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Copper Roofing: An Enduring Link Between Past and Future

Arthur L. Sanders, AIA

Custom-crafted copper roofing, rich in detailing, rich in history, speaks to endurance and long life, its soft blue-green patina a testament to the passage of time. But as a building material, copper shouldn't be relegated to the past, despite competition over the past few decades from lower-cost, pre-formed metal roofing systems and other roofing types. If longevity, low maintenance, and a strong aesthetic statement are a building owner's goals, copper remains the hands-down favorite.

When properly designed, detailed, and installed, a copper roof can easily last 50 years or more with relatively little maintenance or care. And there is ample evidence of copper roofs enduring for a century or longer — as befits the historic, cultural, and civic value of the buildings they so often grace. For example, the standing seam copper roof installed in the 1830s on Philadelphia's Old Christ Church lasted until 1967. One remaining section of the original copper roof on the First Bank of the United States (also in Philadelphia) is still in service today, 202 years later. Stack that up against today's pre-fabricated metal roofing systems, with their standard 20-year warranty. Certainly, not all buildings are intended to last more than 30 or 40 years and may not warrant a copper roof. But many are designed for longevity and merit a roof that will endure equally well.

Installation of a batten seam copper roof on a New York City high-rise office building.

As Senior Architect with Hoffmann Architects, Arthur L. Sanders, AIA oversees masonry, plaza, and roofing rehabilitation projects, including many of the firm's copper roofing rehabilitation efforts.

Without a doubt, copper was and is a high initial cost item, typically two or more times the cost of other roofing types, with the exception of slate and tile. This high initial cost was a primary reason why copper traditionally was selected only for "important" buildings — public facilities, churches, libraries, and other buildings of long-term value to their owners and their communities. That cost came from the high level of craftsmanship required for installation, along with the cost of the material itself. Today, modern tools and equipment have helped reduce installation costs and material waste. Even so, copper installation is still essentially a "field job" requiring great skill and craftsmanship — and properly detailed design documents.

Over the long haul, however, a well-designed and correctly installed copper roof will more than pay for itself. One reason for that is copper's durability, which makes it likely to last the life of the building. Regular maintenance is easily implemented, as long as design documents and construction have addressed the few special requirements of copper, particularly in planning for thermal expansion and contraction.

In contrast, today's low-slope membrane

roof or steep-slope shingle roof needs regular maintenance, patching, and repair, and usually requires full replacement after 25 years. The opportunities for deterioration are greater with these other roofing systems, due to the nature of the materials. And that's not to mention the losses on the aesthetic side. Copper's distinctive color and appearance offer design attributes unmatched in other roofing systems. Whether in a historic setting or in newer structures, a copper roof is well worth restoring or replacing with the same or comparable custom-crafted design.

It's All In The Details

A roof is only as good as it's designed to be, and copper roofing is no exception. Detailing must be exacting, and go beyond industry standard details to address specific field conditions to achieve the best result. For copper roofing, it's vital to create details that shed, rather than trap, water. The following section looks at some of copper's specific problem areas and ways to avoid these during installation or repair.

Deterioration

• Copper is susceptible to corrosion from contact with alkalis, ammonia, some bituminous roofing cements, masonry cleaners, and acidic rainwater (run-off water in contact with moss, lichen, algae, wood shingles, or airborne sulfur dioxide). While the copper patina provides some level of protection from acidic moisture, copper roof valleys, gutters, and skylight frames are particularly susceptible to its damaging effects. That's because moisture tends to linger in these vulnerable areas, giving the acid more time to act on the copper.

• Some early generations of the fire-retardant chemicals used in dimensional lumber and plywood sheathing can also corrode copper. The roof should be detailed to minimize opportunities for salt-laden moisture leaching from the treated wood to come in sustained contact with the copper, or to avoid use of these woods altogether.

• Iron and steel should not be placed above copper, as the interaction of the runoff from either of these metals will eventually stain the copper dark-brown or black.

