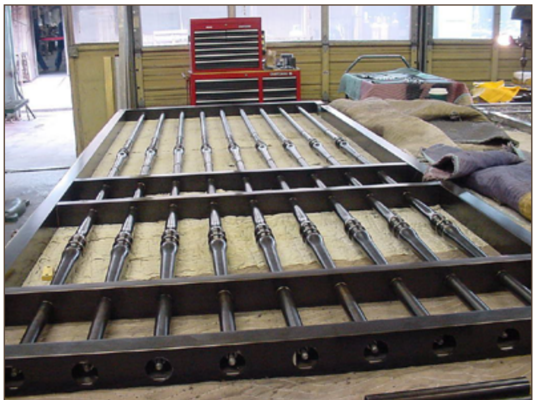


Figure 3.3B. Oil-rubbed bronze gates prepared for installation at the State Capital in Harrisburg, Pennsylvania.

Photograph courtesy of Weimann Metalcraft.

The most common oils are lemon oil (U.S.P.), lemon grass oil (Citratus or East Indian), paraffin oils, linseed oil and castor oil. Popular waxes include carnauba wax and beeswax, either of which can be applied as a mixture with wood turpentine. Quality commercial waxes also give good results.

Oil newly installed metals weekly for the first month to build up a sound base. Apply oils and waxes by hand rubbing with a well-saturated cloth, followed by a second rubbing with a clean cloth to remove excess finish. Application frequency depends on the severity of service: every one or two weeks for heavy traffic areas; monthly for moderate and light duty areas.

Vitreous Enamels

These coatings have their place in artwork, decorative objects and some small architectural elements. They are seldom applied to larger architectural works.

Metallic Coatings

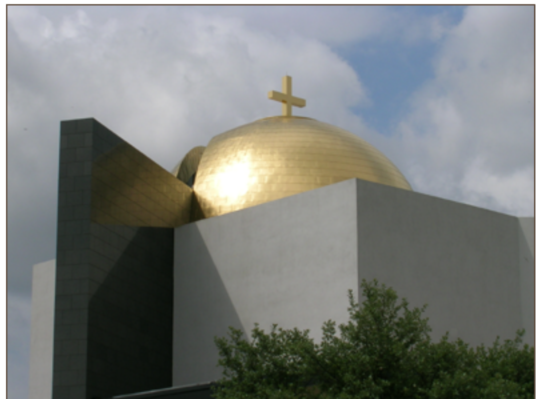


Figure 3.3C. Gilded copper dome crowns the Chapel of St. Basil in Houston, Texas; Niko Contracting, sheet metal installer.

Photograph courtesy of CDA.

This approach is occasionally used with copper metals, two common examples being tinned and tin-zinc coatings used mainly on copper for roofing, flashing and exterior wall panels. Another example is gilding, whereby a thin layer of gilt (typically gold) is applied to the copper surface.

Other examples include chromium and nickel electroplating given to copper and brass hardware, fasteners and plumbing goods. Some high-end plumbing fixtures are finished with electroplated gold. Plated layers are normally thin enough to replicate the underlying surface texture.

Heat Treatment

This is usually a custom artistic treatment accomplished by gas-torching the metal surface to create patterns of colors. The gas in the torch combines with the air to cause a chemical reaction with the copper alloy surface.

3.4. Laminated Finishes

Laminated finishes are not common for copper metals, since most are opaque. Clear polyvinyl fluoride (PVF) and polyvinylidene fluoride (PVDF) coatings provide corrosion and abrasion resistance and demonstrate long-time resistance to degradation by sunlight.

3.5. Standard Finish Designations

Classification of metal finishes has evolved over the years, but even early systems are still occasionally used. One of these is the U.S. Finishes Designations System, developed by the U.S. Department of Commerce. It mainly defines finishes for brass and bronze hardware. Although it was officially discontinued decades ago, it is still used by some hardware manufacturers and architects today. Ultimately, the Builders Hardware Manufacturers Association (BHMA) established an industrywide numerical system, which is now widely used for hardware items. In deference to common practice, BHMA cross-referenced its designations to the nearest U.S. Finishes numbers, as shown in Table 3.7A.

