STEEP-SLOPE ROOFING WITH CRAFTED METALS

BY DAVID HUNT

Foreword

For purposes of this article, "steep slope roofing" refers to roofs with pitches of three in twelve (3:12) or greater. "Crafted metals" refers to those metals that are cut, bent, formed, and installed "in the field" by an architectural sheet metal contractor. "In the field" may be at a job-site or in a contractor's shop. Forming may be done with hand tools (i.e., tongs), power or hand brakes, portable roll-forming and seaming equipment, or (as is often the case) a combination of hand tools and power equipment.

Figure 1 – Old brake.

Background

If building design is "the creation of space that is protected from the exterior environment," it is easy to understand why early civilizations in all but the most arid regions adopted steeply sloped roofs. Whether these early structures were covered with grasses, reeds, animal skins, or bark, it was realized that roofs that directed run-off away from the inhabited space made for more comfortable living conditions.

Besides providing more comfortable surroundings, it could be argued that sloped roofs provided a healthier, safer living space.

The link among moisture, biological growth (mold and mildew), and disease may not have been recognized. But as families moved from damp, natural shelters (caves) to drier structures, life expectancy increased. Pitched roofs would encourage natural ventilation and help draw in fresh air while exhausting smoke and pollutants from cooking fires.

Considering the framing materials available to early civilizations, sloped roofs could be stronger and cover larger, uninterrupted spaces than flat roofs. Sloped roofs could shed ice and snow. It might even be hypothesized that sloped roofs permitted the expansion of societies into the northern climes. A variation of the sloped roof – the dome – allowed the Inuit to inhabit remote, desolate areas devoid of most conventional building materials.

As civilizations grew and were able to construct buildings that were more than mere shelters from the environment, bark and skin roof coverings gave way to slate, tiles, and metals – most importantly, crafted metals.

By the time Marcus Agrippa had the roof of the original Pantheon covered with copper (circa 27 BC), the use of crafted met-

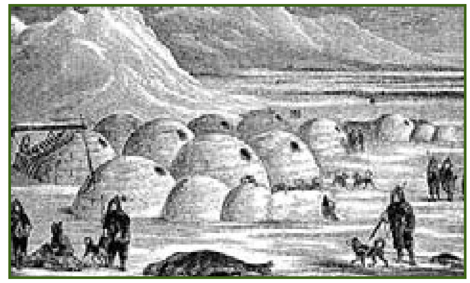


Figure 2 – Igloo village.

als – copper, zinc, and lead – was established.

In the 2,000+ years since the original Pantheon was constructed, building technology, materials, styles, and aesthetics have changed and evolved extensively.

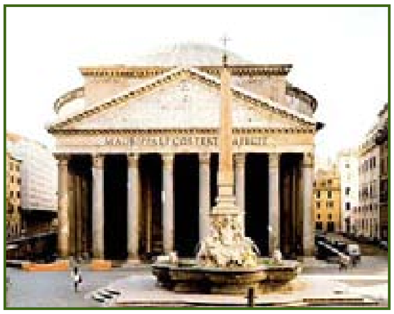


Figure 3 – The "new" (Hadrian's) Pantheon, constructed in 123 AD.

Terne, lead-coated copper, stainless steel, aluminum, terne-coated stainless, and titanium have been added to the original list of three crafted metals. More recently, lead-free terne and tin/zinc alloy-coated copper and stainless have joined the ranks of crafted metals.

Another change relates to vocabulary. As little as 40 years ago, standing seam roofing applied exclusively to roofs crafted of copper, terne, or zinc. Today, the same reference invokes thoughts of pre-formed, painted steel or aluminum systems.

There is no question that today's systems grew out of the precepts established by the craftsmen who formed and installed natural metals centuries ago. There is no question that modern "engineered" systems permit metal to be used for applications and in locations for which it was never considered just a few decades ago. There is no question that the new "boxed" systems have simplified – in some circles "dumbed down" – the installation of metal roofs. None of this is bad.

However, there is also no question that there is a large – and growing – market for crafted metal roofs. Architectural copper represents less than five percent of the total metal roofing market in the U.S. Despite this, the use of architectural copper has grown at a rate faster than all non-residential construction and faster than metal roofing as a whole.

