# THE FREQUENT SINS OF STEEP SLOPE METAL ROOFING

**BY R.M. HADDOCK**


## Abstract

Market trends in roofing would imply that steeper is better. Metal roofing systems have been used in steep roofing applications for centuries. Lessons learned from recent real world experience indicate that mistakes are commonly made in two key areas: underlayments and panel pinning. To correct either problem category, (post-installation), roof removal may be unavoidable.


## BACKGROUND

**Underlayment:** European and early American installations of metal roofing were non-structural, hydrokinetic (water-shedding) systems without underlayments. They utilized soft metals like lead and copper and tightly folded and crafted jointing performed by expert craftsmen. Joints were less prone to infiltration. The use of harder, less malleable metals and market pressure to reduce labor costs have metamorphosed American metal roofing products and systems into many new jointing styles for steep roofing. These are more easily fabricated and installed, placing less demand on installation skill, time, and aptitude.

While more economical, some new jointing methods are also more prone to infiltration during severe weather events. This has mandated the use of waterproofing roof underlayment materials to assist in weather protection. Some practical questions arise with respect thereto. How should these materials be integrated with the metal coverings? To what degree can they be relied upon? What unforeseen demands are placed upon them? How compatible are they with these newer metal systems? How predictable is their performance together? Under certain circumstances can they adversely affect metal panel performance? In the final analysis, what fails and how?

**Panel Pinning:** Earlier standing and batten seam pans were comprised of short lengths of six to ten feet (2-3 meters) which were brake-formed and jointed end-to-end with a folded loose-lock, enabling some minimal dimensional change in pan length and thus tolerating thermal cycling of the roof material. The panels' attachment method essentially ignored issues of thermal movement as they were rigidly cleated into place on roof decks. The short lengths of material used forgave this attachment method, as thermal movement was minimized and never accumulated for the full rafter length of the roof. The small amount of movement experienced by each pan length was accommodated by some flexure of the attachment cleat and minute differential movement between the individual pans.

Newer manufacturing techniques which involve a process called "roll forming" have taken over the manufacturing of metal panels on a wholesale basis. The process is more efficient, more expedient, more dimensionally consistent—just plain better for many reasons —than hand forming and brake forming. It can also be employed to fabricate roof panels from harder and less expensive metals. The nuance is that panels are longer because roll forming permits a panel to be fabricated in infinite length, if desired. Increased panel length results with greater dimensional (length) changes during thermal cycling. This has precipitated changes in the attachment technology of metal roofing. New methods had to be pioneered which would permit a greater range in freedom of thermal movement.

"Floating" attachment became the convention for standing seam metal roofing. Clip designs evolved which had two components—one fixed to the structure and the other locking into the seam and moving with the panel material. Differential movement, then, takes place within (between the two components of) the attachment clip. Alternatively, the clip design is a one-piece stationary design with a frictional fit to the panel seam material, allowing unlimited thermal movement of the panel along its length. When these attachment methods are used, the question becomes, What holds the panels in place so they don't slide off the roof? The answer, of course, is that they must be "fixed" or "pinned"—attached rigidly in some location. What determines the adequacy of such a connection? Where should it be? How should it be accomplished? Who is responsible for doing it?

## INTRODUCTION

Most often, steep-sloped (or "architectural" roofing as it is sometimes called) is sold by the part and piece. Product manufacturers offer limited accessory items, as their primary business is roll forming panels. Almost invariably, the manufacturer sells attachment clips that are compatible with his panels, and will normally offer criteria with respect to clip spacing and method of clip attachment to the deck material. Often, that is all. "Standard" flashing shapes and profiles may be offered, but they are just as frequently fabricated by the installation contractor rather than by the panel manufacturer. This is prudent, as steep-sloped roofing is very project-specific and something of an "art form," reflecting the individualistic craftsmanship of the installer. Often, it is necessary to meld "as-built" conditions and dimensions with specifics of construction details, which can best be done on a job-by-job basis and with some amount of fabrication at or close to the site. Product manufacturers often offer "standard details," but these are more by way of suggestion than mandate, and many manufacturers will show more than one detail option for a given condition. This practice is also reflected by the most popular specification reference document, the *SMACNA* (Sheet Metal and Air Conditioning Contractors National Association) *Architectural Sheet Metal Manual* (5th edition).

Low-slope, hydrostatic, metal roofing is quite different. These systems have evolved primarily from within the pre-engineered metal building industry. In that industry, the practice is that nothing is left to the discretion of the "individualistic craftsmanship of the installer." Instead, everything is pre-engineered, pre-fabricated, and packaged together, down to the last gutter end cap and pop rivet. The fact that these two conventions—steep-sloped (or architectural) metal roofing, and low-sloped (pre-engineered) functional metal roofing—are so different has caused more than a little confusion in the marketplace as well as in the design and contracting communities. To add add further to the confusion, add the magic word, "system."