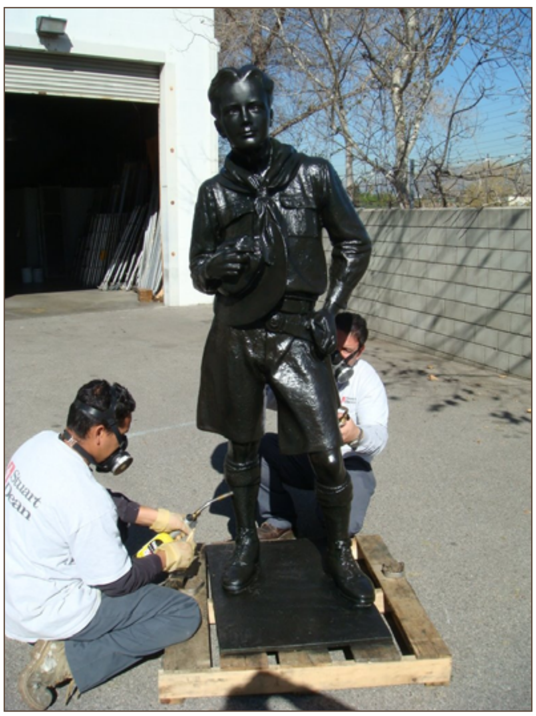


Figure 3.5A. Heat and chemical treatments applied to a bronze statue by experienced metals restoration firm Stuart Dean.

Photograph courtesy of Stuart Dean.

In 1967, the Copper Development Association adopted a system of designations widely used by architects that offers simplicity and uniformity. The system recognizes four most common types of finishes: mechanical, chemical, clear organic coatings and laminated coatings, each designated by the letters M, C, O and L, respectively. A specific finish is identified by one of these letters followed by a two-digit number. Table 3.7B, Table 3.7C and Table 3.7D list specific designations for mechanical, chemical and laminated finishes, respectively. Metal finishing being as much a craft as a technology, the "Examples of Method of Finishing" listed in the tables are merely suggestions and are not to be taken as mandatory. Alternate methods are acceptable in all cases.

Specify finishes by their designation code(s), with preparatory and final steps listed sequentially. Thus, M36-C51 defines a uniform, directionally textured mechanical finish treated with a cuprous chloride-hydrochloric acid conversion coating, in this case a synthetic patina. Specifications need not be that detailed, however, and designers can call out only the final finish, leaving the preparatory operations to the discretion of the fabricator or finisher.

The letter "x" appearing in a designation listed in the tables implies that no number, other than the first digit, has yet been assigned to the finish in question.

When such a finish is called out, follow the numerical designation with a brief written explanation.

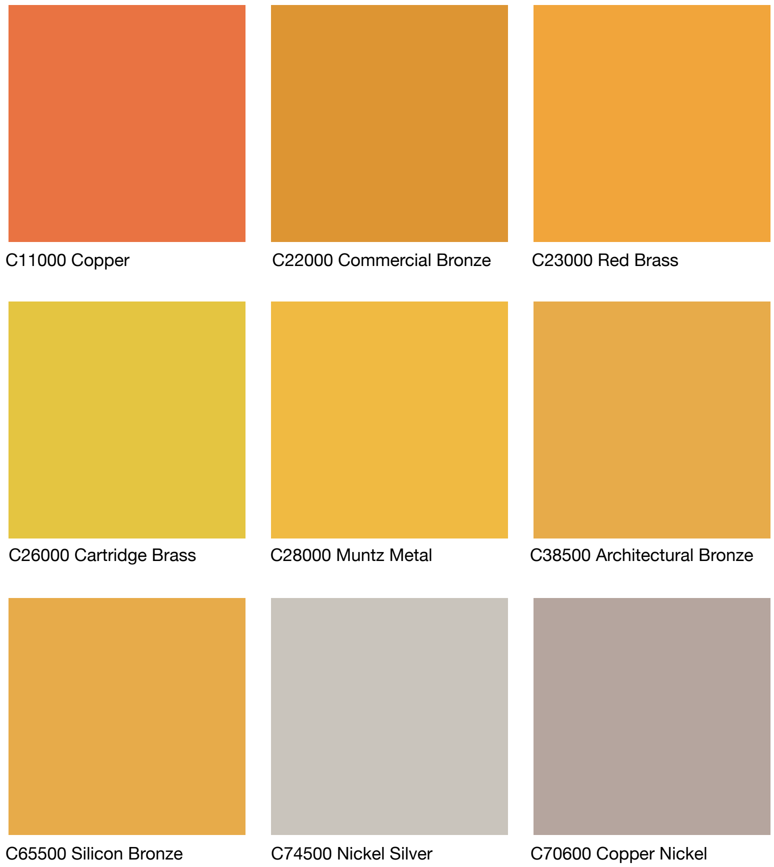
Table 3.5A. Chemical weathering may be used creatively to produce different effects or create color matches. The copper alloy, the chemical solution and the application method contribute to the final result.