• Copper is also subject to erosion from rubbing by cables and ropes, abrasion, excess handling, foot traffic, or the constant dripping of water from above.

Mechanical failure

• Failing to provide adequately for copper's natural expansion and contraction is the leading cause of mechanical breakdown in sheet copper roofing, along with improperly securing the roof to the substrate.

• Flexure — the bending back and forth of the copper sheet that occurs during thermal expansion and contraction, or through movement caused by wind — will eventually cause distinctive star-shaped cracks in the sheet surface, compromising its water-tightness.

• An inappropriate or improperly prepared substrate can also lead to roof failure. For example, copper sheets installed over cupped wood will eventually tear along the sharp, upturned edges of the sheathing, while the high points of a rough concrete surface will telegraph through the copper and lead to pinpoint holes in the roof.

• Secondary causes of copper roof failure can include the use of inappropriate materials, such as using steel nails to secure cleats. The galvanic interaction between the steel and the copper will eventually corrode the steel nail and undermine the structural integrity of the cleat.

Protecting other building materials

Copper can hasten the deterioration of other metal building materials through galvanic action. Galvanic action occurs when a vulnerable metal, such as aluminum, zinc, steel, iron, tin, or lead, comes in contact with copper in the presence of water. Aluminum and zinc

A previous attempt to solder over these failed flat seam joints was not successful.

are the most susceptible to this type of corrosion. Protective measures include painting the aluminum, steel, or iron with a bituminous or zinc chromate primer.

The roof should be detailed to prevent runoff from copper surfaces from reaching adjacent surfaces, as traces of copper salts in the run-off can cause staining of metal, marble, limestone, granite, and brick. A properly detailed drip edge between 3/4" and 1-1/2" wide can help prevent this. Gasketing with sealants, membranes, or other non-absorptive materials is another isolation technique.

Installation Requirements

In most situations, deteriorated copper should be removed and replaced with new material, as patching is not usually feasible or reliable. Attempting to re-solder seams, for example, will serve only to aggravate the problem of failed seams. Whether installing a new copper roof or replacing an old one, the following recommendations will help ensure the best performance:

• Check the substrate: Concrete, stone, brick, stucco, and terra cotta can all provide a smooth installation surface when properly prepared.

• Determine the best seam type based on specific conditions: Soldered seams provide the best water-tightness, and can strengthen joints. Pre-tinned sheets will offer an even stronger bond. Blind soldering (soldering from the back or concealed side of copper components) will minimize unsightly appearance of soldering, as the exposed solder will turn gray/black over time. If blind soldering is not feasible, then all excess solder should be carefully removed from the copper face.

In some instances, sealants or butyl seam tape can replace solder while still providing watertight seams. Be aware, however, that sealants do not strengthen joints, as does solder. Sealants are recommended for roof slopes under 3"-in-12". All sealants should be site-tested for compatibility with the copper, and the use of acetoxy-cure silicones should be strictly avoided. A clean, oil-free surface is essential to achieve the best bond between the copper and the sealant. Butyl tape, a pre-formed rubber sealant with adhesive on one side, is a good choice to use on standing seam copper joints that must

The Many Virtues of Copper

Since antiquity, copper has been a prized building material used for roofing, flashing, and intricate ornamentation. It is a highly durable metal which can easily be shaped, stretched, or drawn for use in wiring, or rolled, hammered, or beaten into sheets without cracking or breaking. Its malleability allows it to be easily folded on-site into waterproof seams to create a weather-tight roofing surface. Copper is easily soldered, welded, or brazed, making it a very accommodating material for on-site installation. It is fire-resistant, and has passed the Underwriters Laboratory's most rigorous test for wind-resistance, making it an excellent choice for hurricane- and tornado-prone areas.

Another benefit is the relative ease of care that copper requires over the years. One reason for that is the distinctive blue-green patina that forms on bright copper over time, creating a tough protective layer which prevents further interaction with the atmosphere. This protective patina is created when airborne sulfur dioxide (a product of burning fossil fuels) settles on the bright copper surface and reacts with the metal to create basic copper sulfate. The patina first appears as a dull brown and then gradually changes to blue-green. This weathering process takes only 8 to 10 years to achieve in our highly acidic atmosphere. Lead-coated copper will develop an equally desirable soft gray color over time.