There was a time, in years past, when, if the word "system" were interjected, it meant (or at least strongly implied) that we were talking about something from within the pre-engineered metal building convention. In more recent years, with heightened awareness of the potential perils of fire and wind, more and more building requirements have mandated "system testing" to determine and quantify performance with respect to these natural phenomena. Of course, steep-sloped metal roofing product manufacturers could not ignore these new criteria in the marketplace, so they tested (and largely by virtue thereof adopted) the new terminology. Before they offered metal roofing; now they offer metal roofing "systems."

So steep-sloped metal roofing is now often sold as a "system." But questions arise as to just where the "system" begins and where it ends. To the steep-roof panel manufacturer, "system" often means the panel, attachment clip, and their interaction with one other. Performance and physical characteristics are tested and/or engineered by computation as they relate to beam strength, attachment, wind resistance, and so forth, using various combinations of these two components—panel and clip. However, in the mind of a user, designer, or specifier, the word "system" may have a far broader interpretation.

When roofs fail, people are forced to figure out why. Of course the finger pointing goes on, and no one thinks it is his fault. If there is anything positive that results from our litigious society, perhaps it is a growing awareness of what kinds of things go wrong and how they might have been avoided had things been done differently. Of course, hindsight is 20/20. Not unlike other roof consultants, a large part of the work I do is to investigate what went wrong. I have repeatedly found the same sorts of problems. The bottom line is that when a roof fails, there is always a reason. "Blame," however, is not always easy to assign, because sometimes "everybody did it" and often "nobody did it," and "who was supposed to do it" is not always clear.

The most redundant mistakes I have seen with respect to steep-sloped metal roofing are the subject of this paper. They fall into two categories: problems related to fixity and problems related to underlayment. The mistakes herein described are in fact so common, so redundant, that they occur in one form or another on more jobs than not.

## PROBLEMS RELATED TO FIXITY

Standing seam and other similar products are, by their design, intended to "float." That is, they are permitted by virtue of their attachment method to have freedom of thermal expansion and contraction. Generally, this is accomplished by a clip design which intergrates with the seam in such a way that the panel slides back and forth on the clip as it cycles thermally. There are also significant forces at work on any roof which try to pull the panel down the slope of the roof. These forces are sometimes referred to as gravity loads or drag loads. If the panel is not pinned at some location, these loads can displace the panels from their intended position, pulling them down the slope of the roof (*Figure 1*).

*Figure 1: As long as the law of gravity remains on the books, panels that are not pinned will migrate down the slope of the roof.*

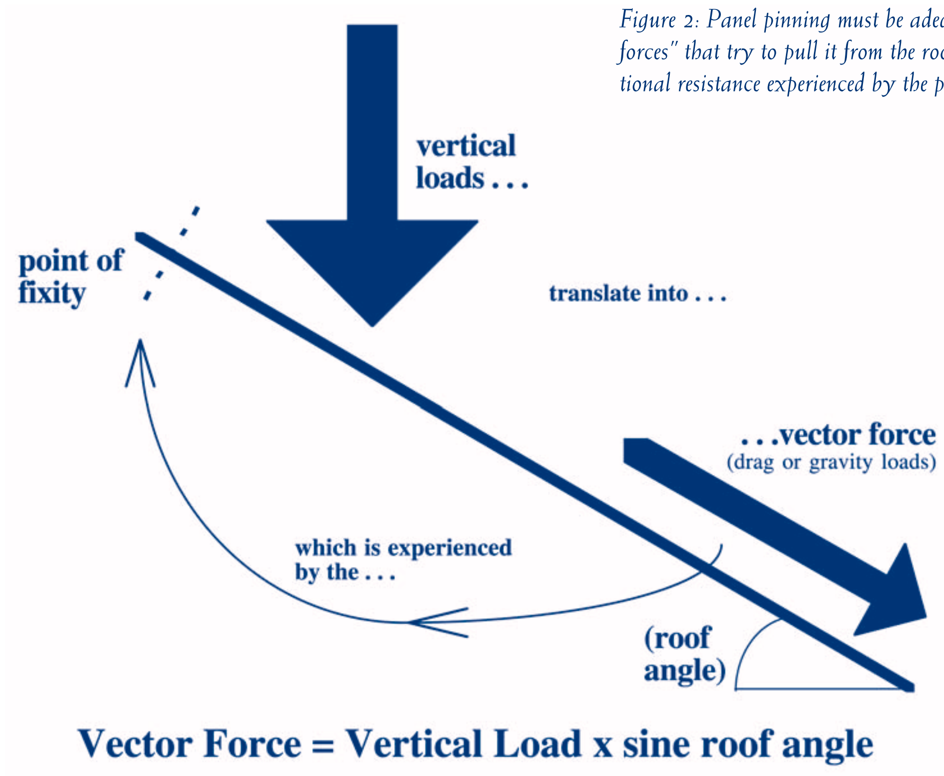



*Figure 2: Panel pinning must be adequate to withstand the "drag" loads, or "vector forces" that try to pull it from the roof. The pinning must also withstand any frictional resistance experienced by the panel during thermal cycling.*