	C11000 Copper	*C23000 Red Brass*	*C26000 Cartridge Brass*
Untreated			
Chemical Weathering			
Sulfide "Statuary" Medium (C-55)			
Sulfide "Statuary" Dark (C-55)			
Patinated (C-52)			

Source: CDA

3.6. Copper Alloys Color Chart

A wide variety of copper alloys are available for use in construction. The variations in color stem primarily from differences in chemical composition (see **2. Copper Alloys**). Shown below are sheet metal samples of some common copper alloys. Additional information is available from CDA upon request. Note the finishes indicated.



3.7. Finishes Tables

Table 3.7A. BHMA and U.S. Finishes for Brass and Bronze Hardware

BHMA Code No.	*Description*	*Nearest US Equivalent*
605	Bright brass, clear coated	US3
606	Satin brass, clear coated	US4
611	Bright bronze, clear coated	US9
612	Satin bronze, clear coated	US10
613	Dark oxidized satin bronze, oil rubbed	US10B
622	Flat black coated	US19
623	Light oxidized statuary bronze, clear coated	US20
624	Dark oxidized statuary bronze, clear coated	US20A
625	Bright chromium plated over nickel	US26
626	Satin chromium plated over nickel	US26D
632	Bright brass plated, clear coated	US3

Table 3.7B. Standard Designations for Mechanical Finishes[1]

Type of Finish	*Designation*	*Description*	*Examples of Method of Finishing*
As-fabricated	M10	Unspecified	Optional with finisher.
	M11	Specular as fabricated	Cold rolling with polished steel rolls.
	M12	Matte finish as fabricated	Cold rolling followed by annealing; also: hot rolling, extruding, casting.
	M1x	Other	To be specified
Buffed	M20	Unspecified	Optional with finisher
	M21	Smooth specular	Cutting with aluminum oxide or silicon carbide compounds, starting with relatively coarse grits and finishing with 320 grit using peripheral wheel speed of 6,000 ft/min (30 m/s). Followed by buffing with aluminum oxide buffing compounds with peripheral wheel speed of 7,000 ft/min (36 m/s)
	M22	Specular	Cutting with compounds as for M21 finish, followed by a final light buffing.
	M2x	Other	To be specified.
Directionally Textured	M30	Unspecified	Optional with finisher.
	M31	Fine satin	Wheel or belt polishing with aluminum oxide or silicon carbide abrasives of 240–320 grit using a peripheral speed of 6,000 ft/min (30 m/s).
	M32	Medium satin	Wheel or belt polishing with aluminum oxide or silicon carbide abrasives of 180–240 grit using a peripheral speed of 6,000 ft/min (30 m/s).
	M33	Coarse satin	Wheel or belt polishing with aluminum oxide or silicon carbide abrasives of 120–180 grit using a peripheral speed of 6,000 ft/min (30 m/s).
	M34	Hand rubbed	Hand rubbing with stainless steel wool and solvent, #0 pumice and solvent, nonabrasive mesh pad or Turkish oil and emery.
	M35	Brushed	Brushing with rotary stainless steel, brass or nickel silver wire wheel. Coarseness of finish controlled by diameter and speed of wheel and pressure exerted.
	M36	(Number unassigned)	
	M3x	(Number unassigned)	To be specified.
Non-directionally Textured	M40	Unspecified	Optional with finisher.
	M41	(Number unassigned)	
	M42	Fine matte	Air blast with #100–#200 mesh silica sand or aluminum oxide. Air pressure 30–90 psi (207–621 kPa). Gun 12 in (305 mm) away from work at an angle of 60–90 degrees.
	M43	Medium matte	Air blast with #40–#80 mesh silica sand or aluminum oxide. Air pressure 30–90 psi (207–621 kPa). Gun 12 in (305 mm) away from work at an angle of 60–90 degrees.
	M44	Coarse matte	Air blast with #20 mesh silica sand or aluminum oxide. Air pressure 30–90 psi (207–621 kPa). Gun 12 in (305 mm) away from work at an angle of 60–90 degrees.
	M45	Fine shot blast	Air blast with S-70 metal shot.
	M46	Medium shot blast	Air blast with S-230 metal shot.
	M47	Coarse shot blast	Air blast with S-550 metal shot.
	M4x	Other	To be specified.