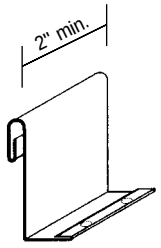
There are three types of copper:

Soft copper is highly malleable, making it ideal for decorative uses and intricate ornamentation. It should never be used for other building construction purposes.

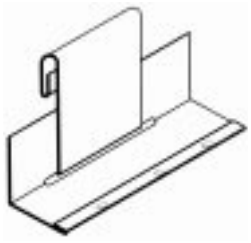
Cold-rolled copper is the most frequently used for roofing and flashing, offering less malleability than soft copper, but much greater strength.

Lead-coated copper (cold-rolled copper coated with lead on both sides) is often used for roofing and flashing, where the soft grays of the lead coating are desired. It offers the same endurance and workability as uncoated old-rolled copper. Lead-coated copper, however, adds toxic lead compounds to rainwater run-off from the roof, which ultimately reaches and contaminates the surrounding soils and waterways. Use of this copper type may be subject to regulatory limitations in the future. ■

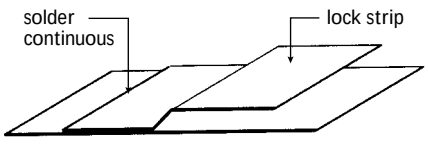
accommodate thermal movement.
• Continuous lock strips can secure copper edges while providing for expansion. (Please see Illustration A below.)
• Carefully detail installation requirements: In flashing situations, frequent restraint (nailing) of the copper will help avoid buckling and provide controlled expansion/contraction. Copper roofing, however, needs to move freely to help avoid metal fatigue, and the number of restraints should be limited. Fewer restraints also mean fewer punctures through the roof that may let water in. Hidden copper cleats should be used to attach the copper roof to the substrate, allowing for unrestrained horizontal system movement while providing vertical resistance/restraint against wind uplift forces.
• Choose the correct joint or seam design: Special joints and seams are required in different situations to aid in copper's natural expansion and contraction. For example, loose-lock seams allow copper panels to slide during expansion and contraction. Batten seams also allow movement along the sheet length while enabling the copper to flex and expand between the base of each batten. (Please see Illustration B on page 6.) Battens of this type also serve as expansion joints in a flat seam roof, where small copper sheets are soldered together, forming large areas, which in turn require expansion relief.
• Plan for insulation: In existing structures, conditions may not allow for the necessary increase in height above the deck to accommodate code-compliant insulation. While not always feasible, an alternative may be to add insulation below the deck. Whatever the solution, all insulation considerations must address condensation of interior vapor, taking into account the dew point location.
• Properly prepare the substrate: Sheathing for copper roofing is typically plywood, topped with asphalt-saturated roofing felt to create a cushion base for copper panels. EPDMs or self-adhering modified bitumens are sometimes used in place of felt. Rosin paper slip sheets are installed over the felt to keep the copper sheet from adhering to it, which would compromise the copper's ability to expand and contract.
• Choose the correct solder: Cold-rolled copper requires a solder of 50% tin and 50% lead. For lead-free installation, 95% tin - 5% antimony can be used. Lead-coated copper calls for 60% tin - 40% lead solder. In many cases, copper roof panels are "pre-tinned" — cleaned, fluxed, and then dipped into molten solder prior to installation. Pre-tinning creates a stronger bond for the roof seams, adding increased protection against water penetration. Rosin flux is usually used to prepare the copper surface prior to soldering. If acid flux is chosen, however, the copper surface must be thoroughly rinsed afterwards to prevent pitting.
• Select the right fasteners: All fasteners should be of hard copper,