With the exception of lead and lead-coated copper, the other crafted metals that are most widely used in the U.S. (terne and zinc) have experienced "better than industry" growth rates.

All manufacturers appreciate market growth and increased sales. But, with the expanded use of crafted metals, new problems and challenges have arisen. A primary reason for today's problems is a lack of understanding within the building community on how crafted metals differ from the pre-formed systems. All too often it is assumed "metals are metals" and design and performance criteria are neglected.

Many in the metals industry are quick to blame architects for not knowing how metals behave. However, the problem extends far beyond any one group. All too many building owners, construction managers, general and sheet metal contractors, and roof consultants are unfamiliar with crafted metals. Even individuals with years of experience with painted steel and aluminum systems often lack knowledge of natural, crafted metals.

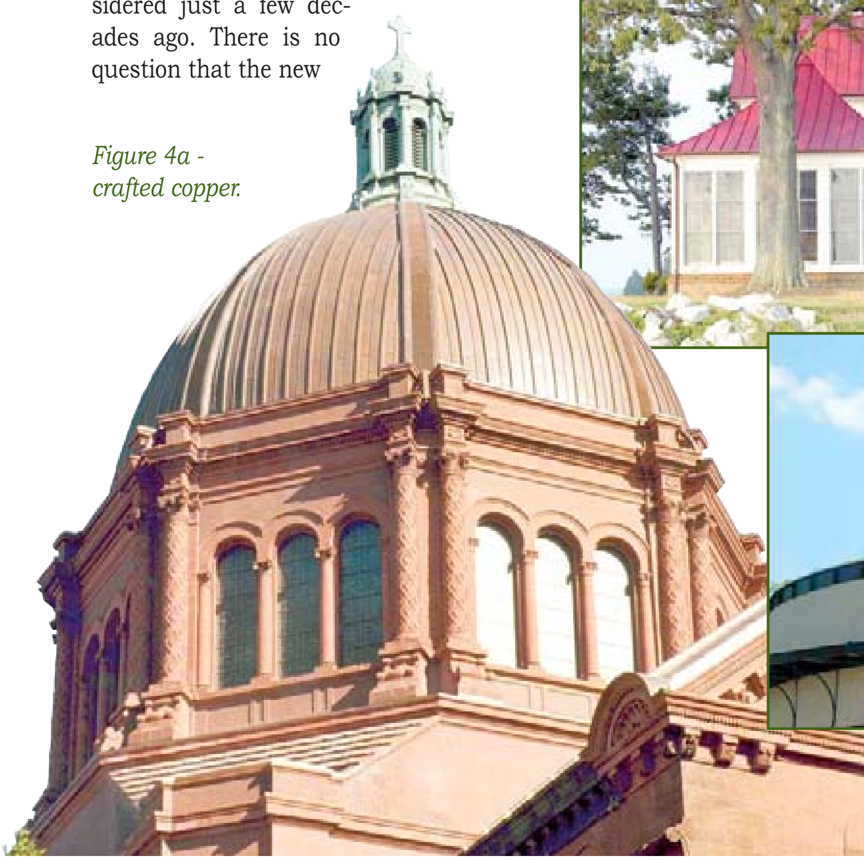
It is not possible to address all aspects of crafted metal roofs in one article – particularly if the intent is to provide comprehensive information. Therefore, the following highlights items that are important to all crafted metal roofs.

Common Sense and Practicality

Many of the details and specifications in design manuals for crafted metals were developed centuries ago. They are the product of experience; they combine common sense and practicality. In some cases, they are labor-intensive, but they work!

Before discarding double-lock "welted" seams in favor of sealants and "snap-lock" panels, ensure that the integrity and function of the installation are not compromised.

Figure 4a - crafted copper.



Left: Figure 4b – Terne.

Figure 4c – Zinc.

