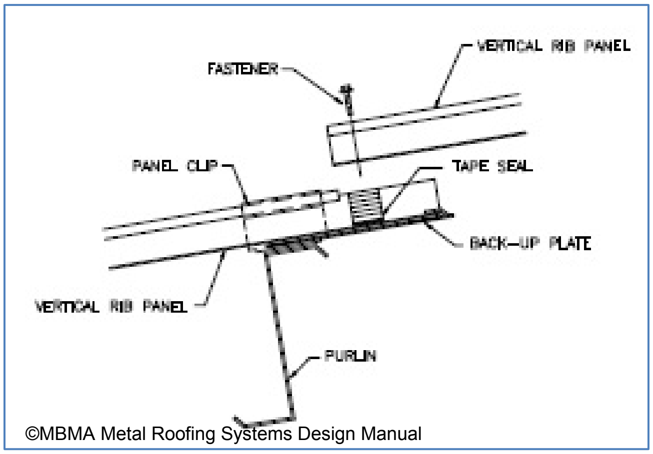


Figure 10-72
Endlap Sealant Locations

Ridge (Figure 10-73) :

- Panel to closure components
- Closure components to ridge flashings

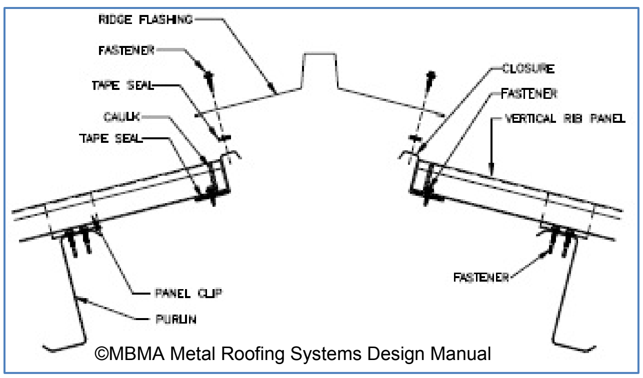


Figure 10-73
Ridge Sealant Locations

Terminations (Figure 10-74) :

- Panel to flashing at rakes or gables
- Panel to flashing at longitudinal expansion joints
- Panel to flashing at parapet conditions

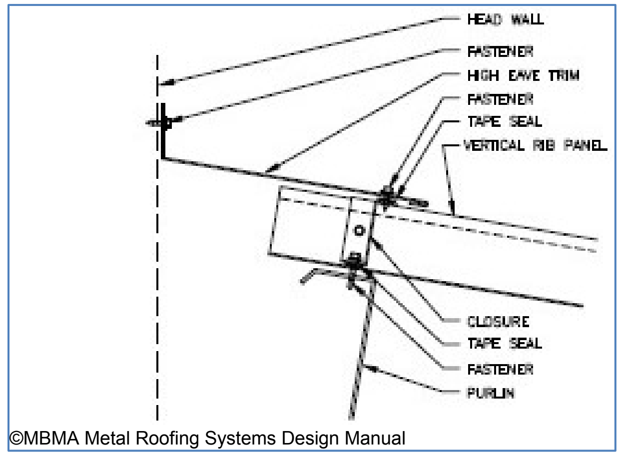


Figure 10-74
Termination Sealant Locations

Penetrations (Figure 10-75):

- Panel and ribs to preformed curbs
- Panel and ribs to other roof penetrations

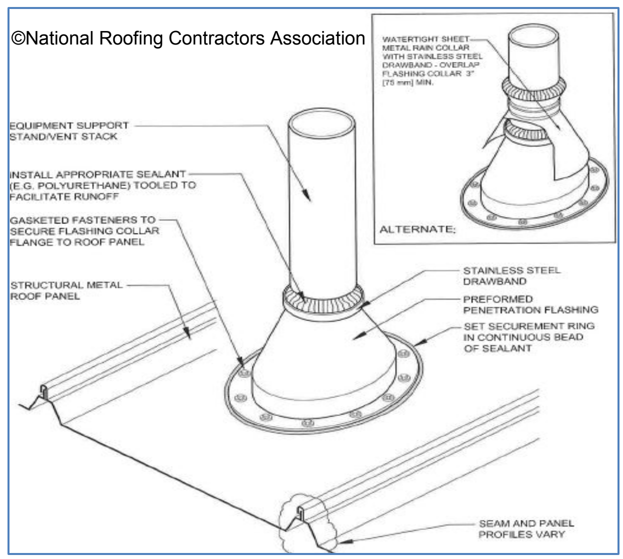


Figure 10-75
Penetration Sealant Locations

Flashings (Figure 10-76):

