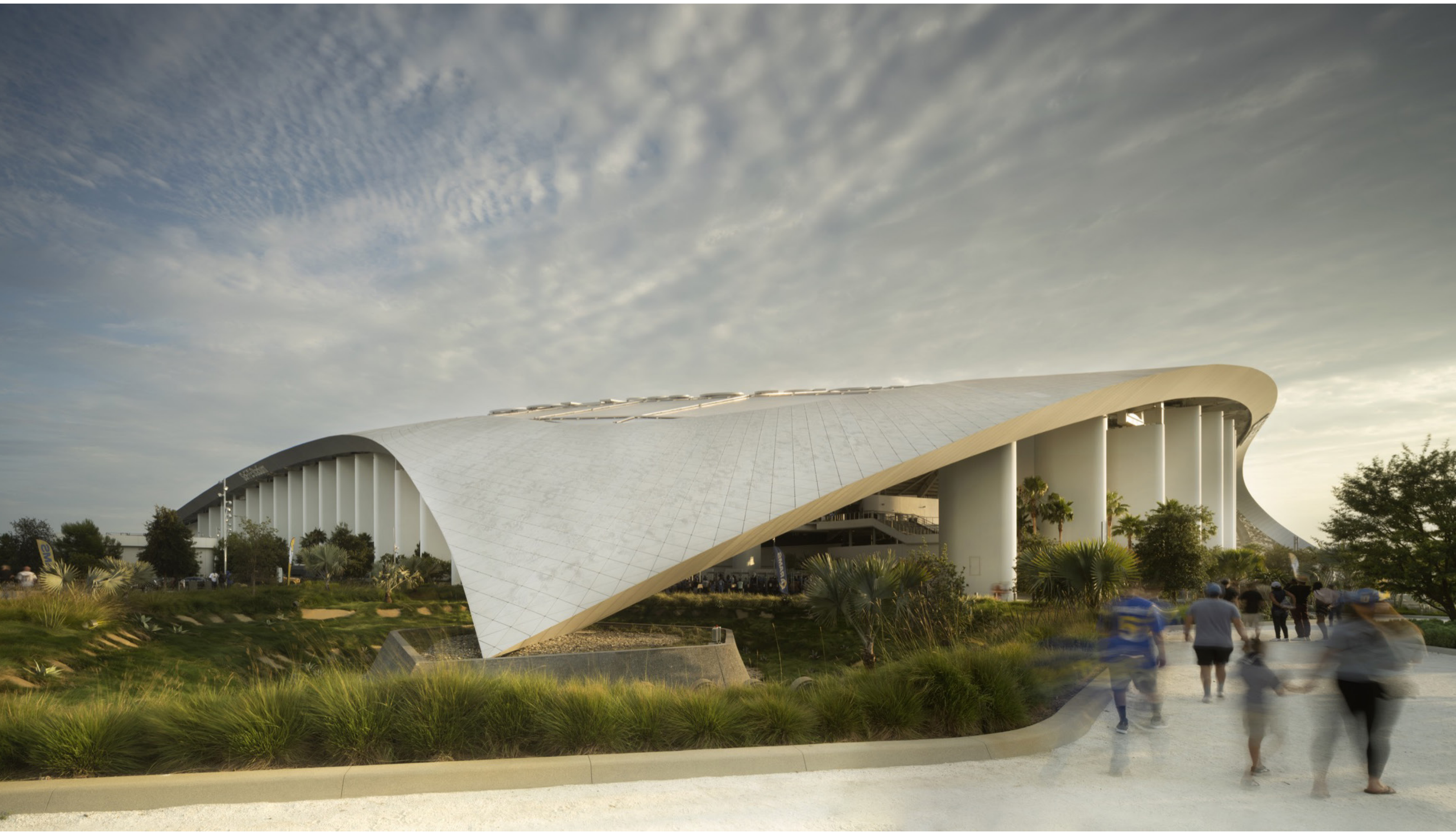
SPECIFIER'S GUIDE TO METAL



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