## Sin #1: Failure to Pin the Panel

The most common pinned location (or point of fixity, as it is sometimes called) is at the ridge end of the panel. This is because the pinning often involves screws through the panel and into the deck or structure. The ridge is a convenient place for such fastening, because the fasteners can be easily concealed by the ridge cover itself, which also then protects the fastening from direct exposure to the elements. There are also other methods used to "fix" or "pin" panels, and depending upon the method chosen, the point of fixity may be somewhere other than the ridge. On very long runs of panels, it may be advantageous to pin the panel at its midpoint rather than at the end. This has the effect of cutting the thermal movement in half, since it is now sent in two directions rather than one (*Figure 2*). Such mid-point panel fixity is not usually done with exposed fasteners for aesthetic reasons, so another method must be employed. Depending upon the panel design, such a "midpoint pinning" may or may not be possible.

The other common method of pinning the panel is via the panel's attachment clip. Sometimes a slightly different clip design might be employed. Traditional double-folded standing seam, for instance, often utilizes an "expansion clip" at all locations other than the panel's pinned point. One or more "fixed clips" might then be used to pin the panel at its intended point of fixity. Normally, a fixed clip is a single-component clip, while an expansion clip is a dual-component clip. Alternatively, on other panel profiles, the male portion of the seam may be mechanically fastened to a single-component clip to eliminate differential movement between these components, thus pinning the panel.

The location and method of pinning must be carefully matched to the panel type and construction details being used on a job-specific basis. Often, this aspect of "applications engineering" falls through the cracks and does not get done at all. The panels' interface with their attachment clips and substrate has enough friction to hold panels in place temporarily, giving the installing contractor a false sense of security. Provided the law of gravity is not somehow repealed, with time and exposure, the panels begin to migrate down the slope of the roof.

## Sin #2: Failure to Pin the Panel Adequately

The forces at work trying to displace a roof panel from its intended location can be considerable. They are a result of live, snow, and dead loads at the roof's surface which then translate into an angular or vector force acting parallel with the slope of the roof (*Figure 2*). The dead load of the panel itself is rather insignificant. Live and construction loads may govern in southern climates, but snow loads are generally the greatest and govern in northern climates.

The panel's fixity must also withstand the cumulative effect of crimping forces at all the clip locations down the length of the panel. When the panel tries to grow thermally, it encounters resistance in the clip connection (*Figure 3*). If that resistance at a single clip location is 20 pounds, and there are 30 clips down the length of the panel, then the total resistance is 600 pounds. That total force of 600 pounds is then transmitted to the fixity point cyclically every time the panel undergoes thermal expansion or contraction. The panel may also develop "tack" to the substrate to which it is applied. This tack also exerts resistance to thermal movement which is experienced by the panel's fixity point.

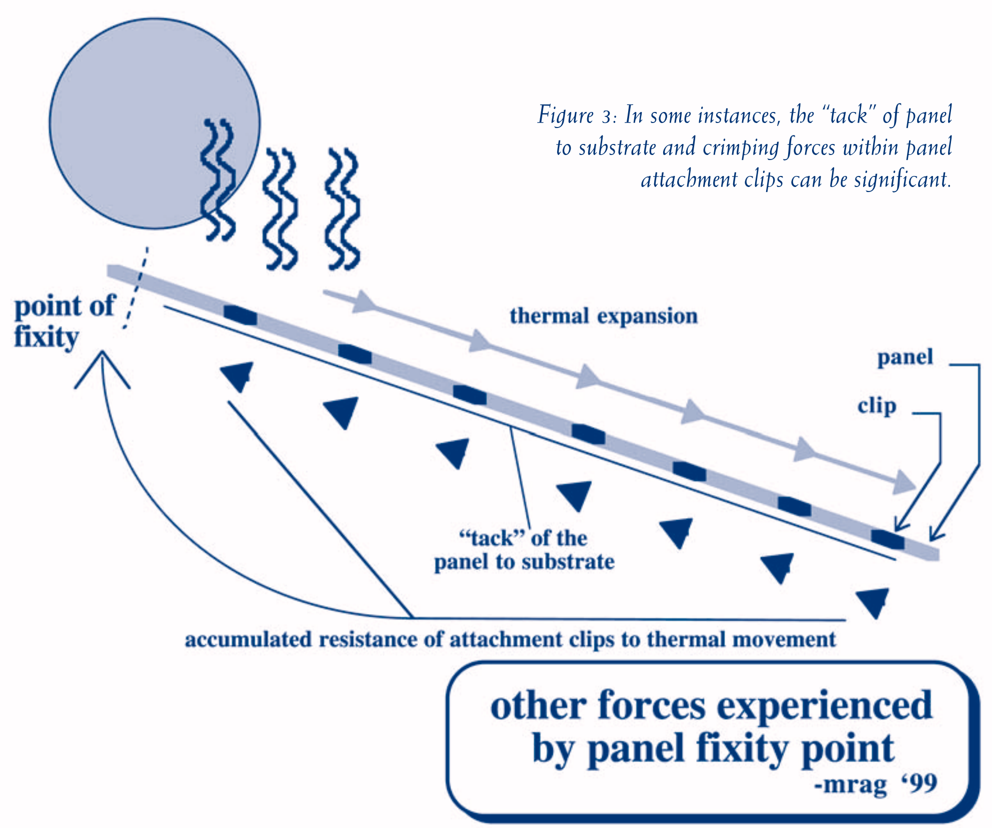



*Figure 3: In some instances, the "tack" of panel to substrate and crimping forces within panel attachment clips can be significant.*