- Laps of adjacent flashing segments
- Flashings to panels

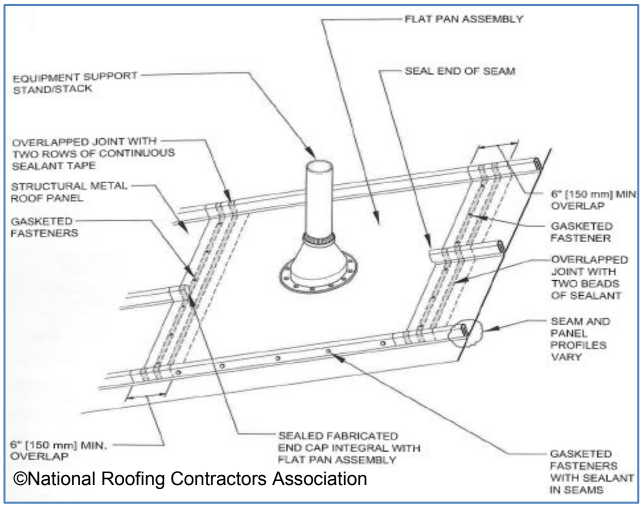


Figure 10-76
Flashing Sealant Locations

Caution should also be used when applying sealant around concealed clips. These clips are designed and are required to have room to move after installation as the roof panel expands and contracts. If movement is restricted by coincidental contact with misapplied sealant, two possible problems may result. One, the panel may deform, or oil canning may occur. The other, and more frequent occurrence, is that the strength from thermal movement actually "shears" and tears the sealant causing an area of potential leakage. This may be avoided by following the manufacturer's instructions, especially with respect to the location and amount of sealant necessary.

10.11.5 Proper Seating of Fasteners

Once the correct fastener is selected and proper spacing and locations are understood, there are three things that can still go wrong when installing the fasteners. Fasteners can be over-driven, under-driven, or driven at an improper angle to the panel as shown in Figure 10-77.

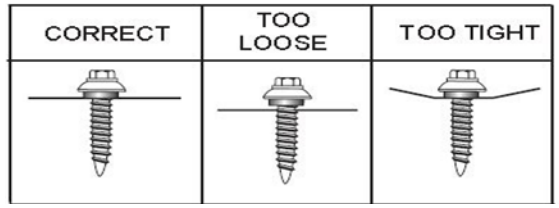


Figure 10-77
Fastener Conditions after Installation

Under-driven fasteners

Under-driven fasteners, like the one shown in Figure 10-78, will definitely leak, but also pose other problems. Under-driven fasteners reduce the roof's resistance to uplift forces, and make the panels and roof structure more susceptible to excessive movement and likely damage. They also reduce the roof's ability to properly act as a system and prematurely fail.

Figure 10-78
Under-Driven Fasteners Will Leak and Corrode

Over-Driven Fasteners

Over-driven fasteners, as mentioned previously, also cause problems. As an installer, remember, tighter is not better when discussing fasteners. Over-driven fasteners cause several conditions which can lead to very different problems.

An over-driven fastener may strip out when only fastening thin panels and other roof members. A stripped-out fastener will not apply enough pressure to the area to keep out water and moisture, nor securely hold the material in place.

Over-driven fasteners deform the area surrounding the installation. Depressions around the fastener provide areas for water, condensation, and moisture to pool, which usually lead to premature corrosion. This can easily be seen in Figure 10-79.

