TOP TEN LIST:
WHAT GETS METAL ROOF DESIGNERS IN TROUBLE?

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**Abstract**

Sheet metal is a unique roof system choice that continues to evolve into new systems and applications. Metal roofs are gaining market share in both commercial and residential markets. Building owners have a high performance and aesthetic appeal expectation for metal roofs. This evolution comes with problems. The speakers will present their top ten problems for metal roof designers. This will include a description of the problem, why it may occur, ramifications, and how to prevent it through proper design. The presenters draw from over 50 years of combined metal roofing experience.

**Speakers**

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BRIAN GARDINER has practiced roof consulting for over 32 years. He is a past director of both RCI’s Region IV (1995-1998) and the Building Envelope Institute, Inc. (2005-2006). Gardiner has created and presented numerous roofing-related seminars for RCI, including its two-day Metal Roofing course. He has specified, provided detail drawings, and reviewed workmanship for millions of square feet of metal roofing. Gardiner’s experience also includes several evaluations of failed metal roof systems.

*CHARLIE SMITH – McELROY METAL, INC., HOUSTON, TX*

CHARLIE SMITH founded Architectural Building Components in 1989. Over the next 23 years, the company grew into an industry-leading metal roofing and wall system solution provider specializing in the use of metal to re-cover existing sloped roofs. In 2012, his company became a part of McElroy Metal. This enabled Smith to focus on educational and product development efforts to help the roofing industry design creative solutions with metal. Smith holds several patents relating to metal re-cover and recently co-wrote the new RCI Metal Roofing course with Brian Gardiner.
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OVERVIEW

Ever-greater demand for metal roofs has resulted in an increased need for education of designers who are not familiar with metal roofs, but now have been asked by their client to design one. Unfortunately, building owners frequently have a higher performance and aesthetic expectation for metal roofs. Metal roof failures are typically more costly than failures associated with other commercial roof choices. This paper is intended to provide a review of the authors’ top ten list of problems for metal roof designers and describe how to prevent problematic conditions. Consider adding these items to the agenda of a pre-roofing meeting, if one of these conditions exists on your particular project. Also consider the value of a roofing manufacturer-produced shop drawing and a contractor-fabricated mock-up before work commences.

INTERNAL GUTTERS

Sloped crickets (aka saddles) are designed to slope to roof drains or scuppers on membrane roofs that slope to a wall. When a metal roof is designed, an internal gutter is installed at the wall, also known as a concealed gutter (Figure 1). This gutter is much more problematic and should be deleted during the design phase of a new building and eliminated in a reroof if feasible. If this is unavoidable, the utmost attention must be given to design, detailing, specification, and quality assurance by the designer. Unlike conventional gutters, an internal gutter is commonly part of the thermal envelope, bringing the challenge of how to insulate and prevent condensation problems on the underside of a gutter exposed to interior conditioned space.

Consult with local contractors and metal roof manufacturers in the building’s geographic area. Consider specifying a heavy-gauge, welded, 300-series stainless steel, with welded endcaps, expansion joints, outlet tubes to connect to drain piping, and welded scupper outlets for secondary drainage (Figure 2).

Consider more robust primary and secondary drainage provisions than the building code requires to prevent water and debris accumulation. Insulate the underside to maintain the building’s thermal envelope, and install an air/vapor retarder to prevent condensation. Determine and specify local proven methods to allow thawing in the gutter in ice and snow regions.

If a gutter liner or a membrane roof with saddles and conventional drains is specified, design a method to allow removal and replacement without having to remove upslope roof panels. The liner and roof membrane will typically have a shorter life expectancy than the metal roof panels.

Metal roofs over retail and office space appear to be the most susceptible building types, as a storefront appearance is desired, and roof height (and structural cost) are reduced by sloping metal roofs to a front wall, with a ridge in the mid-span. The same mindset that strived to save money on the building cost, unfortunately sometimes translates into trying to do the same with the internal gutter design. This is one potential problem worth walking (running!) away from if the building owner is not willing to invest in a sufficient design.

VALLEYS

Often, valleys are the major source of water infiltration on metal roofs. Consider roof panel seam type choice when designing a roof with valleys. Roof panel seams that require a closure at eaves, such as trapezoidal, are more difficult to seal at an angle where it intersects valley flashing. Review manufacturers’ details for roof valley design related to closures, back-up plates, and other accessories to incorporate into detail drawings.

Figure 1 – Internal gutter at parapet wall.

Figure 2 – Stainless internal gutter with welded scupper outlet tube.
It is important to divert water down and out via the valley. Consider designing a diverter in the middle to help prevent water from crossing the valley to the other side. Usually, a 1.5- to 2-inch height of the valley diverter is sufficient, but certain designs may require a higher diverter when a large roof area drains onto a lower dormer valley.

It is particularly difficult to provide a long-term design solution for a valley that terminates at a dormer into the lower roof. Consider a soldered or welded one-piece transition flashing at the intersection of the dormer valley with the main roof area (Figure 3).