Table 3.7C. Standard Designations for Chemical Finishes[1]

Type of Finish	*Designation*	*Description*	*Examples of Method of Finishing*
Non-etched Cleaned	C10	Unspecified	Optional with finisher.
	C11	Degreased	Treatment with organic solvent.
	C12	Chemically cleaned	Use of inhibited chemical cleaner.
	C1x	Other	To be specified.
Conversion Coatings	C50	Ammonium chloride (patina)	Saturated solution of commercial sal ammoniac, spray or brush applied. Repeated applications are sometimes required.
	C51	Cuprous chloride hydrochloric acid (patina)	In 500 ml of warm water, dissolve 164 g of cuprous chloride crystals, 117ml hydrochloric acid, 69 ml glacial acetic acid, 80 g ammonium chloride, 11 g arsenic trioxide. Dilute to 1 l. Apply by spray, brush or stippling. Repeated applications are sometimes required. Avoid use of aluminum containers.
	C52	Ammonium sulfide (patina)	Dissolve in 1 l of warm water, 111 g ammonium sulfate, 3.5 g copper sulfate, 1.6 g concentrated ammonia. Spray apply. Six to eight applications may be necessary under high humidity conditions.
	C53	Carbonate (patina)	Various formulations having copper carbonate as the major constituent.
	C54	Oxide (statuary)	Principal formulations utilize aqueous solutions of copper sulfates and copper nitrates at temperatures from 85°C to boiling using immersion periods from 30 sec to 5 min.
	C55	Sulfide (statuary)	Apply 2%–5% aqueous solutions of ammonium sulfide, potassium sulfide or sodium sulfide by swabbing or brushing. Repeated application increases depth of color.
	C56	Selenide (statuary)	Proprietary formulations recommended. The solutions are toxic, and user preparation should be avoided. Follow manufacturers' directions for use without deviation.
	C5x	Other	To be specified.

Table 3.7D. Standard Designations for Film Laminated Finishes[1]

Type of Finish	*Designation*	*Description*	*Examples of Method of Finishing*
Film Laminates	Unspecified	L90	Optional with finisher.
	Polyvinyl Fluoride	L91	A one-mil clear film, adhesive bonded to the metal surface.
	Other	L9x	To be specified.

1. *NAAMM/NOMMA Metal Finishes Manual*, Chapter 2: "Finishes for the Copper Alloys," National Association of Architectural Metal Manufacturers, AMP 500-06, 2006
2. See also: **How to Apply Statuary and Patina Finishes**

4. REHABILITATION OF COPPER

Maintenance

Due to copper's longevity as an exterior building material it is subjected to long-term man-made pollutants and can, in time, accumulate assorted debris including bitumastics, tar, soot, dirt, oil and bird droppings.

The major concern with cleaning copper surfaces is permanent damage to the copper. Historical information points to some successful cleaning methods.

To remove encrusted deposits on roof surfaces:

Walnut shell dust is blown from a nozzle at 30 psi at the edge of the crust. This forces the crust to lift off the surface without damage to the copper.

To clean unevenly patinated copper:

1. Sponge bathe copper with a mixture of six parts concentrated phosphoric acid to one part concentrated nitric acid diluted by no less than 50 percent distilled water to a pH between 1 and 1.5. A thickening agent can be added to the acid as a buffer and to contain the acid and make its removal and disposal easier.

2. Leave the acid solution on the copper for one minute, then lift off with sponges soaked in sodium bicarbonate solution. Neutralize any residual acid by rinsing the copper with fresh water and treating with a sodium bicarbonate paste at pH 10, rubbed on with sponges and flushed off with water.

3. Apply ammonium oxalate as a second neutralizer to even out any residue left by the first neutralizer. Sponge with rinse water to wash away the residue.