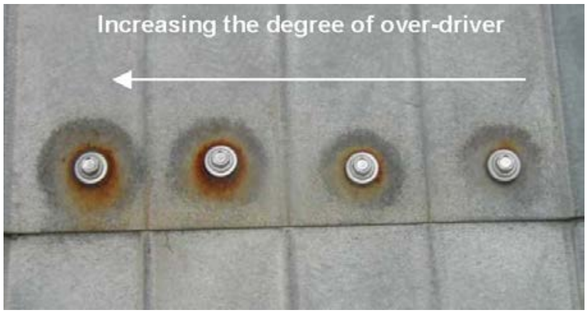


Figure 10-79
Over-Driven Fasteners

Panel deformation resulting from over-driven fasteners also visually mars the overall appearance of the roof surface, especially when using exposed, through-panel fasteners. This becomes even more noticeable when highly reflective coatings and finishes are used.

Installer Tips

There are several things an installer can do to avoid either fastener condition. Confirm and validate:

- All mechanical fastener tools are set-up properly. An off-roof test panel is recommended using scrap material.
- The correct socket is used.
- All tools are in good working order.
- If using pneumatic tools,
  - Confirm the correct air pressure is present *at the tool itself*.
  - Significant loss of pressure occurs when long airlines and worn/leaking couplers are used, or when the hose becomes kinked.

Borrowing any tool is risky. The borrowed tool may have different settings than those required. NEVER ASSUME.

All tool settings and pressures should be per roof manufacturer's recommendations.

10.12 Determining Best Roof Type

The installer normally has no control over the selection of the roof to be installed, but should be aware of some of the considerations used to make the final decision. Some of these considerations are based on climatic and geographic data, while other factors involve the actual structure itself, and some are based solely on customer preference.

10.12.1 Area Climate

The climate of an area helps determine both the normal and the extreme conditions the roof system is likely to experience. Separate data is used to evaluate rain, snow, wind, and temperatures. Climatic data can be useful for evaluation of such parameters like hours of sunlight, number of days above or below certain temperatures, etc. Such data affects surface temperatures, expected thermal movements, and likelihood of extreme climatic events.

Climatic data also plays a role in determining fastener spacing, quantity per panel, and details involving drainage and trim installation.

Wind Speeds

The effect of wind was discussed in Section 10.2 when discussing uplift. Wind speed can be a factor in determining the type and slope of a roof, as well as fastener details and methods.

Code Compliant per Region

"Code compliant per region" means the required standards are met based on posted requirements for established geographic regions. While effective in establishing baseline parameters, regional codes fail to consider local factors which may affect a roof installation, such as nearby trees, structures, proximity to significant bodies of water, etc. Regional codes also fail to consider features unique to the structure, the environment inside the structure, or the processes being conducted within or about the structure which may affect roof system requirements. Code compliant per region specifications also fail to consider any local code requirements within that region.

These local and structural factors generally will require additional materials, fasteners, or work, not less than the regional code requirements. Always remember that any code requirements are *minimum* requirements for the installation. The specific code requirements are what any inspector or auditor will be evaluating when investigating an installation.

Follow Manufacturer's Instructions or Project Specifications

No one understands the product being installed better than the manufacturer. Manufacturers spend thousands of dollars analyzing, testing, and getting their products certified. Manufacturers also analyze the test results in order to develop their warranties and installation instructions.

It is critical for the installer to understand that failing to follow the manufacturer's instructions can void the warranty of the roof, and open the roofing contractor up to many legal difficulties, fines, and litigation.

When the manufacturer's instructions are in conflict with any code the installer is trying to follow, the manufacturer should be contacted for further instructions. It is highly recommended that any variation suggested by the manufacturer be documented, and a record kept on file in case any issues develop as a result of any changes.

ASCE 7

The ASCE, American Society of Civil Engineers, have established minimum design loads for buildings and other structures. This is commonly referred to as ASCE 7. ASCE 7 is updated periodically with the year added at the end, ASCE7-XX. For example, the current version, ASCE 7-10, establishes guidelines, methods, and formulas for determining dead, live, soil, flood, wind, snow, rain, atmospheric ice, and earthquake loads, as well as their combinations, which are suitable for inclusion in building codes and other documents. Be cautioned that many codes and jurisdictions do not automatically adopt the most current version of ASCE 7.

