WEATHERING OF ARCHITECTURAL METALS -THE ULTIMATE DICHOTOMY

By David L. Hunt

The rise in popularity of architectural metal roofing (copper, lead-coated copper, terne, terne-coated-stainless, zinc, and more recently, tin/zinc alloy-coated metals) in the United States over the last decade or so is well documented. Less well documented is a change in the type or nature of complaints regarding these roofs.

Historically, most "call-backs" relating to metal roofs were concerned with water showing up in unintended locations – i.e., leaks. Whether the cause was premature failure, incorrect design, or improper installation, corrective action could usually be accomplished to the satisfaction of most, if not all, parties.

Today, well over fifty percent of the complaints regarding architectural metals relate to aesthetics – in particular, the aesthetics or appearance of recently completed roofs or wall assemblies.

At a time when the building community generally equates metal roofing with Kynar®-coated products, there is limited understanding of natural weathering of uncoated metals. Few building owners appreciate the complex natural process that provides these metals with their unique character and charm. Unfortunately, few architects, contractors, or roof consultants fully understand weathering. As a result, confusion often reigns and tempers flare when an owner believes he has received defective materials or poor workmanship.

The following is a brief overview of the weathering of copper and lead-coated copper ("LCC"). It is not intended to address all possibilities or circumstances. An attempt to explain the weathering of all architectural metals under all conditions would require multiple volumes of exceedingly boring chemical and metallurgical explanations.

Photo 1: This Maryland residence shows normal but unusual weathering.

COPPER

When copper is exposed to the elements, it begins to oxidize or age. Initially, the oxide films are extremely thin interference films that can and often do result in unusual and "shocking" colors. As weathering continues, the films build in thickness. Please keep in mind that "thin" and "thick" are relative terms; the actual thickness of the films is at the atomic level. As the films grow, the color of the copper becomes deeper and more uniform. With continued weathering, the oxides convert to sulfide and eventually to mature sulfate (green) patinas.

The color or appearance of copper can vary considerably due to the composition of surface films or patinas. Depending upon degree of exposure and local (micro) environmental conditions, these can include a host of oxides, sulfides, sulfates, carbonates, hydroxides, chlorides, etc.

Although copper may take on unusual colors during or shortly after it is installed, eventually it will "even out" and "turn green." However, when an owner or architect is withholding payment

and/or demanding the "defective" copper be replaced, explanations of what may happen often fall on deaf ears.

The Maryland residence shown in *Photograph 1* is an excellent example of normal but very unusual weathering. By knowing and understanding the factors that can influence early coloration and how long it takes for a mature patina to develop, a roof consultant should have been able to explain what was happening and to persuade the owner and architect to give Mother Nature more time. However, the "experts" who inspected the roof were unable to offer an explanation as to why the roof appeared as it did.

Reasons that copper can weather, shown in *Photographs 1* to *4*, include:

Initial cleanliness of the copper

Sheet copper is made by passing large cakes through parallel rollers (similar to an old-fashioned washing machine wringer). As the copper is passed through successively narrower rollers, the cake becomes thinner and longer. Rolling requires tremendous amounts of energy and generates significant heat. Lubricants are used to dissipate the heat, to avoid warping the rolls, and to maintain tolerances.

Revere Copper[1] uses an oil/water emulsion during the rolling of architectural copper; other mills may use similar or significantly different lubricants. Although copper is usually cleaned following rolling, a very thin film can remain on its surface.

In addition, prior to packing, a light coating of "anti-stain" compound is usually applied to the surface of architectural copper. This minimizes staining or discoloration during transit and storage. It is not intended to keep the copper bright and shiny.

Many lubricants and anti-stain compounds are water soluble and biodegradable. Upon exposure to the atmosphere, these compounds begin to "break down" and are removed. How fast this occurs depends upon:

- The type of compound present – some are less soluble and/or more resistant to degradation.
- The amount of compound present. This can vary within a single sheet and from sheet to sheet and with the age of the copper (both have "shelf lives").
- Environmental conditions immediately following exposure (rain or snowfall may remove the compounds while hot dry conditions may "bake" them on).

Despite "old wives' tales" and what may be found in some literature, most of the compounds do not color or age copper. (Since sulphur-bearing materials can darken or stain copper, lubricants and anti-stain compounds are essentially sulphur free.)

Although the presence or absence of lubricants does not color copper, until they are removed, "bare" copper is not exposed to the atmosphere. Therefore, so long as these compounds remain on the copper, little or no weathering occurs.

Photograph 2 shows a new copper roof on a home near Charleston, South Carolina. After soldering the vent stack flashing in place, the contractor "neutralized and washed-down" the copper to remove residual flux. In doing so the contractor also removed the anti-stain compound and residual lubricants from a small area. The cleaned area began to weather much quicker than the surrounding uncleaned copper – literally overnight. Again, the homeowner was displeased and questioned the quality of materials and workmanship.