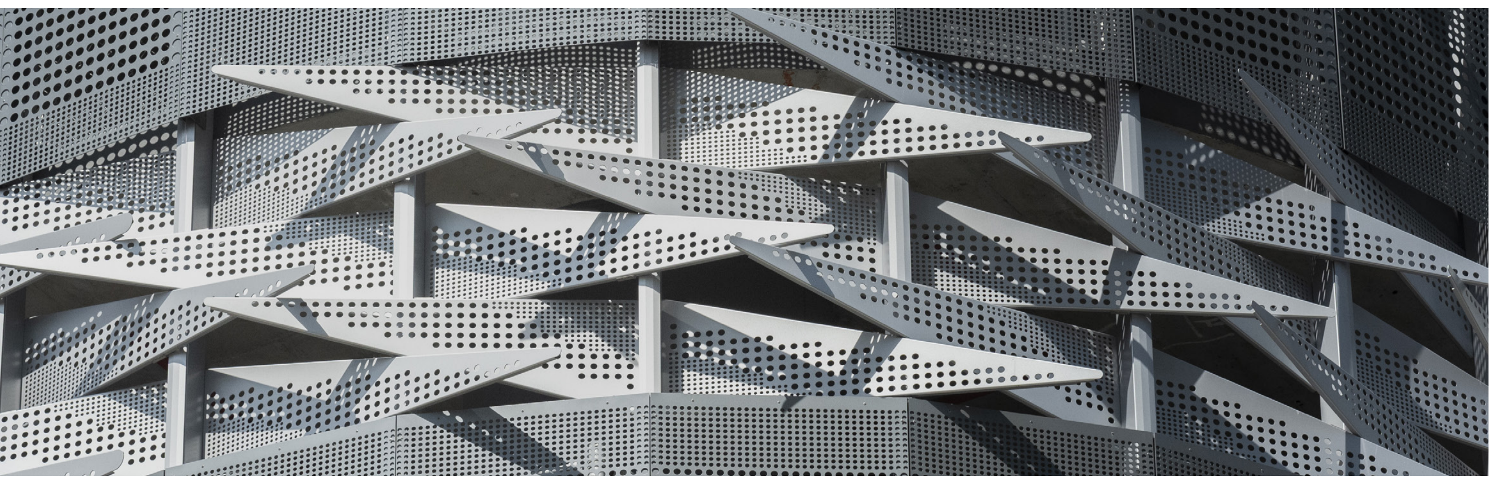
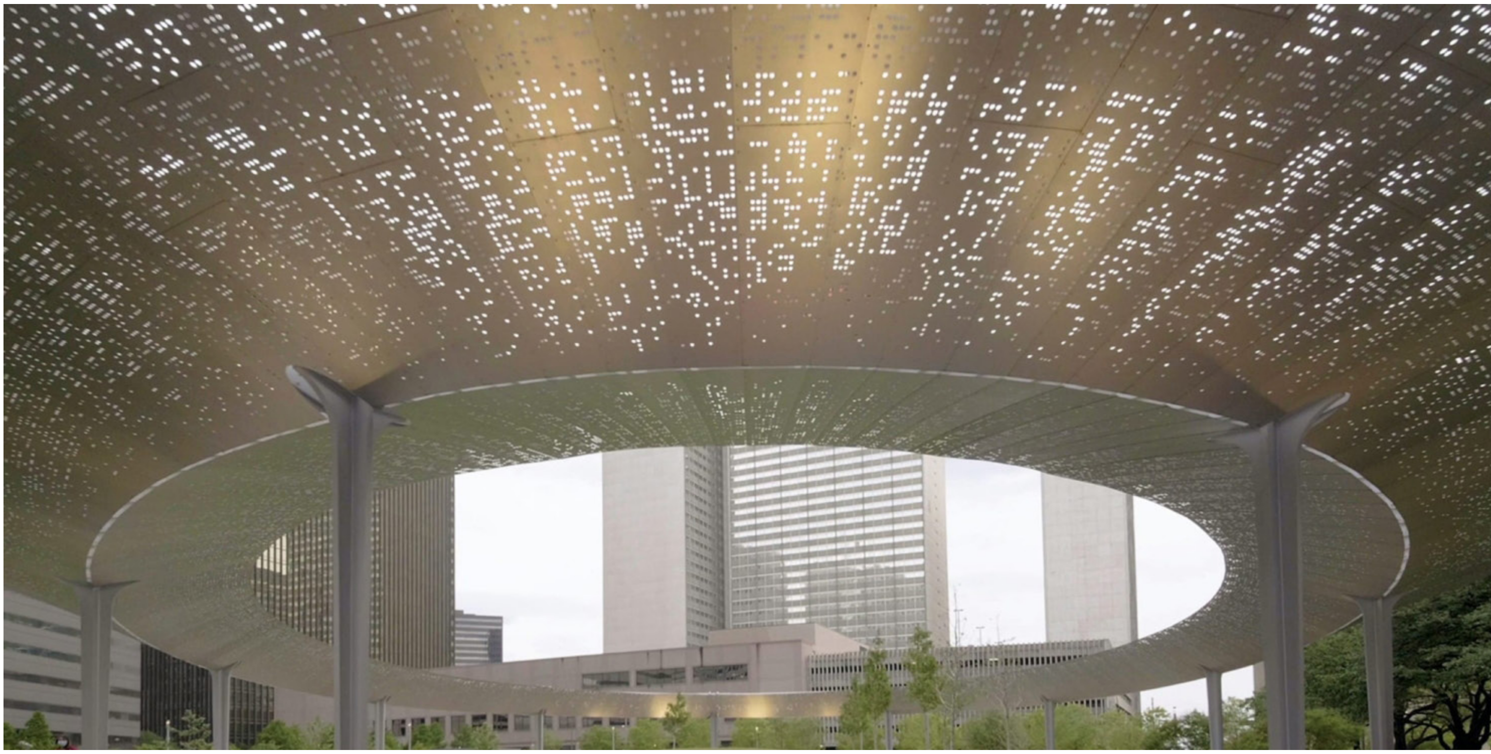