Standard ASCE/SEI 7 is an integral part of building codes in the United States. Many of the load provisions are substantially adopted by reference in the International Building Code and the NFPA 5000 Building Construction and Safety Code.

The reasons certain materials, procedures, and methods must be used are based on the guidelines established by ASCE 7.

Rainfall Intensity

Except for condensation, virtually all the water a roof system experiences is due to rain. Two rain factors are important considerations in roof design: Rain amounts and rain intensity. Rain intensity is the ***rate*** the rain falls, usually given in inches-per-hour. Both rain amounts and rain intensity have plenty of historic data available on which to base a decision.

Typically this historic data is based on the amount of rain a geographic region received during various periods of time, such as 5-minute, 2-hour, 1-day periods, etc.

This information is critical in determining design factors like:

- The amount of runoff a roof is likely to encounter.
- The amount of water, typically in gallons per minute, a drainage system must handle.
- Hydrostatic pressure roof seams must withstand.

Also consider that increased rain intensity is often accompanied by periods of stronger wind and sometimes hail.

These considerations affect the sealant requirements, panel and fastener styles, gutter size, and other installation details.

Snow Loads

The snow load of a roof is ***not*** the same as the amount of snow that falls from the sky. Snow load considers the weight of the accumulated snow that remains on the roof. This includes drifted snow as well as any snow held on the roof by snow guards and snow fences. Roof areas which are prone to drifting and snow build up are illustrated in Figure 10-80. Other snow load considerations must factor in such characteristics as wet and dry snow types, and increased weight from the melt and refreeze cycle which occurs daily. Roof size, slope, and amount of sun the roof receives may significantly increase the snow load.

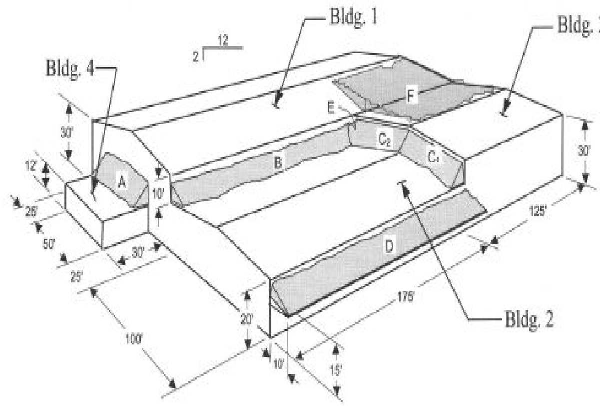


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Figure 10-80
Roof Areas Subject to Drifting and Snow Build Up

Temperature Differential

The temperature differences a metal roof may experience will vary greatly and affects some aspects of the installation. The temperature differential of a metal roof structure will be much greater than the ambient, or climate, temperature ranges. This is due to several factors.

The style, color, and coating of the metal roof surface help determine heat absorption of the roof. A darker, lower-luster roof surface can reach temperatures of 200° F, much greater than any ambient temperature. A highly reflective, lighter color panel will reflect much of the heat and remain cooler. The structure beneath the roof surface, any applied insulation, as well as any heat generated by work performed inside the structure, all affect the temperature differential the roof will experience.

Metal roof surfaces are also affected by low-end temperature extremes. Thermal emittance of the metal roof (the ability of the roof to radiate the heat it has absorbed) will cause the temperature of the roof surface to drop below the ambient temperature; sometimes by as much as 25° to 30° F.

The large temperature differentials of the roof directly affect the thermal expansion and contraction of the roof panels, thereby affecting installation details, such as fastener types, spacing, and panel pinning.

It is worth noting that it is not always best to designate the "coolest" roof with high reflectivity and low heat absorption. Design selections are based on the climate in an area. In colder environments, a "warmer" roof may actually be a more efficient design for the user. Engineers and designers will use established climate data and roof data to determine the appropriate selection.