Many of the above discussed loads can also be experienced in various combinations. Some are foreseeable and calculable; others are very difficult to quantify. In many cases, none of this is done or even attempted. The architect or designer is usually aloof to this aspect of roof design. The structural engineer rarely concerns himself with the roof, and in many cases, would be lost if he did. The contractor often does not have the knowledge or expertise, and the panel manufacturer is not usually involved with these kinds of particulars on a job-by-job basis. The result is that this aspect of metal roof attachment design falls into a "black hole" and simply does not get done. The contractor installs the panel fixity method and frequency the same way he did it on the last job, which may or may not be adequate for this one. It is often very arbitrary and not really designed for job specifics as it should be.

## Sin #3: Multiple Points of Fixity of the Panel

Having properly executed the panel's point of fixity, it is free to respond to thermal cycling as need be and without migrating out of position. In an expansion mode, the increase in length accumulates to the panel's free end—the end opposite its fixity point. In a contraction mode, the loss in length is also experienced at the panel's free end. The difference between the extremes in these dimensional changes is the total thermal movement. This total dimensional change (thermal movement) is directly related to the panel's length—the longer the panel the greater the dimensional change (*Figure 4*). It is central to the integrity of this freedom of thermal movement that the panel is indeed free to move toward its free end without restriction.

Another frequent mistake is the fixing of the panel in more than one location. For instance, the panel may be inadvertently fixed at both ends—at both the ridge and at the eave end. This

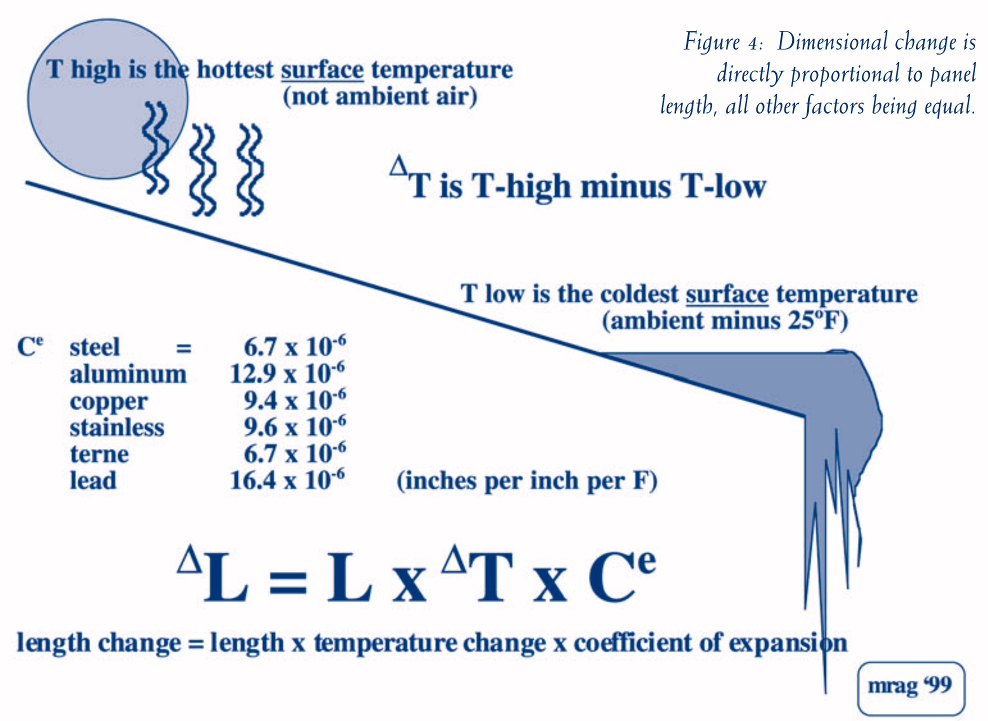



*Figure 4: Dimensional change is directly proportional to panel length, all other factors being equal.*

*Above: Figure 5: A "fascia break" detail constitutes panel pinning because the vertical panel plane is cleated to the wall, inhibiting any movement along the slope of the roof at this interface.*

often happens when the ridge is pinned in normal fashion, and then a "fascia break" detail is incorporated at the eave end. The fascia break inadvertently pins the eave, because the vertical portion of the panel is cleated to the face of the structure (*Figure 5*).