INTRODUCTION

The Specifier's Guide To Metal provides a valuable reference tool for anyone evaluating and specifying metals for an architectural project. From metal hardness, thickness, and reflectivity to density, costs, and more, you'll have the reliable input you need to make a well-informed decision about the materials you specify. If you have any questions about the information here or you're looking for an expert point of view on a metal surface, don't hesitate to reach out to our project assistants at 816.474.8882 or assistant@azahner.com



METAL HARDNESS

Metal hardness is a characteristic that determines the surface wear and abrasive resistance. The ability of a material to resist denting from impact is related to hardness as well as a material's ductility. Various degrees of hardness may be achieved in many metals by tempering, a heat treatment process used in cold rolled and cold worked metals. As the grain structure of the metal undergoes cold forming, the grains are stretched and altered. The surface becomes harder, resisting deformation from contact. Tempering heats the worked metal to temperatures at which the grains begin to dissolve. There are series of standard tempers available. These tempers and their availability in a particular alloy vary, depending on the nature of the grains as they recrystallize. The temper designation is actually determined by this grain size, rather than the yield strength of the metal.

METAL HARDNESS CHART

The below chart is useful for determining which metals will be impervious to scratching and dinging, as it relates to the Rockwell scale and ductility. The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by a preload.

Metal	Alloy & Temper	Hardness Rockwell B-Scale	Yield Strength (KSI)	Yield Strength (MPa)	Ductility Degree 1. Very Ductile 5: Stiff
Aluminum	A93003-H14	20 to 25	21	145	1
Aluminum	A93003-H34	35 to 40	29	200	1
Aluminum	A93003-H14	20 to 25	20	138	1
Aluminum	A96061-T6	60	40	275	4
Copper	1/8 hard (cold roll)	10	28	193	1
Gliding Metal	1/4 hard	32	32	221	1
Commercial Bronze	1/4 hard	42	35	241	2
Jewelry Bronze	1/4 hard	47	37	255	2
Red Brass	1/4 hard	65	49	338	2
Cartridge Brass	1/4 hard	55	40	276	1
Yellow Brass	1/4 hard	55	40	276	2
Muntz Metal	1/8 hard	55	35	241	3
Architectural Bronze	As Extruded	65	20	138	4
Phosphor Bronze	1/2 hard	78	55	379	3
Silicon Bronze	1/4 hard	75	35	241	3
Aluminum Bronze	As Cast	77	27	186	5
Nickel Silver	1/8 hard	60	35	241	3
Steel (Low Carbon)	Cold-rolled	60	25	170	2
Cast Iron	As Cast	86	50	344	5
Stainless Steel - 304	Temper Pass	88	30	207	2
Lead	Sheet Lead	5	0.81	5	1
Monel	Temper Pass	60	27	172	3
Zinc-Cu Tn Alloy	Rolled	40	14	97	1
Titanium	Annealed	80	37	255	3

INCREASING METAL HARDNESS

There are a number of ways to harden architectural metal, through the mill, or during the fabrication process. Each of the hardening mechanisms is introducing crystal lattice irregularities into the metal crystal structure, causing dislocation of the metal's structure to become more difficult. The result is a harder, less ductile metal surface.