Typical Fixed Cleat

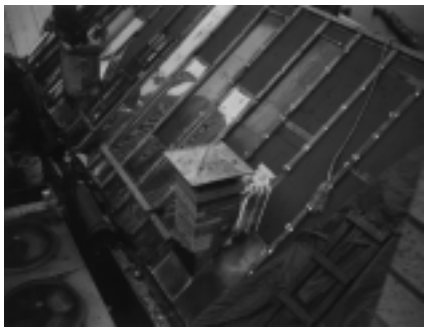


Expansion Cleat



Lock Strip

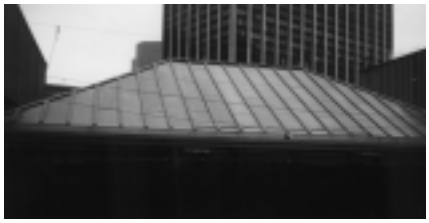
Illustration A: Cleat and lock strips provide securement to the deck while allowing for expansion and contraction.



Standard industry details must often be customized to specific field conditions.

The substrate must be tested for pull-out resistance to determine the most appropriate fasteners.

copper alloy, or brass, except for washers and expansion shields, which can be made of lead, bronze, rubber, or plastic. Nails are best for flashings, at gravel stops, and on eave strips. Screws are called for when the copper must be held rigidly in place, such as at a ridge roll exposed to severe wind or if expansion shields have been required for a masonry substrate. Screws should have round heads and flat seats that won't puncture the copper roof surface. Copper caps can be soldered over screw heads in gutters and other areas of heavy water exposure to limit the potential for water intrusion. Copper button-head rivets are commonly used to join seams which do not need to accommodate



The finished batten seam roof provides strong visual lines.

expansion and contraction, with solder used to provide water-tightness. Be wary of pop rivets; if used, these should have brass mandrels, not steel.

Roof types

There are three basic types of copper roof designs, with each offering a specific benefit to meet a given field condition or design intent. Illustrations of the seam types used in these roof designs are shown on page 6.

Batten seam roofs are often used on barrel vaults, domes, or cupolas. This seam type creates a deep, well-defined roof line or shadow, and allows for

Fire Hazards in Replacing Copper Roofing

Replacing a copper roof often calls for soldering new seams on top of a combustible substrate, such as wood sheathing topped with asphalt-saturated felt and rosin paper slip sheets. Protecting against open fire, smoldering fire in the plywood substrate, or melting of the roofing membrane in this situation is of great concern. There are ways to minimize the danger, however, without adding significantly to labor or material costs.

Below is a summary of relevant temperatures for the materials involved in copper roof installation:

Rosin paper and plywood	ignition temperature	492° - 496° F
50% tin/50% lead solder	solidus temperature	361° F
50% tin/50% lead solder	liquidus temperature	421° F
Average soldering temperature with hot irons		400° - 600° F
Torch temperatures		900° F

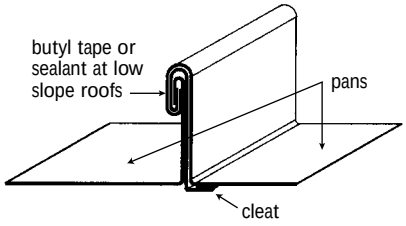
The industry standard (and preferred method) for soldering calls for the use of heated copper or brass bars, which are heated either through an attached or separate heat source. Open flame torches are not recommended, but are quite common on many job sites. While torches may offer the easiest and fastest method of installation, they also create the greatest fire hazard, and require great skill and care by the installer. On the other hand, heated soldering irons, with tips of copper or brass bar, require constant attention to maintain the required level of heat, but do not reach the temperature extremes that torches will, and thus minimize the danger of fire.

Following the guidelines below can provide the best protection against heat and fire damage during soldering operations. These guidelines should be included in the specifications.