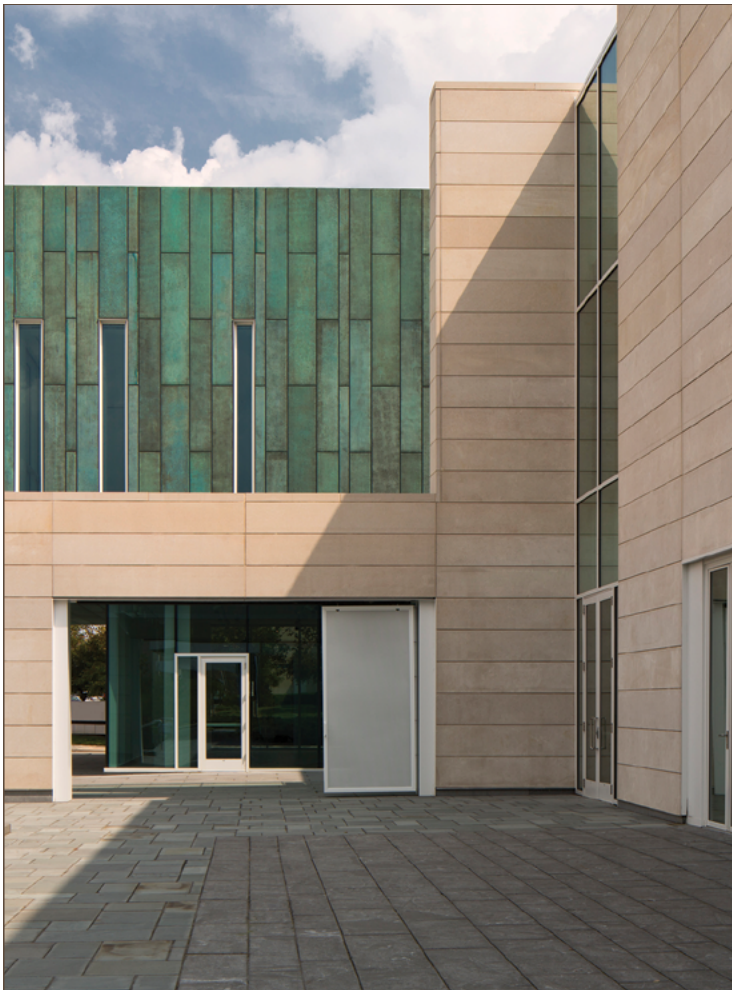
4. Wipe the cleaned copper, using parallel strokes, with a clean cotton cloth until no color shows on the cloth.

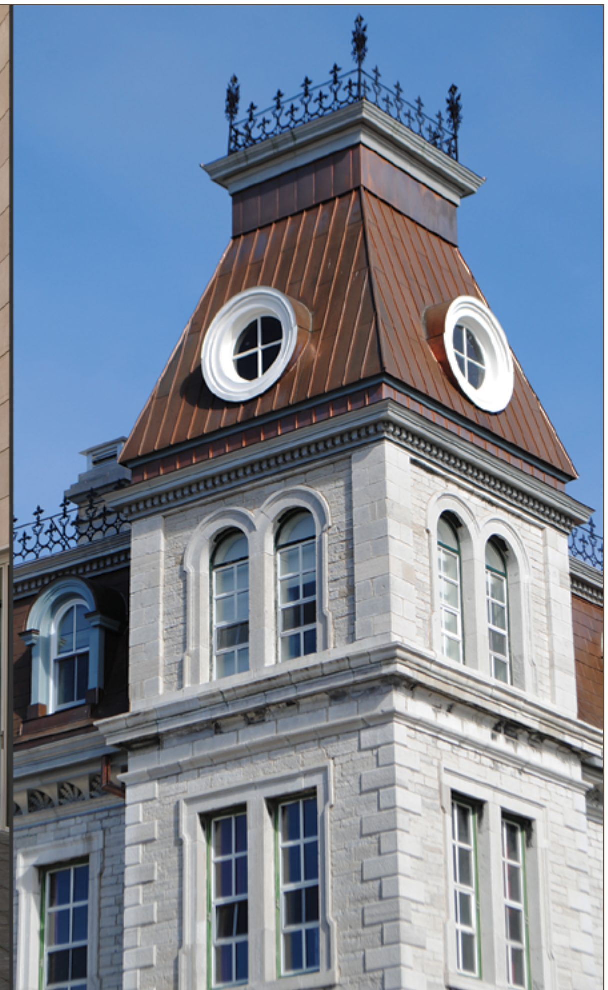
5. Wipe again with a cloth saturated with mineral spirits (no less than 96 percent aliphatics) and continue wiping until no color shows on the cloth.