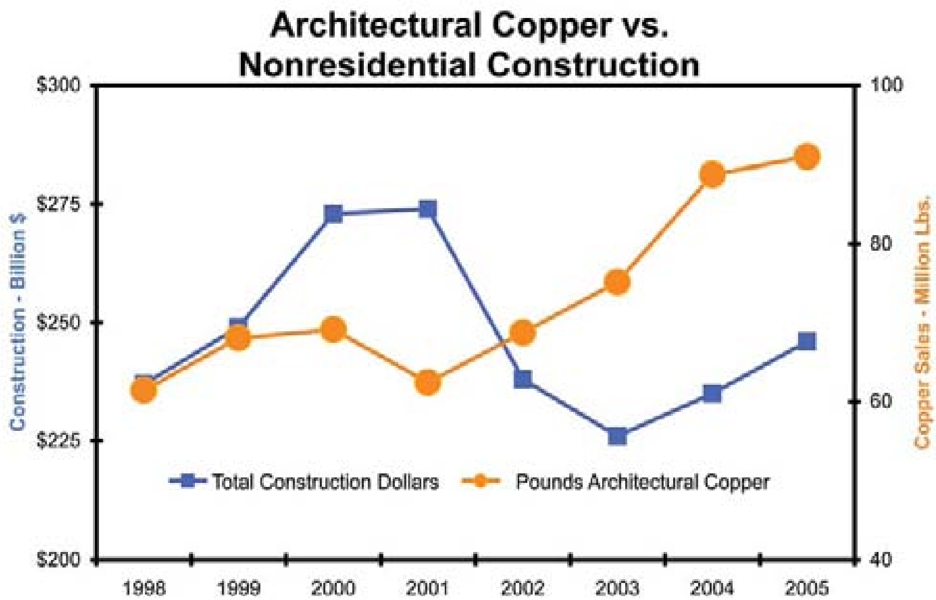


Figure 5 – Architectural copper versus nonresidential construction.

There are always easier, less expensive ways to install a roof, but "what is the ultimate cost?"

Roof Slope

Crafted metal roofs may be installed on any slope equal to or greater than three in twelve (3:12).

Except for locked and soldered flat-seam roofing, all crafted metal roofs are weathertight (water-shedding) and watertight. Weathertightness is achieved by the height of seams and alignment of locks. Water flows over the roof without breaching the metal membrane. If water is "ponded" on a crafted metal roof so that the seams are submerged, the roof will leak!

There are special methods and techniques that allow crafted metal roofing to be installed on roof slopes less than three in twelve (3:12). However, each case should be investigated with respect to the potential for local weather conditions to flood the seams.

Substrates or Decks

Crafted metal roofs are not structural elements, as are many pre-formed steel systems; they are roof coverings or membranes. All crafted metal roofs should be installed over a supporting deck or substrate.

Generally, crafted metals are installed over wood or plywood decks. (Due to reported problems of stability and fastener "pull-out," the writer does not endorse the use of OSB under metal.) When the surface behind the metal is gypsum or concrete, wood nailing strips should be provided to secure the cleats.

When crafted metals are installed over a structural metal deck, it is suggested that a smooth material, sufficiently strong to "bridge" the deck corrugations, be provided. The purpose of this material is to prevent the metal from "sagging" to the profile of the deck. As an alternate method, the corrugations may be filled with a rigid insulation so that the metal is installed over a level surface.

Regardless of the composition of the substrate or deck, the surface to receive the metal should be dry, smooth, and free from projecting nail heads or other obstructions. The entire surface should be covered with an approved underlayment.

Underlayments

Due to the unique properties of architectural zinc, the writer cannot suggest underlayments for this product. For information regarding underlayments for zinc and/or necessity of "reverse-side venting," the reader should contact a technical representative of the product to be used.

With respect to other crafted metals (copper, terne, etc.): "It is always advisable to cover all surfaces, whether they are wood or sandstone, brick or concrete, with building paper. The paper serves not only to smooth out all uneven parts of the under structure, but at the same time protects the copper against moisture from condensation. Such an under-lining is absolutely necessary for stone and concrete roofs. Non-sanded asphaltum paper or tar-free paper [that] is cemented on should be used. The latter roofing method is more expensive.