Local environmental conditions

The weathering of copper depends upon moisture and air contaminates – primarily sulphur compounds. These combine to form weak oxidizing acids that react with and age the copper. Copper will not age in an entirely clean or dry environment.

Aging occurs when moisture and pollutants are on the copper's surface. Due to a longer "dwell time," mists, condensate, and dewfalls are more conducive to weathering than heavy rainfalls. (Rainfalls may remove residuals but do not remain on the copper long enough for significant reaction to occur.)

All atmospheres contain the compounds necessary for aging copper – sulphur, chlorides, etc. These may be the result of natural events (i.e., volcanoes) or human activities (i.e., burning fossil fuels). In general, the greater the concentration of these items, the faster copper ages.

Photo 2: A new copper roof on a home in Charleston, SC, showed uneven weathering after the contractor "neutralized and washed down" the copper to remove residual flux.

When considering environmental conditions, "local" means the microclimate at the time of installation and thereafter. It is not at all unusual for copper roofs installed in the same city but several miles apart to weather at different rates and with different initial aesthetics. It also is not at all uncommon for copper installed in the same area several months apart to weather initially at different rates. In fact, it is not uncommon for copper on a north elevation to weather differently than copper on the south elevation of the same building.

Photo 3: The owner of this roof off the coast of Maine complained that the lead was coming off his lead-coated copper. In actuality, "red lead" patina was forming.

This is not due to a fault in the copper or method of installation, but in almost every case is due to minor environmental differences.

All other things being equal, copper will weather fastest in a marine-industrial atmosphere (i.e., Boston, Massachusetts) and slowest in a dry, pristine environment (i.e., the desert Southwest in the U.S.).

Angle or degree of exposure

As noted above, weathering occurs when moisture and pollutants are on the copper's surface. Obviously, these accumulate quicker and remain on flat surfaces longer than they do on sloping surfaces. All other things being equal, horizontal surfaces (the top of coping covers) weather faster than sloping roofs which weather faster than vertical walls. Reverse slopes (soffits, underside of gutters, etc.) weather slowest of all.

Different products

Architectural copper is produced to ASTM B370 – "Standard Specification for Copper Sheet and Strip for Building Construction." It is composed of at least 99.9% copper. It is supplied in two different forms – sheet or coils – and a variety of tempers from soft (O00) to hard (H04).

Depending upon the product (sheet or coil) and the producing mill, architectural copper may be supplied with a highly polished "mirror-like" surface, or with a dull, cloudy, "salmon color" appearance. This is due to the manufacturing limits of the machinery (rolling mills) used to make the specific product and/or specific temper.

While these aesthetic and/or temper differences between products do not adversely affect the corrosion resistance of copper, they can have a pronounced effect on early weathering. When copper from sheets and coils is mixed on the same installation,

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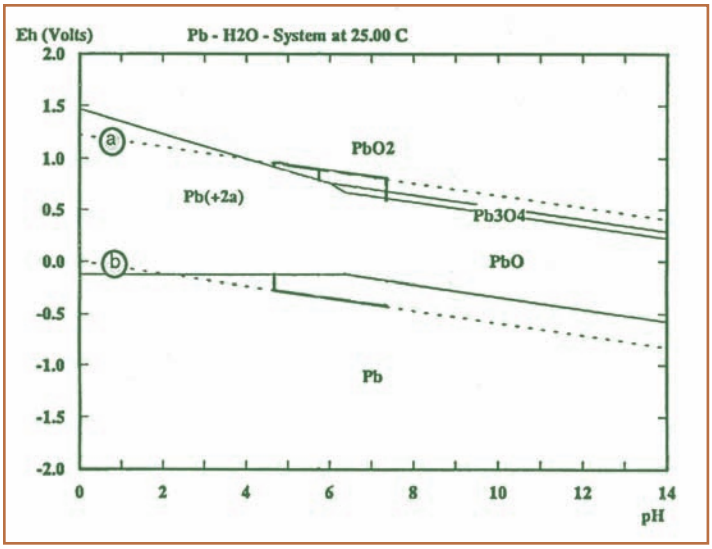

Figure 1

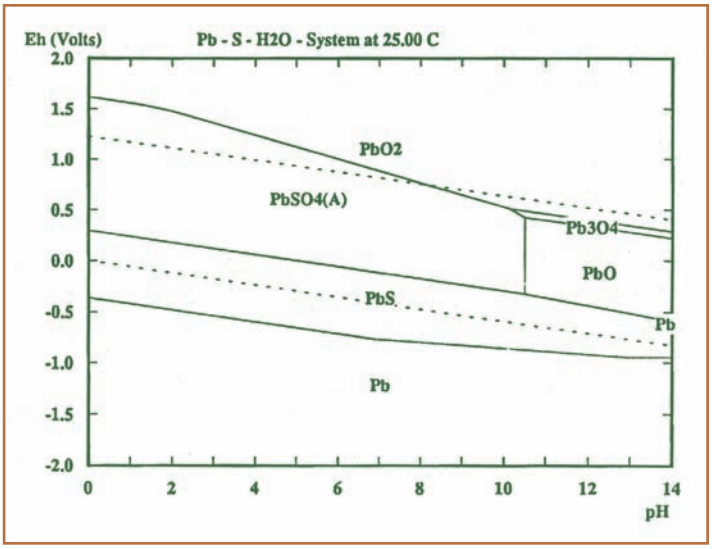

Figure 2

some may turn dark (black) shortly after exposure while adjacent copper may remain bright or develop a brown or bronze tone.