Work hardening refers to the straining or cold-hardening of a metal surface. As metal is bent or strained repeatedly, the plasticity of the metal reduces, becoming work-hardened and less ductile. Usually, it refers to strain-hardening behavior of the metal as it is worked at room temperature. Certain metal alloys such as nickel-titanium do not undergo strain hardening but actually have a characteristic of strain relieving as they return to the original shape.

Solid Solution Strengthening refers to a metal in the alloying process, in which an alloying constituent is inserted into a solid material. One or more elemental constituents are able to enter into a heated but solid solution. The metal is then rapidly quenched to capture the element in solid solution.

Age hardening is a process that occurs rapidly in the first few days after casting, then much slower over the next several weeks. This process is often referred to as "natural age-hardening". Another artificial version of this process can be used by heating the metal for a short period of time at a high temperature. The result is that it will stabilize the properties, further strengthening the alloy. This process is known as "artificial age-hardening" or precipitation hardening.

Anodization, a process specific to aluminum, has a hardening effect. The final step in creating anodized aluminum is to harden and seal the surface by the use of deionized boiling water or metal salt sealers. Sealing is required to close the pores of the oxide film and provide uniformity to the exception of the alloying constituents.

Case hardening refers to a surface heat treatment process used to produce a hard, wear-resistant surface on metal. Methods of case-hardening include carburization, cyaniding, nitriding, flame hardening, and electroinduction hardening.

Tempering is a heat treatment process used in cold rolled and cold worked metals. As the grain structure of a metal undergoes cold forming, the grains are stretched and altered. The surface becomes harder, resisting deformation from contact. Tempering heats the cold worked metal to temperatures at which the grains begin to dissolve into one another. There are a series of standard tempers available. These tempers and their availability in a particular alloy vary, depending on the nature of the grains as they recrystallize. The temper designation is actually determined by this grain size, rather than the yield strength of the metal.

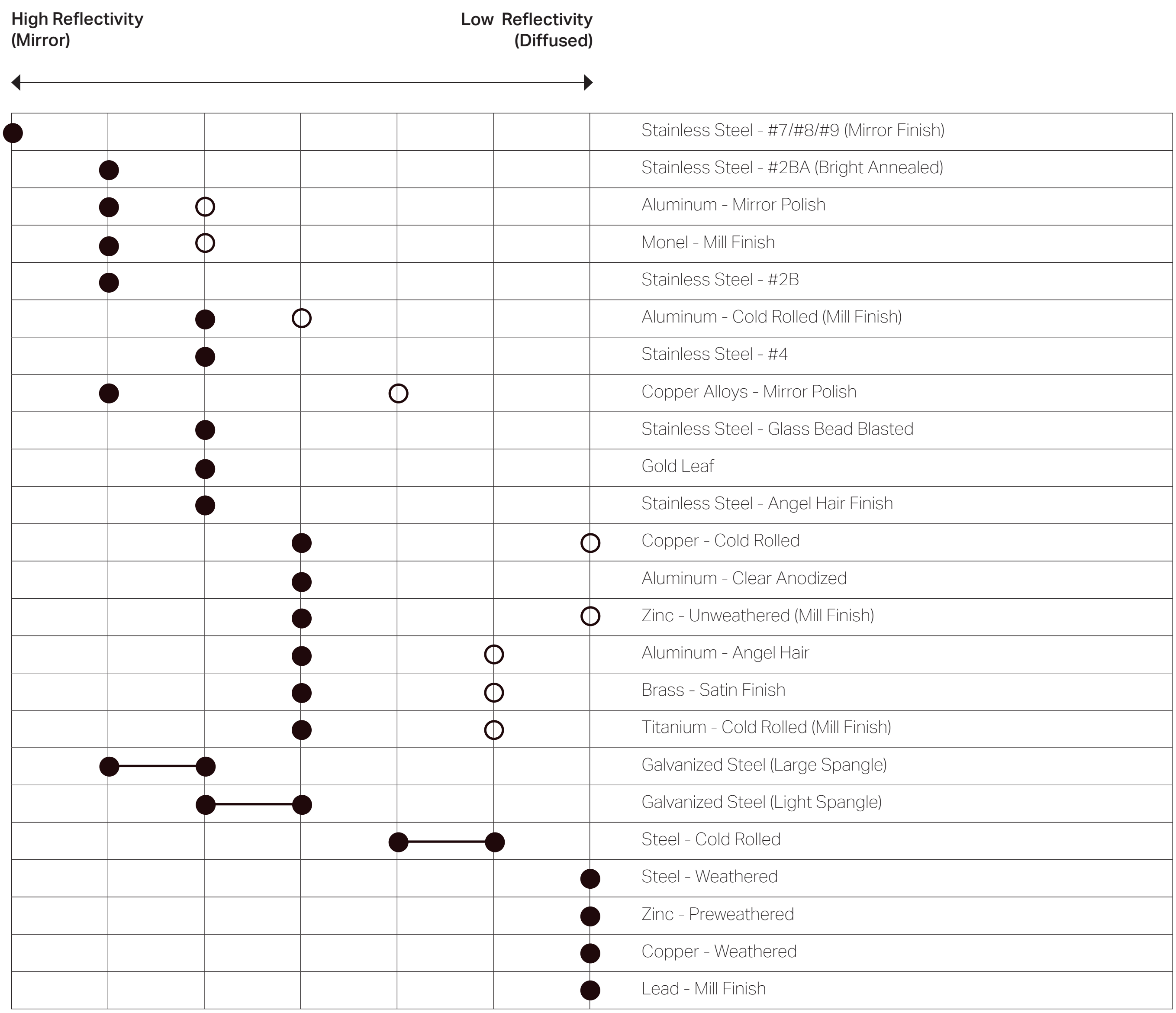
Back-blasting a metal surface is a way of flattening metal, which also tends to greatly increases the surface hardness. It is advised to back-blast a material after forming operations because the material will become harder to work and form after blasting the surface.