Another example of multiple panel fixity can occur when a soil stack or similar protrusion is flashed to the surface of the roof using a rubber or metal pipe flashing. Often such a flashing is fastened through the roof panel and into the deck, thus pinning the panel (*Figure 6*). The deck should be "over cut"—that is, the hole in the deck should be larger than the base dimension of the rubber flashing so that the flashing can attach to the roof panel but avoid attachment to the deck material. Thus the "pinning" at the pipe flashing location is avoided, and freedom of thermal movement is preserved (*Figure 7*).

Another example of dual pinning is when the usual ridge pinning is done, and then snow guards (which screw into the deck) are installed at the lower end of the panel. The attachment of the snow guard *through* the roof panel and into the deck or structure constitutes multiple pinned locations of the panel (*Figure 8*). Instead, use snow guards which attach to the panel seams in a non-penetrating fashion.

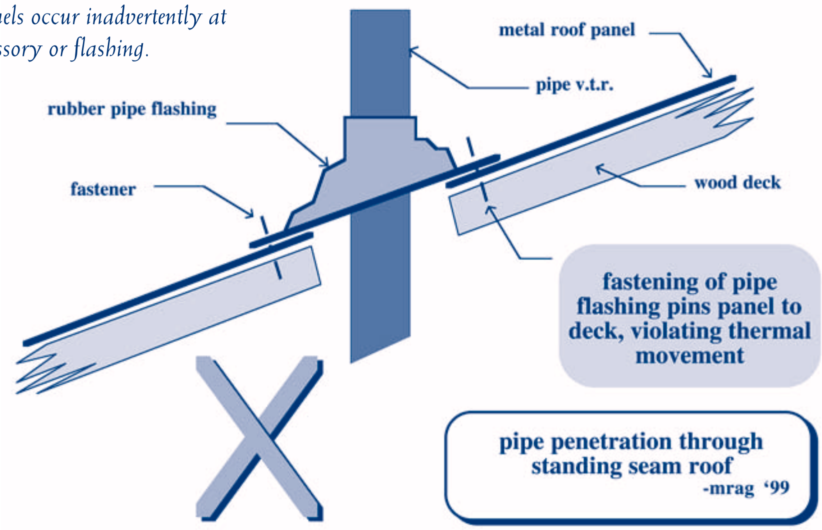
Other examples of inadvertent fixity occur less frequently. Many manufacturers' "standard" rake details violate thermal movement and constitute multiple points of panel fixity by attaching rigidly to the panel as well as the rake fascia or deck material. In some cases, poorly-designed ridges, slope transitions, or headwall details may also inhibit freedom of thermal movement, these can lead to fastening fatigue, oil canning, or outright fastening failures.

These are some typical examples (but only a few of many) of how panels get pinned at multiple locations. When such dual pinning occurs, failure is almost certain. The forces generated when a steel panel moves thermally— or tries to —are measured in tons for a single panel. Dual points of fixity of long panels means certain failure—something is going to give.

## PROBLEMS RELATED TO UNDERLAYMENT

Most steep-sloped roofing systems are "hydrokinetic" by design. They rely upon water to shed freely over their joints and interfaces. At some point in the life of the roof, some amount of moisture may infiltrate a construction detail or the panel seams themselves. For this reason, such a system is always used in "belt and suspenders" fashion. The metal panels and flashings must keep all the water out most of

*Figure 6: Often dual pinning locations of panels occur inadvertently at a roof accessory or flashing.*