As disconcerting as this can be, it is a temporary phenomenon. Eventually all copper on an installation will weather and blend. The time required for this to occur may, however, be several months to a year.

Different producing mills

As noted previously, different copper mills use different lubricants and anti-stain compounds. They also use different equipment and manufacturing specifications to make copper that conforms to ASTM B370. While the result of these differences may or may not be discernable when the copper is first installed, copper from two or more suppliers can exhibit significant color differences for the first year or more.

LEAD, LEAD-COATED COPPER, AND LEAD ALLOY (TERNE) COATED STAINLESS

When lead and high-lead alloys are exposed to moisture and sulphur compounds, they develop a dark gray patina. During the first half of the twentieth century throughout most of the United States, there were sufficient airborne sulphur compounds to ensure that sheet lead, lead-coated copper ("LCC"), and lead alloy coated stainless steel weathered in this manner.

As environmental awareness grew in the latter part of the century, the level of atmospheric sulphur (and other pollutants) was reduced. Early in 1992, Revere was contacted by a New England architect regarding an LCC roof on a residence on an island off the coast of Maine. The owner of the home was complaining that "the lead is coming off the lead-coated copper" (See *Photograph 3).*

Inspection and tests showed that the lead was not coming off but that a "red lead" patina (Pb_3O_4) was forming. *Figures 1* and *2* are pourbaix diagrams developed by an MIT metallurgist retained by the homeowner to provide an explanation as to why the LCC was turning red.

The diagrams show the "products of corrosion" for lead + water and lead + water + sulphur. These are for pure conditions – no other elements. Obviously, this is not the state in nature, but they do show that red lead can develop naturally.

Subsequently, red lead was seen on a locked and soldered flat-seam LCC roof of a residence near Myrtle Beach, South Carolina. As shown in *Photograph 4*, the red is not only on the LCC, but also on the solder.

Typically, it takes three to six years for sufficient red lead to form before it is noticeable. Although first noticed in marine environments, red lead has formed on numerous projects throughout the world. It has been found in the European Alps, the Bahamas, Alaska, California, Colorado, Illinois, Louisiana, New Hampshire, New Jersey, New Mexico, New York, etc. No area or location in the U.S. seems to be totally immune to this occurrence.

Photo 4: Red lead on a locked and soldered flat-seam, lead-coated copper roof.

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SUGGESTIONS

Although an architectural metal may not be weathering in the expected manner, it probably is weathering normally for its location.

In the case where "bare/bright" copper has not yet obtained a uniform brown or bronze color, our best suggestion is to leave it alone. With the passage of time, it will continue to weather. In most locations it will develop a more uniform brown or bronze color within four to six months.

Do NOT attempt to clean or artificially color copper. In all likelihood, to do so will only prolong the time necessary for Mother Nature to "correct" the problem.

Likewise, red oxides on lead are a natural occurrence. They are not an indication of defective product, incorrect design, or poor workmanship. The copper is not "bleeding through." Chemically or mechanically removing the oxides may provide temporary relief but will not correct the problem or cause the lead to weather "normally." Unless sulphur is added to the atmosphere, it is likely that the red color will reappear.

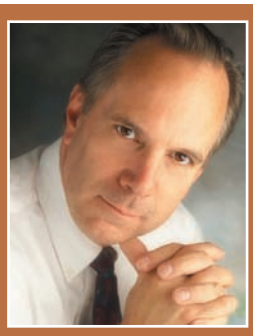
Whenever possible, all copper – plain or lead-coated – for a project should be the same product (sheet or coil) obtained from the same producer at the same time. This will minimize initial aesthetic differences due to manufacturing techniques.

In closing, I know a woman who equates an architectural metal roof to a daughter. Your eleven-year-old daughter (new copper) is lovely, beautiful, and full of life. Likewise, as a young woman in her twenties (copper with a mature patina), she is also lovely and beautiful. However, during her teenage years you often wonder what happened to her beauty and grace.

If, as with your daughter, you are patient, and give your roof time, then you almost always will be pleased with the end product.

[1] Editor's Note: Revere Copper is one of the ten oldest continuous brand names in the U.S. The company was founded by Paul Revere in 1802.

About the Author



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