METAL REFLECTIVITY

With metals, it is often desired to have a reflective surface-not necessarily blindingly bright but one that catches the eye. Its relative reflectivity is much greater than surrounding surfaces. A gold leaf surface shimmers in the sunlight like a beacon when seen from a distance. It is as if the light is generated from the metal itself. Even on an overcast day, gold will appear remarkably bright. A zinc surface, by contrast, dulled by oxide, reflects a blue-gray tone in bright light and looks the color of pewter in overcast sky.

The reflective nature of the surface of metals can be adjusted through the use of various processes. This is true of all metals. However, over time certain metals may change in reflectivity as the metals oxidize. For this reason, some surfaces are limited in their choices. However, if desired, you can achieve a dull, flat, black appearance, devoid of the slightest visual sheen of any kind. Blackened by oxide, copper, zinc, and aluminum can have grainy, black, mottled surfaces. The mottling has degrees of black, some with a reddish tint, others with a gray tint.

RELATIVE REFLECTIVITY OF VARIOUS METALS



● Solid dot indicates reflectivity at new stage

○ Hollow dot indicates reflectivity after aging

METAL THICKNESS

Metals are measured in varying units. This seemingly strange set of measurements is in part due to the history of each metal.

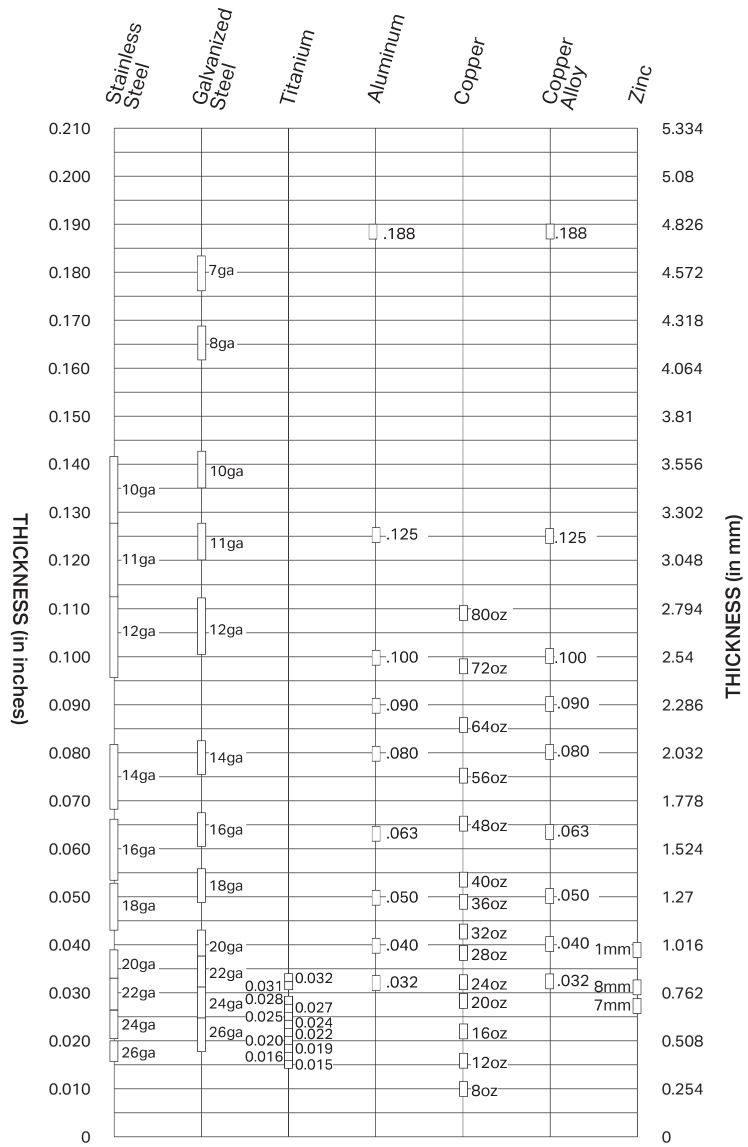
The steels (and stainless steels) are measured in gauge, and correspond with a decimal inch thickness. The higher the gauge number, the thinner the sheet. 16ga (gauge) is roughly 1/16 inch, which is a nice thing to remember if you remember nothing else about sheet metal gauge.

Galvanized steel, which has a thin layer of zinc on a steel sheet, also uses the gauge system. Because of its thin coating, it is slightly thicker when converted into inches than uncoated steels.

Aluminum is measured by the more familiar decimal relationship. Copper is another story altogether. Copper is measured in ounces per square foot, which continues to this day in part due to copper's use in computer transistors, the smallest of measurements. 1oz copper is equal to 1.37 mils, or thousands of an inch. For architectural use, 48oz copper is close to 16 ga stainless steel, to put things in perspective.

Mastering the world of architectural metals might seem like traveling across the different countries of Europe. Each material has its
own language, and understanding them can take time.