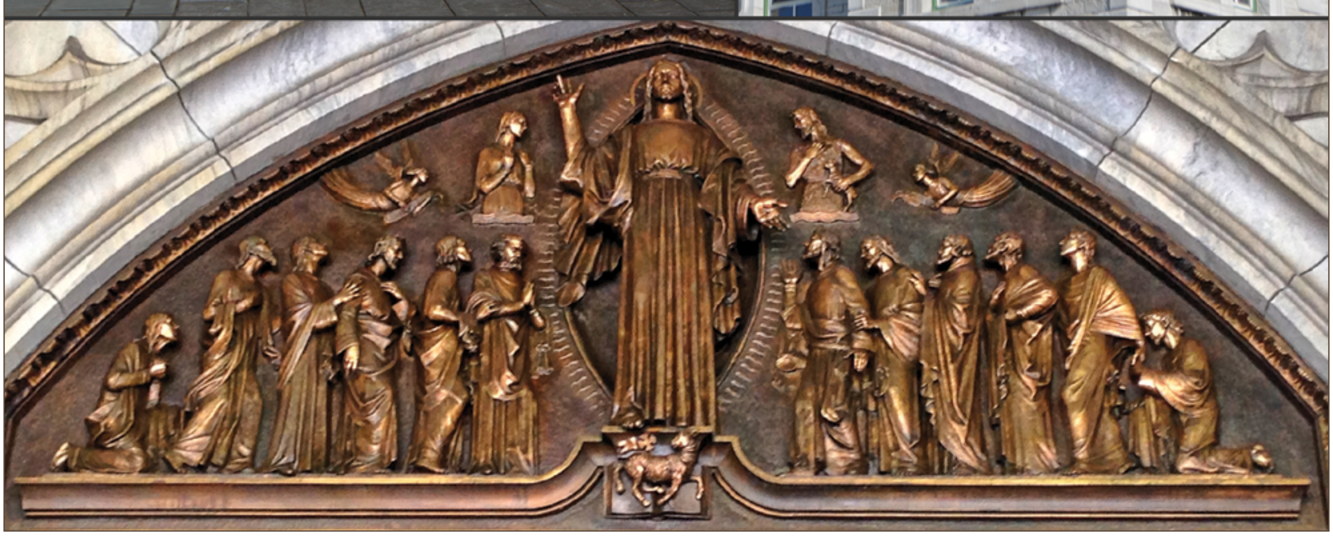
6. Apply a thin coat of carnauba wax. While the wax wears off fairly soon, it allows the copper a chance to start its repatination uniformly.

The above procedure can be used when replacing portions of a patinated copper roof or in instances of an addition where a new copper roof abuts a fully patinated copper roof. Treating the existing copper roof allows it to patinate along with the new roof resulting in a uniform finish for both roofs.

DESIGNS







5. FEATURED PROJECTS

Our Featured Projects gallery is available online at Copper.org. It highlights a wide array of architectural copper, brass and bronze applications.

Transcending any limitations of style or classification, our selection of original and creative works includes both modern and classically influenced installations, and each project is complete with narrative descriptions from the architects and project owners themselves.

We hope that these illustrative examples of dynamic and creative uses of copper, brass and bronze materials in architecture will serve to inspire students, designers, installers and builders alike.

If you are an architect, installer, contractor, or building owner, we encourage you to submit any built projects located in the United States or Canada for consideration and potential inclusion in our Featured Projects section.

SUBMIT YOUR PROJECT for a chance to be featured on Copper.org!