"It is also important that the metal roofs be ventilated. This is required for flat roofs as well as for steep roofs. The latter, particularly church roofs, require it in order to create proper circulation of air. During certain seasons (spring and autumn) there is always a great deal of condensation that may cause considerable damage to the building if no provision has been made for evaporation. Ventilation is also required because air currents enter into the tower through louvers and other openings without being able to escape at the top of the tower and this may cause pressures which are liable to loosen the metal sheets of the roofing."[1]

While taking exception to the inference that copper must be protected "against moisture from condensation," the writer agrees with this 80-year-old text as to the desirability of providing a proper underlayment between a crafted metal roof and the substrate.

Historically, the most widely used underlayment in the U.S. has been one or two layers of asphalt-saturated roofing felt, lapped two inches. Ideally the felt would be secured with nails driven through flat, sheet metal washers. The underlayment should not be fastened with metal or plastic "tin tabs" that are raised above the underlayment.

More recently, a wide range of "improved" underlayments has been made available. These include "peel and stick" self-sealing membranes, "breathable" products, etc. So long as the manufacturer of the underlayment has no objection to their use under metal (i.e., the products can withstand expected service temperatures), and the overall performance of the assembly is not compromised, these products should be acceptable for use with crafted metal roofs.

When products such as saturated felts that may become tacky at elevated temperatures are used under crafted metal, a layer of smooth building paper should be placed between the underlayment and the metal immediately before the metal is installed. The purpose of this paper is to serve as a "bond-breaker" between the metal and the underlayment. It allows the metal to expand and contract freely without restriction by compounds that "bleed" from the underlayment.

Self-sealing Underlayments

Self-sealing "peel-and-stick" underlayments are generally acceptable for use under crafted metal roofs. However, as others have reported, these products prevent the transmission of water vapor from the inside-out (as well as preventing leaks from the outside-in). The indiscriminate use of self-sealing membranes to create a "bullet proof" roof may cause as many problems as it solves.

Fasteners

Crafted metal roofs are secured to the deck with cleats – typically of the same metal (or compatible metal) as the roof membrane. Cleats should be fastened with two nails or screws each and spaced not more than twelve inches apart.

Tests conducted by Revere and others show that one-inch, number 12, barbed "slater nails" provide adequate resistance to "pull-

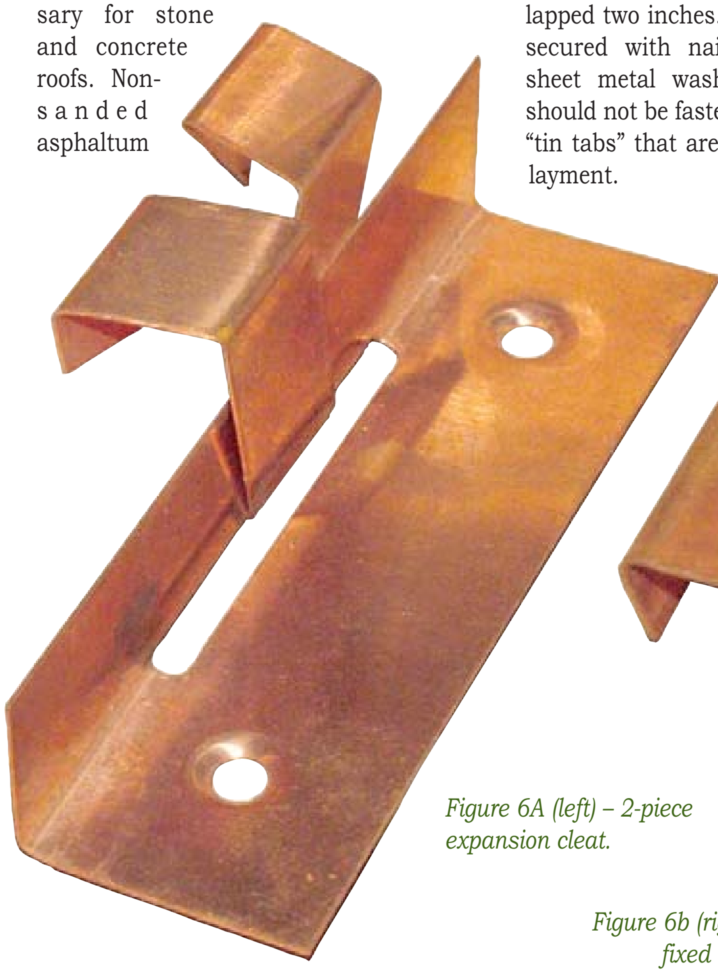


Figure 6A (left) – 2-piece expansion cleat.