The aluminum and copper industries are as different from each other as they are from the steels. Monel, titanium, and zinc, for example, address their own industries with a jargon created from a mixture of the others. This leads to confusion for those using the materials. You must translate your understanding from ounces per square foot to decimals or gauge numbers, depending on your familiarity. Adjacent is a simple chart that should help when comparing standard sheet metal thicknesses between various metals.



METAL RELATIVE COSTS

A relative cost comparison of metals can be made between materials, but it should come with a number of caveats.

First and foremost, it is important to note that metal prices are always changing. Metals are commodities and are traded as such. Their value rises and falls with demand, and as global markets dictate. The more common metals such as aluminum, are fairly predictable. Aluminum is the third-most abundant element, after oxygen and silicon. As such, it rises and falls with the cost of electricity. A rare metal such as gold, on the other hand, is far more volatile.

The second aspect to consider is a material's lifecycle cost. Quality materials used in architectural systems will typically have higher upfront costs. Many of the less expensive options have a short life expectancy, costing more over time.

Third, and last: it is better to measure the installed material than the base material. For most metals, the fabrication and installation costs will be the same. So a metal like copper, which is two or three times more expensive than a steel sheet, might only be 2% more expensive when installed. This is the illusion of cost per square foot when discussing raw materials.

Note that commercial quality standards are rarely to the levels needed for good architectural or ornamental work. Moreover, one mill's commercial quality may be another mill's architectural quality; therefore it is always advisable to acquire metal samples that represent the quality a mill can provide.

Comparative costs do not usually account for the maintenance, long-term performance, or weathering characteristics of the metal. These factors, as well as others, must be included to arrive at a true, albeit subjective, conclusion as to which metal is best suited for a particular surface. For up-to-date pricing on these materials, contact Zahner.

METAL DENSITY

Density is a concept to consider in addition to a metal's weight and hardness. Every material has a particular feel to it, a weight and a surface resistance. This feel is partially characterized by the density of the material.