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Royal Military College, Photo Credit: Colbourne & Kembel

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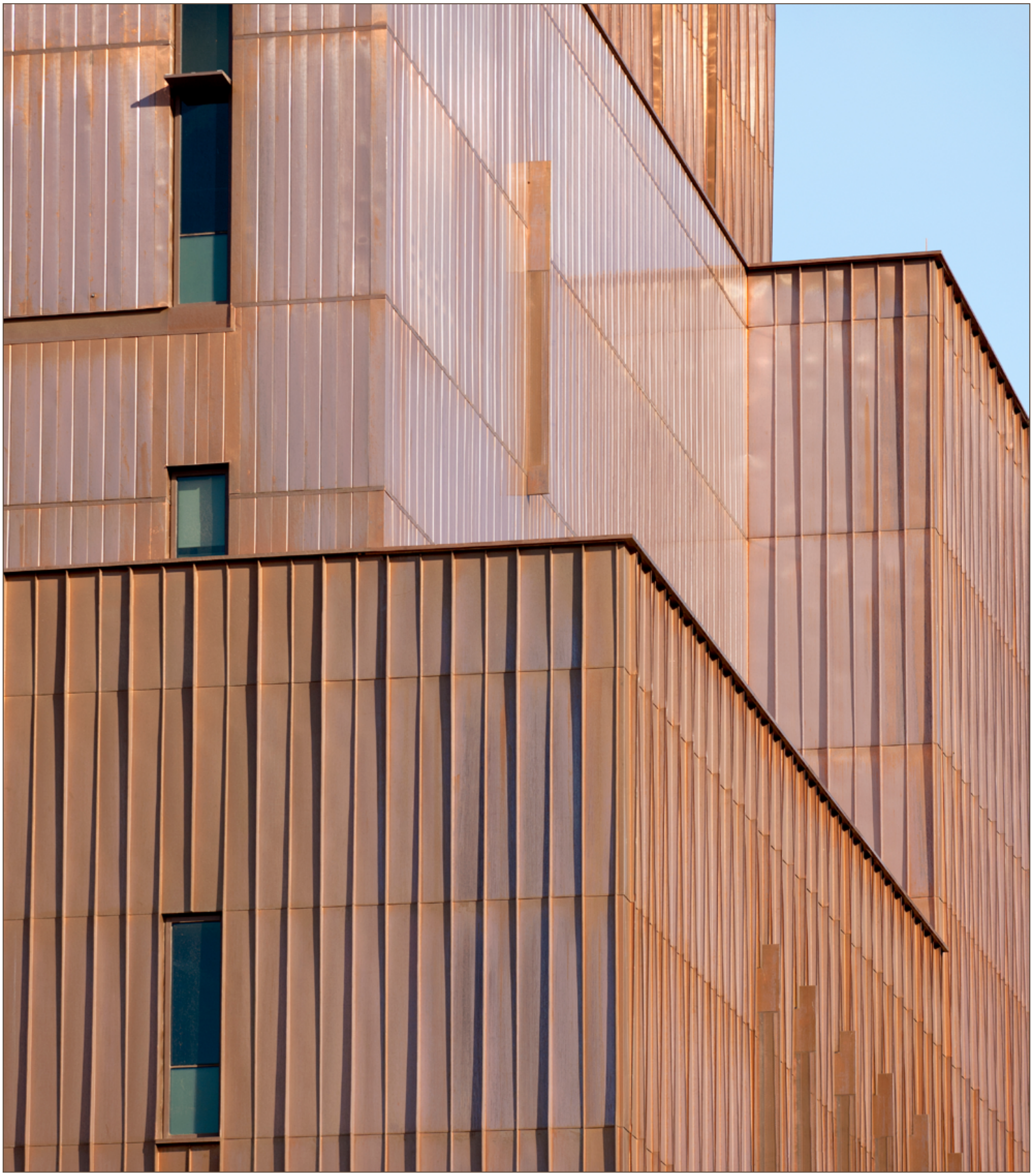
Columbus Museum of Art, Photo Credit: Brad Feinknopf

ARCHITECTURAL DETAILS



Maricopa County Downtown Court Tower, Photo Credit: Bill Timmerman

- [6. General Design Issues]
- [7. Basic Details]
- [8. Roofing Systems]
- [9. Flashings and Copings]
- [10. Gutters and Downspouts]
- [11. Building Expansion Joints]
- [12. Wall Cladding]
- [13. Domes, Spires and Vaults]

This section contains drawings for the proper design and construction of sheet copper details. It is divided into subsections by topic, such as "8. Roofing Systems".

Each subsection has an introduction that gives general information for that topic. Within each subsection, there are divisions that cover variations of that topic. For example, in the 8. Roofing Systems, there are divisions for standing seam, batten seam, flat seam roofing and more. These divisions are comprised of one or more drawings each with a facing page of descriptive text.

The drawings are presented in two colors. Copper materials are shown in copper color, all other building materials are shown in black. The drawings are intended to show the relationships of the materials.