10.12.2 Roof Slope

There are two main roof slope classifications: low-slope and steep-slope. Roofs with a slope of 3 inches per foot, or less (3-in-12, or 14 degrees or less) are classified as low-slope roofs. Low-slope roofs are considered to be a water-barrier (hydrostatic) type of roof, meaning they are designed to withstand ponding or slow moving water, including the additional pressure from such accumulated water. Installation factors will focus on sealing of joints, connections and fastener locations, as well as additional underlayment, or moisture barrier, materials.

Roofs with a slope greater than 3 inches per foot (3-in-12, or 14 degrees) are classified as steep-slope roofs. Steep sloped roofs are to be water-shedding (hydrokinetic). Installation factors will focus on directing and withstanding high volumes of fast-moving run-off water, interfacing to the drainage system, and sealing areas where various roof surfaces merge, such as valleys, parapet walls, etc. Additional attention is given to sealing the down-slope end of the panels to prevent any water back-up from leaking under the roof surface.

In addition to the slope of the initial roof, there are instances where other slope transitions will occur. Porch and dock overhangs, structure additions, renovations, or re-roofing applications may require areas where there is a change in the slope of the roof. Typical metal roof transitions are shown in Figure 10-81 and Figure 10-82, although details will vary based on the panel design and many other factors.

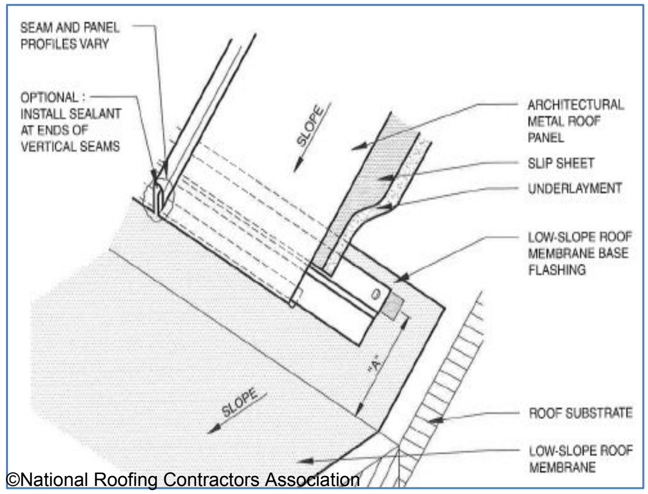

Figure 10-81
Transition from Metal Roof to Membrane Roof

A common variation of the transition in Figure 10-81 is the use of a buffer/isolation plate installed which allows runoff from the metal roof portion to run directly onto the membrane surface.

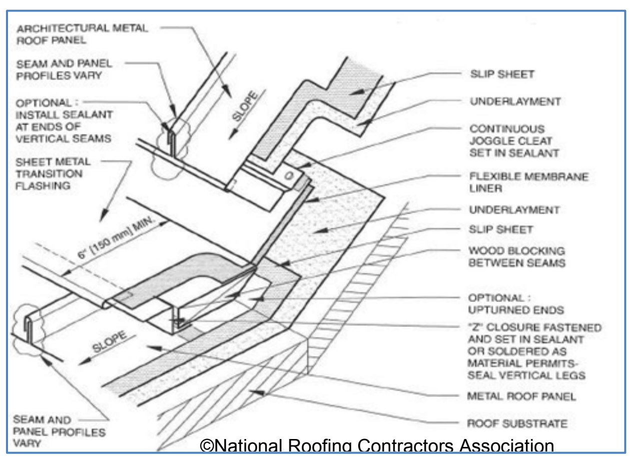

Figure 10-82
Transition from Metal to Metal Roof Slope

These transitions can occur on low or steep slope roofs and may require special installation methods and additional material, including custom-formed transition trim. Additional details will be discussed in Section 10.12.5, *Roof Geometry*.

The 2012 IBC (International Building Code) designates several minimum slope requirements for metal roof installations:

- The minimum slope for lapped, non-soldered seam metal roofs *without* applied lap sealant shall be three units vertical in 12 units horizontal (25-percent slope).