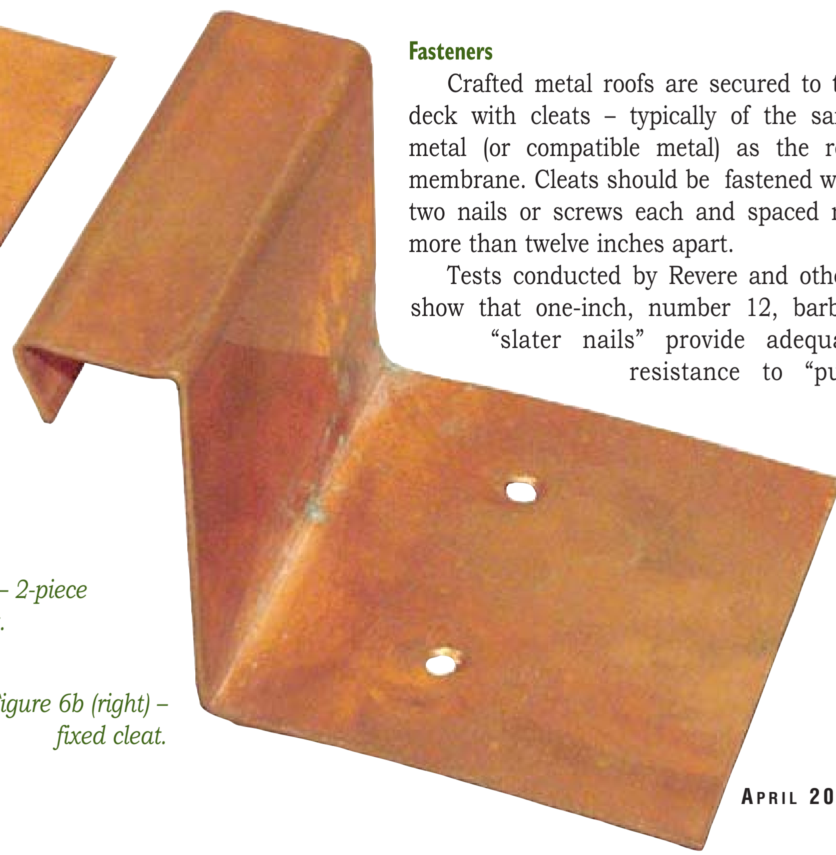


Figure 6b (right) – fixed cleat.

out" from wood or plywood. Screws may be used, but they must be compatible with the metal and should have a low-profile head.

Cleats may be the traditional "one-piece" and/or "two-piece" expansion cleats. The necessity for expansion cleats is based on each metal's unique physical properties.

With copper, "one-piece" cleats may be used to secure standing seam roofing on roof runs up to thirty feet in length. For roof runs greater than thirty feet, a combination of fixed and expansion cleats should be used.

For information regarding the necessity of using expansion cleats with other metals, the reader should contact a technical representative of the product to be used.