There are several designs of valley flashings for a metal roof: those with hems, and those without. Discuss with contractors and manufacturers what designs have been successful in your geographic area. Valleys that are fabricated with integral hems require a high degree of workmanship to fabricate the lap joint. They should be fabricated in full length or tapered so the ends nest into one another without cutting out hems.

It is recommended that the contractor provide a mock-up of the valley lap joint to ensure proper fabrication. Another design is to detail an offset cleat. The cleat can be set in sealant tape and fastened through the valley into the deck or structure below. Another solution is a double cleat that allows the panel to be hooked into the valley trim with no penetrations, providing a simple lap joint. On valleys installed on open-frame applications, consider specifying a 48-inch-wide, heavy-gauge backup plate under the valley with a water-resistant, self-adhesive membrane on top. Allow for water that may enter to weep at valley eave terminations.

On lower-slope jobs or retrofit applications, dropping the valley below the plane of the roof may help with drainage, in effect constructing a valley gutter. In cold-weather regions, this will help thaw the ice and snow at the valley first. Water flow is controlled below the plane of the panels, which helps decreases the width of the valley pan.
On curved valleys, consider specifying a welded or soldered stainless steel valley (Figure 4). Curved valleys make it difficult to construct a watertight flashing. Discuss with local contractors and manufacturers to determine what has been successful locally.

**ROOF PENETRATIONS**

Although flashing roof penetrations is typically a simple process with the products available today, these flashings continue to be a potential leak source. Specify and detail pipe penetrations in the middle of the panel with at least 2 in. of clearance between the seam and the pipe boot to allow water flow and prevent debris accumulation. If intersecting the seam is unavoidable, consider detailing a stainless steel pan that spans two roof panels, integrates into the adjoining seams, and provides a flat surface to seal the pipe penetration flashing. Detail a welded end cap that goes over the panel seam(s) on the low side of the pan (Figure 5).

Include provisions in the specifications to include the penetration flashing in the weathertightness warranty. Manufacturers may require a particular type of boot. Specify a high temperature-rated boot when flues or other hot pipes are flashed. Detail a stainless steel drawband to ensure a tight seal at boot intersection with vent pipe.

**CURBS**

Consult with the selected roofing manufacturer to determine which third-party curb manufacturers are acceptable and have the ability to fabricate standing seams to integrate with a roof panel seam. Specify a one-piece, welded stainless steel or aluminum curb, and detail a shingle-fashion installation, with no back-water joints. Determine anticipated loads on curbs and the need for a structural curb separate from the roof curb that floats with the roof panels.

Specify and detail curbs with integral crickets on the upslope side to prevent debris and ponding water accumulation (Figure 6). When numerous large curbs are located on a metal roof, consider detailing raised platforms behind the curbs with standing-seam roof panels that drain onto the lower main roof (Figure 7).
Metal roof retrofits come in two varieties, each with their own design challenges. One version is a sloped metal structure over an existing low-sloped membrane roof when an attic space may be created (Figure 8).

The other is a compact assembly in which the new metal roof is placed over the existing roof, usually with insulation in between (Figure 9). In both scenarios, the original structure needs to be evaluated by a licensed design professional for additional dead load and wind uplift resistance. The existing building's structure may require enhancement to meet the current building code.

A retrofit with a new framing system constructed to add slope should be reviewed by the designer for uniform loading across the existing structure, rigid attachment to the structure, and to ensure that local fire codes are complied with related to creating a new attic space. Other design decisions include what to do with the existing roof membrane and encapsulated rooftop equipment. Consult the owner’s property insurer to determine what additional design features he or she recommends be implemented. Retrofit frames may need to be attached to every bar joist for uniform loading of the existing structure. In order to create a rigid attachment, it may be necessary to cut holes in the existing roof system to connect directly to the structure. This can create a waterproofing challenge during construction of the retrofit frame system. Include detailed temporary waterproofing specifications and details that indicate how to keep the building interior dry. There are stories of entire schools being flooded by several unintended “roof drains” created by holes for structural attachment.

Many pre-engineered metal buildings are designed for balanced loading across the entire structure. Purlins are run straight with no camber, so when they are installed, they naturally deflect downward between the main rafters. When
there is a ribbed metal roof in place, water is controlled between the ribs of individual panels for equal loading on the structure. Re-covers over an existing metal roof with a smooth-surface membrane roof allow water to flow to purlin mid-span. Localized ponding over a deflected purlin increases over time as ponding water increases with increased deflection. As the deflection accumulates more and more water and forces the weak purlin down in the affected bay, the purlins in the two adjacent bays will rise. Eventually, this can divert water from adjacent bays into the affected bay. The result can be catastrophic (Figure 10).

When designing a compact retrofit over an existing metal roof, it is important to consider the type of structure that is being re-covered. An existing metal building with spaced purlins performs differently than a structure with bar joists and a steel deck. Bar joists and a steel deck will distribute loads more evenly. Re-covering an existing metal roof over this kind of structure can be done by several methods. A metal roof on a metal building is attached directly to C- or Z-shaped purlins, which are lapped and connected to each other over the top of each rafter. Equal loading across each purlin is critical to the proper functioning of metal building roof framing.