- The minimum slope for lapped, non-soldered seam metal roofs *with* applied lap sealant shall be one-half unit vertical in 12 units horizontal (4-percent slope). Lap sealants shall be applied in accordance with the approved manufacturer's installation instructions.

- The minimum slope for standing seam of roof systems shall be one-quarter unit vertical in 12 units horizontal (2-percent slope).

- Metal roof *shingles* shall not be installed on roof slopes below three units vertical in 12 units horizontal (25-percent slope}.

10.12.3 Longest Roof Run

Except for the most basic of roofs, the roof itself is made up of geometric areas of various sizes and shapes. Consideration needs to be given to the area of the longest roof run. This area will have the greatest thermal movement, the longest length of material, and most likely involve end lapping of roof panels. Depending on the style and configuration of the panel, aesthetic considerations may also apply, such as oil canning and exposed fasteners.

10.12.4 Deck Substructures

Deck substrates were covered in detail in Chapter 6, *Roof Deck Substructures*. Several considerations are made when a designer selects a roof deck. Structural panels are normally, but not always, attached to spaced structural members over open areas. The panels are specifically designed to support additional weight and loads between the structural members.

Architectural panels, on the other hand, require a solid or closely spaced deck substrate. The deck may be made from plywood, individual wood members, metal decking, or even cement or a similar material. However; the substrate should be smooth and flat, free of debris and obstructions which would cause panel distortion. Underlayment and slip sheets are often required when installing a metal roof over a solid deck substrate. Insulation and vapor retarders are also sometimes specified.

The type of deck, substrate material, and any additional insulation will affect fastener requirements of any roof surface. Always consult with the roof manufacturer for fastener requirements to any specific installation.

10.12.5 Roof Geometry (Hips, Valleys, Dormers, etc.)

Roof profile and geometry are factors used in determining many other aspects of the specified roof. Common roof profiles are shown in Figure 10-83.

Historically, each geometric profile originated to meet a need. That need may have been to create a more open storage area, or a sleek, attractive low-profile which is barely visible from the ground. Whatever roof geometry is being installed, attention to the areas of slope change (dormers, hips, valleys, etc.) and roof edges (eave, ridge, and gable ends) during installation is necessary. Roof geometry will also determine a roof's hydrostatic or hydrokinetic characteristics and underlayment requirements.

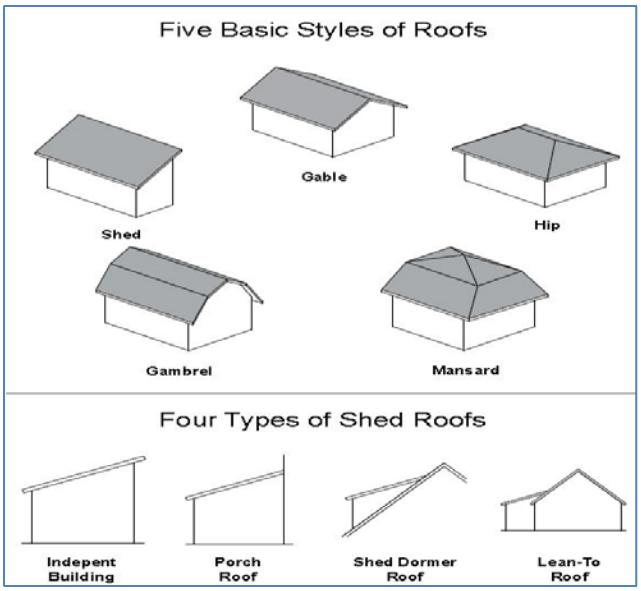

Figure 10-83

Basic Styles of Roof Design

10.13 Field Measurement

Field measurement of certain roof parameters is the best way to determine the specific requirements for the installation. "Seeing is believing" and taking a field measurement provide critical installation information not available from any drawing. Accurate dimensions cannot be determined from pictures, but should be measured on-site.