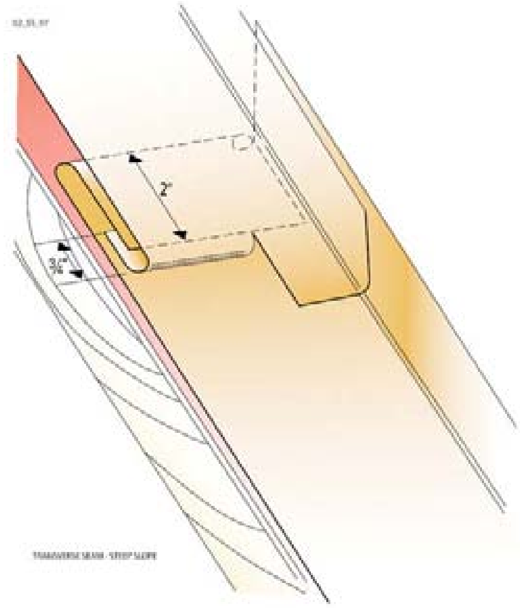
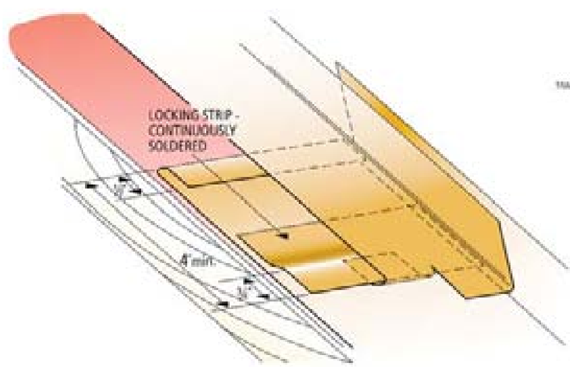


Figure 7 (above) – transverse seam, steep slope.

Figure 6 (below) – transverse seam, low-slope..



Expansion Movement

All building materials are subject to expansion and contraction with temperature change. The amount of change is the Coefficient of Thermal Expansion.

This coefficient is generally defined as: "The fractional increase in length per unit rise in temperature." (The coefficient can vary over a temperature range, but this is not of concern with crafted metal roofing, since the difference between minimum and maximum temperatures to which a roof is subjected is relatively small.)

The coefficient of thermal expansion is different for each metal. The table below lists coefficients for common copper, stainless steel, terne, and zinc.

Copper	0.0000098
Stainless steel	0.0000098
Terne	0.0000067
Zinc	0.0000174

Coefficient of Thermal Expansion

In theory, unless normal movement of a shape (i.e., roof panel) is restricted, the shape will expand from its center in all directions. This movement must be recognized in the design of any crafted metal roof.

When "traditional" crafted metal roofing is formed from sheets less than ten feet long, do the transverse seams act as expansion joints and relieve movement? Perhaps, but possibly not.

As shown below, a different design of transverse seams is suggested for "steep" (greater than 6 in 12) and "low-sloped" (3 in 12 to 6 in 12) crafted roofs. This is to minimize the possibility of wind-blown water being "drawn" through the seam by capillary action.

With crafted standing seam roofing, the

transverse seams should be staggered or "offset" horizontally. This is to reduce the number of "plies" or layers of metal in the finished lock. Even so, on one side of the panel (female side) there will be eight layers of metal in the finished lock and seven on the other (male) side. When the seams are finished and the multiple layers of metal are compressed, the resulting "mass" of metal can effectively lock the panels together so tightly that little or no "slippage" can occur at the transverse seam. In effect, adjacent panels are joined so tightly that they expand as a single unit, eave to ridge.

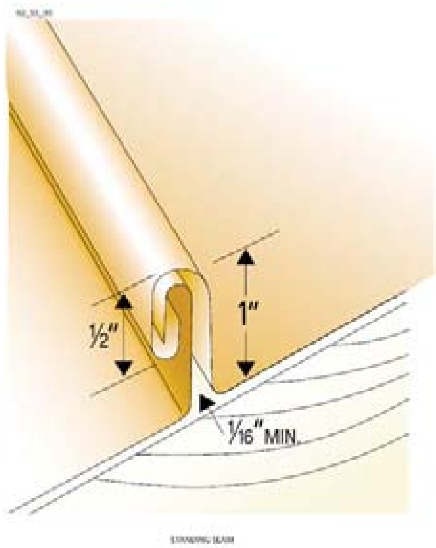


Figure 8 – Standing seam with space.

Due to the method of finishing traditional batten seam roofing, this "locking" phenomenon does not normally occur.

Horizontal expansion movement on crafted metal roofs is usually accommodated at the standing or batten seams. Extra provision is not required.