Although the drawings show the components in detail, some items, such as nails, may not be shown for the sake of clarity. The specifications and descriptive text should always be consulted before using the details in any specific application.

AutoCAD Details

All of the details shown in this section of the Handbook are available as **AutoCAD Detail Files**. The details have been developed using AutoCAD. They may be inserted onto a sheet as stand-alone details, or incorporated into larger drawings.

- **Download AutoCAD Detail Files** [Complete set, ZIP - 4.5MB]

Some steps have been taken to simplify the use of these files:

1. All components are drawn actual size in "model space".
2. The dimensions of some elements, such as transverse seams, have been exaggerated to make them more readable in printed form.
3. All details have been drawn in two dimensions. Although many drawings use axonometric views, the views are actually constructed in two dimensions. It is felt that full threedimensional models of the elements would be much more complicated than necessary for construction documents.
4. Five layers are used in these files:

Layer Name	Color	Description
AXON-COPPER	5	Copper material in axonometric view.
AXON-OTHER	6	All other material in axonometric view.
BASE-COPPER	10	Copper material in plan or section.
BASE-OTHER	9	All other material in plan or section.
CDATEXT	3	Text, leaders, dimensions, and dimension lines

This layer naming convention allows the user to easily turn off and on the axonometric layers, or to separate copper from other materials.

6. GENERAL DESIGN ISSUES

This section provides a summary of major issues that should be considered by the designer. Much of the information is based on successful historic practice. The majority of the issues presented are related to the climatic conditions of the site and the configuration of the building.

- **High Winds** In areas where high winds occur, the design of roofing systems must be carefully evaluated. High winds can place extreme positive or negative pressures on roof edges, such as, ridges, ridge vents, eaves, rakes, copings, gutters, and fascias. Under these conditions it is particularly important to ensure that the edges of roofing and flashing are securely fastened.

  In areas of high winds and rain special care must be exercised in designing transverse seams and flashing. The headlap may be increased in these conditions, to reduce the likelihood that moisture will be driven past the roofing membrane.

- **Heavy Rain** Where heavy rain is expected, special attention should be given to roof slopes, headlap, seam details, valleys, gutters and downspouts. Unless soldered flat seam roofing is used, low slopes, which do not promote positive drainage, should be avoided. The headlap of transverse seams or overlapping roofing components (at a valley, for example) can be increased for improved protection. Increased seam heights can help prevent water infiltration. Seams may also be filled with sealant or fully soldered, to provide a watertight barrier. Valleys, gutters, and downspouts should be sized adequately, and their design should account for the volume, speed, and direction of the expected water flow.

- **Ice and Snow** In areas where ice and snow may be severe, the designer should carefully consider their effect on all components. Many of the problems associated with ice and snow are caused by damming. This often occurs when snow on a roof, over heated space, melts and flows to the eaves. The roof temperature at the eaves can be significantly lower, especially if the roof has an overhang. The flowing water can freeze and form a dam which prevents proper roof drainage. These conditions can be intensified by roof shapes, such as valleys.

  Eave snow flashing may be used to make the roof perimeter watertight. The headlap of roofing material over valley flashing, roof edge strips, gutter aprons, and other elements may be increased by extending the underlying copper material higher up the roof. The amount of increase is related to the slope of the roof or valley and the likelihood of a dam condition. Other steps that increase protection under these circumstances include: increased seam height and the use of solder or sealant in seams. In areas of extreme ice and snow conditions, heating elements can be installed on eaves and in gutters to help prevent ice build-up.

  Another potential problem with ice and snow build-up is its weight. If snow accumulates on a sloped roof, it can slide down its surface with tremendous force, damaging the roof, eaves, or gutters. In areas where ice can accumulate in gutters, the proper design of gutter support is very important. The use of snow guards is neither supported nor opposed, rather their use must be determined and evaluated for each specific application.

- **Temperature Range** When designing copper roofing systems or accessories, the effect of temperature changes should be considered. The expansion and contraction of copper material, as well as that of any other adjacent material, is a function of variations in temperature. The temperature during installation can also play an important role, since future thermal expansion and contraction will occur as the temperature rises and falls relative to this initial value. This is particularly important when installing components with potential restrictions to movement in one direction. For more information on expansion and contraction, see 8.8. Long Pan Systems.