**ROOF SLOPE TRANSITIONS**

When a steep-sloped roof intersects a lower sloped roof, it is prone to leakage (Figure 11). If possible, reconfigure the roof design to eliminate slope transitions. If transitions are unavoidable, provide a detail drawing and include a requirement in the specifications for a shop drawing. Consult with the manufacturer for warranted detail requirements for their particular roof panel system. Include a specification provision to review a mock-up before proceeding with installation. Detail redundancy, such as a double-closure and water-resistant barrier backup, in extreme circumstances (i.e., a large roof area draining onto the flashing, or if the project is in a cold weather region).

**ENDLAPS**

Metal roof panel endlaps are a major source of leakage. Avoid roof panel endlaps by specifying continuous length panels where possible. Where endlaps are unavoidable, consult with the manufacturer for requirements, and incorporate them into specifications and detail drawings. Manufacturers will often have a very detailed procedure and material list for endlaps to comply with their warranty.

**Figure 11 – Previous repair attempts at roof pitch change.**

**Figure 12 – Roof panel endlap.**

**Figure 13 – Severe oil canning on curved roof.**
requirements (Figure 12). Specify a detailed shop drawing indicating endlap accessories, fastening patterns, and sealant(s). Include in specifications the coordination necessary to review initial installation of endlaps by a roof observer in the presence of the roofing manufacturer’s technical representative. Attempting to repair a roof with poorly constructed endlaps is very disruptive to roof panels and will often shorten roof life expectancy.

OIL CANNING

Building owners frequently have a higher performance and aesthetic expectation for metal roofs, especially those on a steep slope. Oil-canning or waviness in the flat portion of the metal roof panel is inherent in the sheet metal used for metal roofs. It is somewhat subjective; what is acceptable to one person may not be to the next (Figure 13). Steps can be taken in the specifications to significantly reduce the amount of perceivable oil-canning, such as incorporation of striations, planks, or pencil ribs to help stiffen the flat portion of the roof panel (Figure 14). Discuss with the roof panel manufacturer how to reduce oil-canning in their particular roof panel, and coordinate potential methods with architect and owner. Visit a recently completed project that has incorporated oil-canning reduction techniques to determine if they have resulted in an acceptable aesthetic for the architect and owner.

Specify an in-place 30-ft.-wide section of roof mock-up for review by the owner and architect prior to installing remaining panels to review oil-canning. This can then be used as a standard of care for the remaining roof areas. This in-situ mock-up can also be valuable in review of seaming, clip-spacing, attachment, insulation, underlayment, and other items. This small area of roof can prove very beneficial if there is a question as to installation and aesthetics on subsequent roof areas.

ROOF PANEL SELECTION

There are several roof panels available for the designer to choose from. Each has its own list of advantages and disadvantages. A few of the many properties important to selection include roof slope, geographic area, wind-resistance, hydrokinetic vs. hydrostatic, structural vs. non-structural, ease of repair/modifications, finishes, and aesthetic qualities. Discuss with local contractors and manufacturers what has performed well in the project’s area. Review the project characteristics with roofing manufacturers to ensure that the selected panel(s) provide the desired characteristics. Choosing an incorrect roof panel can have significant ramifications, especially if not corrected prior to installation.
WIND UPLIFT

Just as there are several roof panels to select from, there are also several methods to achieve code-compliant metal roof wind uplift resistance. Existing metal buildings may not have enhanced structures to accommodate current design wind pressures, especially if the building is classified as partially enclosed. Depending on slope and configuration, metal roofs can have additional roof areas that are in the enhanced uplift zones. The design safety factor can also vary, depending on the authority having jurisdiction and possibly the number of uplift tests by the manufacturer. Depending on particular project characteristics, consider specifying a structural engineer-sealed roof plan(s) submittal indicating purlin layout, wind uplift zones, and roof panel layout.

A particular roof panel wind uplift performance can vary depending on panel gauge, base metal properties, panel width, seam properties, type of clips, clip spacing, and substrate characteristics. It is important to match all these properties that were laboratory tested with what is specified and detailed. Review wind uplift design specifications with the roof panel manufacturer to determine what panels and accessories would comply with each of the wind uplift zones (Figure 15).

SUMMARY

Metal roofing has several characteristics that are different than other commercial roof choices. RCI, Inc. and SMACNA have recently produced a publication entitled the Architectural Sheet Metal Quality Assurance Guide that has design and quality assurance information for both the metal roof designer and the roof observer. RCI has a two-day metal roofing course that has several chapters involving metal roof design and installation. Metal roofing manufacturers may offer training on their particular roof system that would be valuable for the observer. Experienced local metal roofing contractors can be a very valuable source of information for what has performed well in their area. The metal roof manufacturer may provide on-site technical assistance during construction, especially for systems intended to have a weathertightness warranty. A metal roof can certainly provide long-term service if well-designed and installed according to proven techniques.