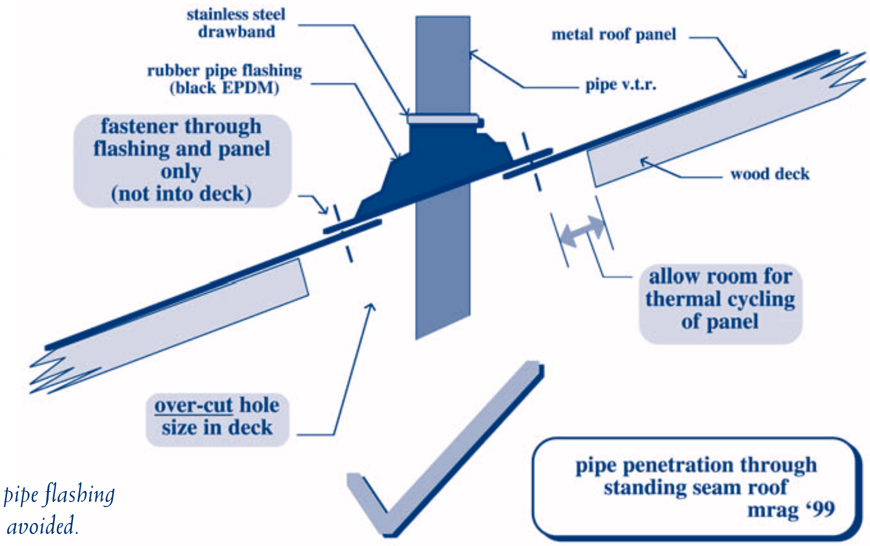
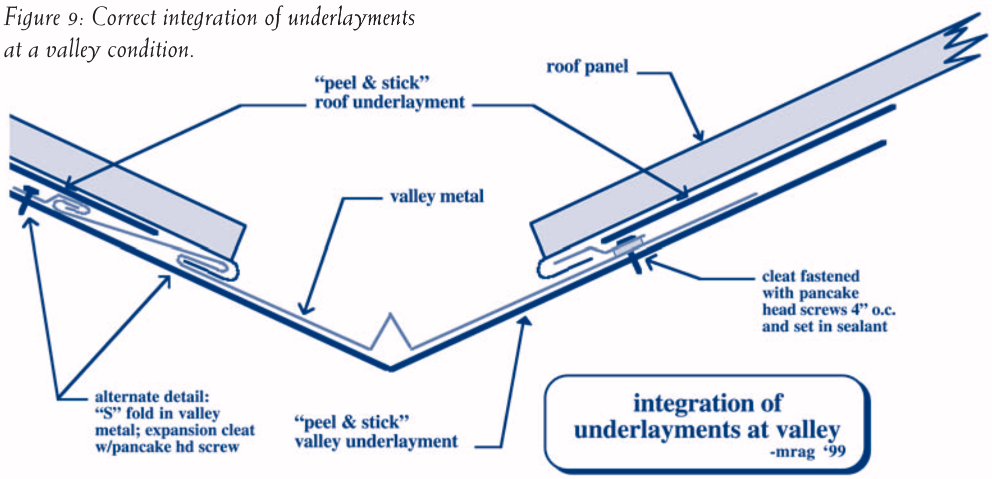




*Figure 7: By over-cutting the hole in the deck and fastening the pipe flashing only to the cantilevered portion of the panel, the dual pinning is avoided.*

*Figure 8: Snow guards which are mechanically fastened through metal panels and into the deck, constitute pinning of the panels at that location.*

the time, but on occasion, during a particularly severe weather event, they may admit minor amounts of moisture. It is then the job of the underlayments to direct that moisture back outside the building envelope rather than to let it drip onto the floor.

*Figure 9: Correct integration of underlayments at a valley condition.*

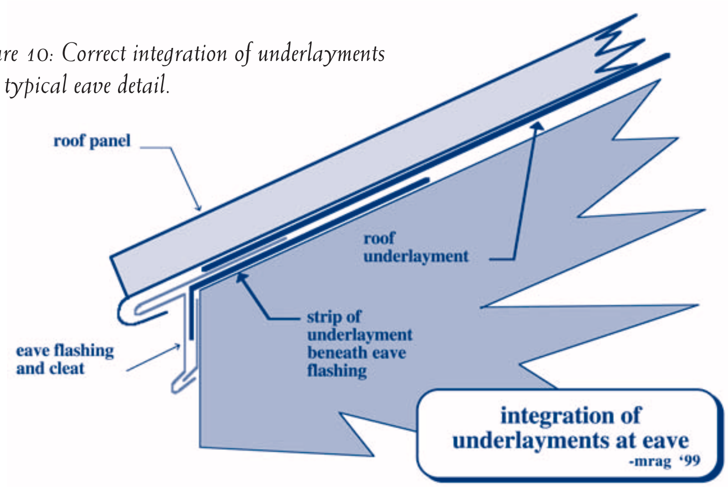



## Sin #4: Failure to Integrate Underlayment Correctly with Metal Flashings

The underlayment should bring infiltrated moisture back to the roof's surface at the soonest opportunity. At valleys, this dictates sequencing the installation of underlayment and related metal flashings. Valley underlayments must be in place first; then the metal valley flashing itself, including the lock strip for the panel. Next, underlayments for the roof field are installed so that they weep to the top of the lock strip. Finally, the panels are placed (*Figure 9*). NRCA details fail to recognize this.

The same concept is used at the eave detail. Lock strip is installed to the fascia first. Then a strip of felt is applied at the roof edge and ideally should be folded over the fascia, weeping to the surface of the lock strip. The function of this particular underlayment is to back up the eave flashing. Joints and nailing of the eave flashing may be subjected to some minor

*Figure 10: Correct integration of underlayments at a typical eave detail.*



amounts of infiltration, that should not be permitted to find its way to the deck material. This underlayment strip will also protect the underside of the eave flashing from any corrosive chemicals that may be present in some wood products (*Figure 10*). This underlay is not shown in NRCA details.

The installation mistakes commonly made with respect to these details are that the roof felts are installed in a continuous fashion beneath the metal so that infiltrated moisture is directed *under* a flashing rather than back to the weather side (top) of the flashing. This aspect of underlayment integration is done wrong far more frequently than it is done correctly. It is also shown incorrectly in many industry documents, including panel manufacturers' standard details.

The same general concepts apply to underlayments at transitions, headwalls, coping covers, and the like. Once again, incorrect graphics and execution of these details are the rule rather than the exception.