10.13.1 Before Ordering

If at all possible, there are several construction details the roofing team needs to confirm before ordering the roofing material. Roof squareness, penetrations, roof mounted equipment, and surrounding features may all affect how the roof panels are laid out, installed, and finished or trimmed. Often, significant savings can be found by slightly shifting panel layouts. Care should be taken to maintain balanced seams on gable ends as well as noting how panel seams fall in relationship to any roof jacks, accessories, and curbs.

Roof condition (in a reroofing situation), accessories, and renovations installed by other tradesmen should be field-evaluated. Rarely can such items be accurately evaluated from drawings and sketches. Field evaluations often reveal opportunities to simplify the installation and reduce costs. For example, rerouting of vents, elimination or removal of unused vents or roof mounted equipment, and similar items can simplify the installation as well as lower the cost.

10.13.2 For Curves

Any radius application, installing metal over a curved surface, is best accomplished after field measurement of the curved section. Figure 10-84 is an example of field measurements a manufacturer typically requires in order to ensure proper material and installation methods are used. Sometimes curved sections are "custom-fit" in order to account for irregularities, or to provide smooth transitions between two sections, meaning the only way to get an accurate dimension is to measure the actual area. Manufacturers often require additional structural information besides dimensions of the curved roof section.

Radius applications require additional work and care in installation. Curving the metal without creasing or damaging the panel, while preventing gaps and leaks at joints is critical. Aesthetic considerations are also a major concern. Most curved applications are in a highly visible section of the roof; therefore, care must be taken to allow the panel to curve without warping, twisting, or distorting. Consideration must also be given to pinning and the potential thermal movement of the curved section of material.

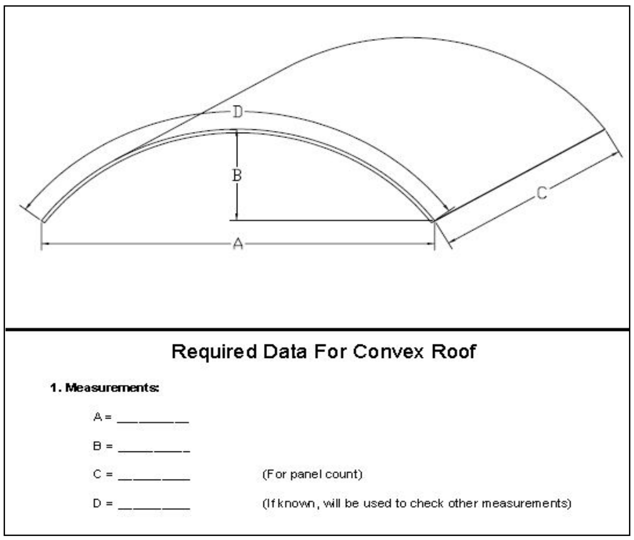

Figure 10-84
Typical measurements for Radius Applications

10.13.3 Eave Overhang

The eave overhang measurement will be a factor on underlayment and ice dam material requirements. In addition to the size and style of trim material that may be required; eave overhang may be a factor in a designer's use of ventilation options. Keep in mind that the overhang portion of the roof is considered a cold portion of the roof, and is especially vulnerable to freezing in colder temperatures.

10.13.4 Pitch

Roof pitch, or slope, has already been discussed in Section 10.12.2, but field measurement of this roof parameter will ensure an accurate estimation of necessary material and supplies.

This can be determined using several methods. One method requires taking a few simple measurements and either calculating, or using a table, to determine the slope or pitch.

Another method uses a simple slope measurement tool as shown in Figure 10-85. This is basically a protractor-type tool, which is placed on the roof slope and directly read off the dial.

Figure 10-85
Slope Measurement Tool

Summary

While it is true that designers and engineers normally do not do the roof installation, and installers do not do the design and engineering function, it is important that every installer understands key design concepts and principles involved in roof selection.

Every day, installers are faced with challenges and situations which have no "step by step" solution. Understanding the reasons behind key design areas will allow the installer to either make the best informed decision during an installation, or intelligently discuss the issue with a member of the design or engineering team.

Notes:

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