Compatibility

In theory, when two metals are coupled in the presence of an electrolyte (moisture), galvanic corrosion of the anodic metal may occur. Such corrosion may also occur when run-off from a cathodic metal flows onto an anodic metal. Whether corrosion does occur and whether the corrosion is of consequence depends on a host of factors, including type and strength of the electrolyte, how far apart the metals are on the galvanic series, mass of the two metals, "dwell" time, temperature, etc.

Based on the chart below, it would appear that gold corrodes copper, copper corrodes lead, and stainless steel corrodes zinc. However, throughout the world there are many "gold-leafed" copper domes, lead wedges were the historic method of securing copper flashings into reglets, and stainless steel cleats and fasteners secure countless zinc roofs. There have been few (if any) documented cases of galvanic corrosion in these constructions.

Corroded End (Anodic)
Zinc
Aluminum
Mild Steel
Stainless Steels 18/8 (Active)
Lead
Tin
Brass
Copper
Stainless Steel 18/8 (Passive)
Silver
Titanium
Gold
Protected End (Cathodic)

Galvanic Series of Crafted Metals (in Seawater)

This is not to say that compatibility issues should be ignored with crafted metal roofs, but that experience and common sense in addition to science should be considered when dissimilar metals are used together. When questions regarding compatibility arise, the reader should seek advice from technical representatives of the metals involved.

Weathering

With the exception of terne (which is typically field-painted for aesthetics and improved corrosion resistance), all crafted metals develop a patina when exposed to the atmosphere. The color(s), length of time for patina to form, its durability, etc., vary from metal to metal.

Since the patination process is both complex and metal-specific, the reader is encouraged to contact a technical representative of the product to be used for additional information.

Oil Canning

Oil canning (or lack of visual flatness) is inherent to all crafted metals. While the severity of oil canning will vary from application to application, it is impossible to guarantee that any crafted roof will appear totally flat under all environmental conditions.

A complete discussion of oil canning would be too long for this article. In part this is due to the number and complexity of the factors that can affect the appearance of oil canning:

- Shape of the sheet prior to forming.
- Thickness of the metal.
- Spacing of joints or seams.
- Method of forming.
- Underlayment and deck beneath metal.
- Method of securing or fastening the shape.
- Profile of the formed shape.
- Presence or lack of transverse seams.
- Differential solar heating.
- Age of the metal.
- Lighting conditions, etc.

No one person or company is responsible for or can control all of the above. Further, at this time there are no “industry standards” that define “acceptable” or “excessive” oil canning. In many respects, oil canning, like beauty, “is in the eye of the beholder.” What one person considers excessive, another may not.

Summary

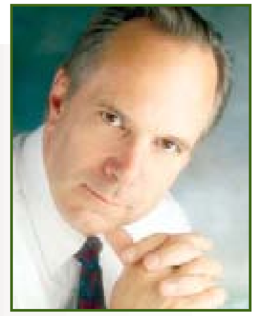
In closing, crafted metal roofs have a long and successful history. There are examples of copper, lead, terne, and zinc roofs that have provided centuries of maintenance-free weather protection to buildings throughout the world. There is no reason that a properly designed and correctly installed crafted metal roof cannot provide similar protection to contemporary structures. In fact, it is easier to obtain a durable, economical crafted metal roof today than it was years ago.

The manufacturers of copper, terne, and zinc maintain technical staffs to help the building community. Take advantage of these services. Assistance is usually provided at little or no cost and it can be invaluable.

Footnote

[1] *Copper Roofing and Copper Sheet Metal Work*, German Copper Institute, Berlin, Germany, 1926.

David L. Hunt



David L. Hunt has over 37 years of experience with Revere Copper Products Inc., Rome, NY, and is now manager of architectural services there. Hunt is co-author of Revere’s *Copper and Common Sense*, the most widely referenced copper manual in the U.S. He is past chairman of the Copper and Brass Fabricator’s Council Environmental Committee, is on the board of the Metal Construction Association (MCA), and is a member of Copper Development Association (USA) committees. Dave was a contributor to CDA’s *Copper in Architecture* design manual and developed Revere’s “Green Marketing Program.” He is a registered presenter of AIA continuing education seminars and a member of NRCA, WSRCA, RCI, CSI, USGBC, and RICOWI.