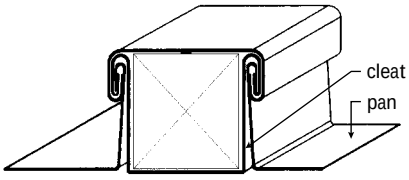
1. Require all contractors and subcontractors working on the roof to provide a detailed fire safety and fire avoidance plan. Hoffmann Architects recommends that this plan include a fire watch for up to three hours after soldering activities.
2. Use only heated irons for all rooftop soldering.
3. Pre-tin all joints, which will help reduce the time needed to sweat the joint and reduce the amount of heat required to properly solder the joint.
4. If appropriate or practical, replace the rosin paper slip sheet with a non-combustible fiberglass product.
5. Pre-fabricate all penetration curbs and sleeves away from the substrate prior to installation. ■

creation of unique shapes. Batten seams are created by using copper panels, set parallel to the roof slope, which are separated by a wood batten. This batten provides the framework for the distinctive box shape of the seam. The batten cap provides water-tightness while accommodating expansion.

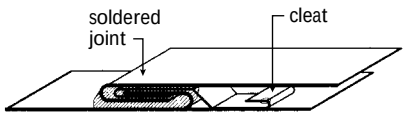
Flat seam roofs are unique to copper and are usually found on a low-pitch roof (below 1"-in-12") or on curved surfaces, such as domes and barrel vaults. Flat seams are either *flat-locked* or *soldered*, depending on the roof slope. Typically, the greater the slope, *(continued on page 8)*



Standing Seam



Batten Seam



Flat Seam

Illustration B: Each of the three seams above is best suited to a specific roof condition or design.

The Facility Manager's Bookshelf: **Copper Roofing**

A. Basic References

1. *Copper in Architecture Handbook.* Copper Development Association, 260 Madison Avenue, New York, NY 10016. (800) 232-3282 or (212) 251-7200, fax (212) 252-7234.

   Handbook, bound in 3-ring binder with information, details, and guide specifications on sheet copper applications in roofing, gutters, flashing, expansion joints, etc., $85.00

   CAD Diskettes: Four "AutoCad 12" diskettes of sheet copper details, $40.00 Video: six-tape series, $40.00. Catalog also available.

2. *Copper and Common Sense.* Revere Copper Products, Inc. P.O. Box 300, Rome, NY 13442. (315) 338-2022, fax (315) 338-2224. From outside New York: (800) 448-1776. Other information on sheet copper is also available.

3. *Architectural Sheet Metal Manual, Fifth Edition,* 1993, $141.00. CAD version, $425.00. *Standard Practice in Sheet Metal Work,* 1929 (reprinted by SMACNA as a reference for work on older buildings), $151.00. Sheet Metal and Air Conditioning Contractors' National Association, 4201 Lafayette Center Drive, Chantilly, VA 22021. (703) 803-2989, fax (703) 803-3732.

4. *Soldering Manual.* $32.00. American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. (800) 334-9353, fax (305) 443-7559.

5. *Metals in America's Historic Buildings: Uses and Preservation Treatments.* Margot Gayle, David W. Look, AIA, and John G. Waite, AIA. National Park Service, Preservation Assistance Division, 1992 (update of 1980 edition). 168 pages, 183 illustrations. GPO Stock Number 024-005-01108-1, $10. Contact the Superintendent of Documents at (202) 512-1800 for credit card orders.

B. Technical Articles from *The Construction Specifier*

To order reprints, contact the Construction Specifications Institute at (800) 689-2900. Reprints are $4.00 each, $10.00 minimum order.

1. Cechvala, Steven. "Crafting the Custom Sheet Metal Roof," *The Construction Specifier,* November 1989, Volume 42, Number 11, p. 116-120.

2. Copper Development Association. "Sheet Copper Fundamentals," *The Construction Specifier,* January 1995, Volume 48, Number 1, p. 48-63.

3. Weaver, Martin E. "Copper Top," *The Construction Specifier,* November 1991, Volume 44, Number 11, p. 40-46.

C. Other Technical Articles

1. Copper Development Association. "UL's Highest Winds Can't Topple Copper Roofing," *Copper Topics,* Winter 1996, p. 1.

2. "Copper Roofing Design," *Progressive Architecture,* August 1990, p. 151.