## Sin #5: Inappropriate Selection of Underlayment

The industry standard underlayment material is #30 asphalt saturated organic felt, or two layers of #15 felts conforming to ASTM D-226. This is not adequate for some situations. Repeated wetting of asphalt felts will cause them eventually to become water-soaked. When this happens it can cause the deck to rot or corrode, depending upon the deck material. It can also cause underside panel corrosion. Coated steel is very intolerant of moisture being trapped against its surface, and when subjected to such a condition, will corrode very, very rapidly. I have seen such conditions rust completely through to perforation in as little as two years (*Figure 11*).

If the underlayment material is going to be subjected to frequent wetting, it should be a non-absorptive sheet, such as a modified bitumen sheet. Some editorializing is called for here—if we anticipate frequent infiltration, then perhaps we should re-think the detail and halt the infiltration at its source. There are only limited occasions when we knowingly allow such infiltration. One is when using a tight radius curve. In order to achieve such a detail economically, often a cap seam-type panel profile is used. The panel is advertised as a one-inch seam height, but in actuality, the upstand is often only 5/8 inch. Such a minimal dimension makes the profile easy (and therefore affordable) to curve, but it is also rather prone to infiltration. Modified bituminous "peel and stick" membrane is a must for such an installation.

Another example for use of a premium-grade underlayment is the eave area of a roof in a northern environment where some flooding of the seams may be a seasonal probability due to ice damming. In such climates, the addition of seam sealant is advisable, but on some profile types, this may not be easily accomplished. In such cases, the use of a "peel and stick" at the eave area is cost-effective insurance, as is the case when using other types of roofing. The same things can be said of a valley in almost any climate. The modified asphalt will not absorb moisture with repeated wetting as organic felt will.

A word of caution when using modified asphalt membranes pertains to their "softening point." Metal roofs can achieve surface temperatures of 200ºF or more in some instances. Many rubberized asphalts soften below this temperature and may begin to flow (*Figure 12*). When roofing material is a dark color, low gloss finish, or both, caution should be exercised in the selection of the membrane with respect to its softening point. Copper, weathered zinc, and CorTen (or black) steel can reach extremely high temperatures under a hot summer sun. Even if the softening problem is overcome, "tacking" of metal panels to underlayment can still occur. This also contributes to forces acting on the pinned connection as discussed earlier. Some of these adverse side effects can be mitigated by: 1) using a paper or foam slip sheet between underlayment and metal panels, and/or 2) using a panel clip which elevates the panel a fractional inch above the surface of the underlayment, allowing a small air space.

## Sin #6: Prolonged Exposure of Underlayments

Almost invariably, the reality of the construction process is such that when the last sheet of deck material is laid, the general contractor is on the phone to the roofing contractor to come out and "dry in" the job. At this juncture, the roofing contractor is

*Figure 11: These panels are corroded through to perforation from the underside as a result of frequent moisture infiltration and felt saturation. They are two years old.*

ready to field measure and order material. He is still far from ready to install metal panels. Relentlessly, the general contractor demands the roof be "dried in" so that other trades can proceed with their work.

Finally, the roofing contractor yields to the threats and demands of the general contractor and installs the felt. Three or

*Above: Figure 12: Metal panels can get hot enough to exceed the softening point temperatures of some modified asphalt materials. This is especially true of dark colors and low gloss finishes.*

four weeks later, when the roofing panels arrive at the site and work is ready to commence, the felts are shot: sun-bleached, wrinkled, wind-torn, and possibly even water-soaked. Because no one is willing to foot the bill for replacement felts, they are covered with metal panels even though they are not fit for use. Such practice is the rule rather than the exception, and so most metal roofing is installed over unsuitable underlayment. That underlayment has a rather poor chance of performing to expectation when any infiltration finds it.

### Sin #7: Too Much Reliance Upon the Underlayment

A steep-sloped, hydrokinetic roof is a "belt and suspenders" partnership. Partnerships are rarely successful when one partner is expected to do all the work. Often, craftsmanship of critical sheet metal details is compromised by an installer who simply has too much faith in the underlayment and its ability to act as a "roof." The installer is not the only one deceived by this misguided faith. Frequently, the panel manufacturer also puts far too much faith in the underlayment's ability to function as a "roof." Such an attitude, and the workmanship standards associated therewith may allow frequent infiltration, placing too much demand upon the underlayment and often yielding disappointing results.

## CONCLUSIONS

1. Although these roof assemblies are called "systems," often the term applies only to the panel and clip interface, clip frequency, and clip attachment. Someone must still perform certain aspects of "applications engineering and evaluation" on a job-specific basis. Exceptions are rare as the nature of this work is not conducive to putting everything "in a can," and often parties other than the metal panel manufacturer may be more qualified to evaluate the job-specific conditions.

2. Roof designers should identify (or cause to be identified) a panel fixity point and inspect construction to verify as-built compliance. The location of fixity must be compatible with construction details being used and vice-versa.