3. "Copper Roofing From the Bottom Up," *RIEI Information Letter,* Spring 1992, p. 7. Roofing Industry Educational Institute, Englewood, CO (303) 790-7200. E-mail: REIROOF @ aol. com.

4. Thompson, Craig L. "What Are Some of the Fundamentals of the Copper Top?" *Professional Roofing,* June 1993, p. 40-43.

Compiled by Alan P. Eddy, Technical Information Specialist ■

REPRESENTATIVE PROJECTS

Copper Roof Rehabilitation

Hoffmann Architects provides investigation, design, and construction administration services for copper roofing for a number of clients, including work on private and public facilities. The firm is often called in by major corporations, private institutions, and real estate owners to provide specialized consulting on the rehabilitation of deteriorated copper roofing.

Hoffmann Architects' work begins with an in-depth analysis of the existing roof and structure to determine the scope and causes of damage and deterioration problems. The firm's architects and engineers research and evaluate repair options based on technical merit and ability to meet budget and life cycle goals, occupancy needs during construction, and aesthetic considerations. The project team's efforts include careful research into the building's architectural history to ensure that detailing and restoration work is consistent with the style of its time, a key consideration when restoring historic structures.

Once the repair method has been selected, the firm prepares detailed plans and specifications for competitive bidding. On-site project staff and contract administrators track the progress and quality of construction throughout the project.

The following is a sampling of the firm's work in copper roof rehabilitation:

Smithsonian Institution
Patent Office Building
Washington, District of Columbia
(Hartman-Cox Architects)

Bronx Community College
Gould Memorial Library
Bronx, New York
(Dormitory Authority of the State of New York)

United States Courthouse
40 Foley Square
New York, New York
(Brennan Beer Gorman Architects/ GSA)

Saint Theodosius Cathedral
Cleveland, Ohio
(Saint Theodosius Cathedral)

The Hartford Fire Insurance Company
Hartford, Connecticut
(ITT Hartford)

Congregation Rodeph Shalom
Bridgeport, Connecticut
(Congregation Rodeph Shalom)

New York Stock Exchange
New York, New York
(New York Stock Exchange)

310 Orange Street
New Haven, Connecticut
(Southern New England Telephone)

Rockefeller Center Complex
New York, New York
(Rockefeller Center Management Corporation) ■

The Performing Arts Center at Kingsborough Community College in Brooklyn, New York.

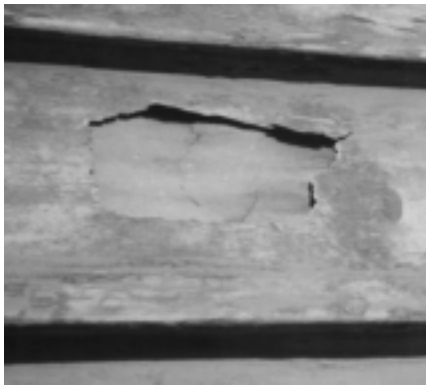
NYNEX, 104 Broad Street, New York, New York.

the less need for solder to create a watertight bond.

The *standing seam roof* is either field-formed or constructed of pre-formed panels of 18" to 24" widths which are placed parallel to the roof slope and joined to other panels using a double-locked standing seam.

Conclusion

With proper detailing and carefully supervised installation, new and replacement copper roofs can provide a handsome return to building owners in both endurance and beauty. An architect well-versed in traditional steep roofing techniques and who has wide experience in roofing, water-proofing, and sheet metal work is the best candidate for this project type. Working with the accumulated problems of an existing building and the idiosyncrasies of its dimensions and materials requires skill and patience — and the same holds true when designing a custom-crafted replace-ment copper roof. ■



This copper roof failed — after 70 years of service and acid rain.

A batten seam roof edge with hung gutter and snow guards.

JOURNAL is a publication of Hoffmann Architects, specialists in investigative and rehabilitative architecture/engi-neering, including the analysis and solution of problems within roofs, exterior walls, glazing, and structural systems of existing buildings, plazas, and parking garages.

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