3. The method and frequency of fixity should be carefully reviewed for adequacy in view of live, construction, and snow loads anticipated as well as frictional resistance during thermal cycling. While the use of a slip sheet is not standard industry practice beneath painted steel and aluminum panels, its use is prudent to reduce tack, promote freedom of movement, and relieve stress on panel fixity.

4. Roof penetrations and other construction details should be carefully reviewed to be sure that freedom of thermal movement is preserved and dual pinning does not occur. Rooftop accessories should be attached with utility clamps that do not penetrate or pin the panels to the roof deck or building structure. Inspections should verify that as-built construction complies with this design intent.

5. All metal panels are not created equal. Infiltration characteristics vary, placing differing demands upon the underlayment. Underlayment type must therefore be suited to the panel (as well as other factors).

6. Care should be taken to integrate underlayment correctly with metal flashings. Infiltrated moisture should be brought to the "weather" side of the metal coverings at the earliest possible opportunity. Field inspections should verify that this intent is served when executing the work. Many industry standards documents and manufacturer drawings do not detail underlayment, and many that do are incorrect in this regard.

7. The practice of using #30 asphalt felt, which is then left exposed for prolonged periods, is a poor one. Steps should be taken to ensure that exposed felts are replaced or recovered immediately prior to metal roof installation. Specs can be written to mandate this practice by calling for a "dry-in" felt. Then a stipulation should be made that it be removed or recovered immediately prior to metal roof panel installation.

8. All underlayments are not created equal. In many instances it is advisable to increase underlayment diligence by using modified bituminous peel and stick membranes. They are more durable, more waterproof, and do not absorb moisture.

9. Exercise caution when using peel and stick membranes with respect to their softening point temperatures to avoid flow problems beneath hot metal roofing.

10. Use slip sheet and/or air space immediately beneath the panel to prevent "tacking" of panel to underlayment.

11. Panel manufacturers possess little knowledge or expertise concerning underlayment types and performance characteristics but generally agree that it is needed, often leaving the particulars of its specification to the designer.

12. All installation contractors are not created equal. The nature of steep-sloped, architectural metal roofing is such that it depends heavily on contractor experience and craftsmanship. The frequency and volume of infiltrated moisture is often a result of the individual technique and craftsmanship of construction detail execution by the contractor. Challenging details should be performed by expert mechanics, not rookies.

13. Good, durable metal details should not be compromised in favor of heavier reliance upon underlayment.

14. All climatic environments are not the same. Some climates place much higher demands upon roofing systems than others.

15. Steep-sloped metal roofing applications are very job-specific. In addition to the above, the following aspects are all interrelated on an individual job basis.

- Type of underlayment used.
- Panel style used.
- Panel material used.
- Nature of roof geometry.
- Nature and infiltration characteristic of construction details.
- Degree of slope.
- Other particulars of roof design, e.g., cold or warm; cold overhangs, etc.
- Climate at project site.
- Method of fixity.
- Length of panels (amount of calculated thermal movement).
- Point of fixity.
- Type of deck.

If one variable changes, prudence may dictate a change in another. All these factors should be reviewed by the vendor chain, design team, and installation contractor to be sure that all bases are covered. There is no acceptable short cut to a job-specific evaluation of the many variables listed. No specification reference, ASTM standard, or industry standards document or combination thereof will ensure that all the appropriate selections are made.

## BIBLIOGRAPHY & COMMENTARY

Both SMACNA and NRCA offer some construction details for steep-sloped metal roofing. Portions of both are very good in some areas and rather poor or inadequate in others. Both are weak with respect to underlayment integration with metal roofing and flashings and in a few details, downright incorrect. The NRCA manual offers some limited information on panel fixity locations but nothing regarding methods or frequency of attachment. Both publications offer multiple details to accomplish a given construction condition, which is appropriate due to the many variables listed above. Someone must still choose which detail befits those variables the best, as they are not all appropriate or even acceptable for every job and condition

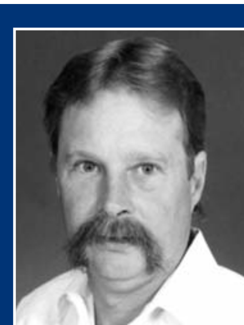
*Architectural Sheet Metal Manual*, 5th Edition; Chapter 6; Sheet Metal and Air Conditioning Contractors National Association, Inc., Chantilly, VA, 1993.

Haddock, Robert, "What Makes a Metal Roof a System?" *Contractors Guide*, Niles, IL, October 1995.

*The NRCA Roofing and Waterproofing Manual*, 4th Edition; Metal Roofing Section; National Roofing Contractors Association; Rosemont, Illinois, 1996.

The best educational source for metal roofing is still the two-day course offered by the Roofing Industry Educational Institute; Littleton, CO, (303) 703-9870. The Metal Building Manufacturers Association is currently working on a book entitled "Metal Roofing Systems Design Manual." MBMA; Cleveland, OH (216) 241-7333. ■

## About the Author



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