Density can be measured by its mass per volume, but it can also be understood in more familiar terms by understanding a material's specific gravity. Specific gravity is the ratio of a material's density to that of water. It is a relative (unitless) measure of the weight of a material. For example, gold has a specific gravity of 19.32, so if you took a cubic meter of gold, it would weigh 19.32 times as much as a cubic meter of water.

METAL DENSITY CHART

The chart below describes the various specific gravities of architectural metals, which range from the lightness of titanium and aluminum to the heavy density of lead and gold metals. Magnesium and silver, though not necessarily architectural metals, are indicated for relational comparison.

Another way to understand specific gravity is how it relates to other materials. Plastics have a very low specific gravity, hovering around 0.9 to 1.5. When you pick up a piece of plastic it feels light and has a cheapness to it. Plastic materials can be formed and painted to look like metal, but they will always feel hollow. What you're feeling is the material's density – its specific gravity.

With the exception of aluminum, most architectural metals are very dense. They have a very high specific gravity. Metals typically have a dense crystal structure. The atoms which make up the material are aligned in a very dense pattern. You can feel that sense of density to the touch. If you tap the material, you can hear the metal resonate. This is because of its dense and hard atomic structure. This is what makes metal sound like metal.

Metal	Density (lb/in 3)	Specific Gravity
Magnesium	0.064	1.77
Aluminum	0.098	2.7
Titanium	0.161	4.51
Chromium	0.25	6.92
Zinc	0.258	7.14
Tin	0.264	7.3
Stainless Steel (Type 410)	0.278	7.7
Iron / Steel	0.284	7.87
Stainless Steel (Type 304)	0.285	7.9
Muntz Metal	0.303	8.39
Cartridge Brass	0.308	8.53
Commercial Bronze	0.318	8.8
Monel	0.319	8.83
Nickel	0.321	8.9
Nickel Silver	0.323	8.95
Copper	0.323	8.96
Silver	0.379	10.49
Lead	0.409	11.34
Gold	0.687	19.32

METAL THERMAL MOVEMENT

Thermal movement in architecture is the expansion and contraction of materials at an atomic level, based on temperature. In short, metal surfaces expand when the temperature rises. When the temperature dips, metal surfaces contract.

Thermal movement is one of several important aspects to understand when creating any architectural system. When designing a metal facade or roof, thermal movement ranks up there with joinery methods, constructibility, water shedding, and the behavior of light on the surface. These are some of the primary constraints for designing any large architectural system.

THERMAL MOVEMENT ANALYSIS OF METAL FABRICATIONS

Using this chart, you can easily determine how various metal systems will perform and what kind of tolerance your design should employ.

For instance, a length of metal, 120 inches (roughly 3 meters), when installed outdoors can experience a temperature differential of as much as 100°F (38°C). When this occurs, the metal will increase in length the amount indicated for that metal. If the metal is to be subjected to a higher temperature range, then you must allow for the additional expansion.

Metal	Coefficient of Thermal Expansion u in./in. C	Expected Expansion of a 120 inch sheet* (in)	Expected Expansion of a 3 meter sheet* (mm)
3003 Aluminum	23.2	0.11	2.79
5005 Aluminum	23.8	0.11	2.79
6063 Aluminum	23.4	0.11	2.79
Copper	16.8	0.08	2.03
Gliding Metal	18.1	0.08	2.03
Commercial Bronze	18.4	0.08	2.03
Jewelry Bronze	18.6	0.08	2.03
Red Brass	18.7	0.09	2.29
Cartridge Brass	19.9	0.09	2.29
Yellow Brass	20.3	0.09	2.29
Muntz Metal	20.8	0.09	2.29
Architectural Bronze	20.9	0.10	2.54
Phosphor Bronze	18.2	0.08	2.03
Silicon Bronze	18.0	0.08	2.03
Aluminum Bronze	16.8	0.08	2.03
Nickel Silver	16.2	0.07	1.78
Iron	11.7	0.05	1.27
Steel	11.7	0.05	1.27
Cast Iron	10.5	0.05	1.27
304 Stainless Steel	16.5	0.08	2.03
Lead	29.3	0.13	3.30
Monel	14.0	0.06	1.52
Tin	23.0	0.10	2.54
Zinc - rolled	32.5	0.15	3.81
Zinc - Cu, Tn Alloy	24.9 with grain	0.11	2.79
Zinc - Cu, Tn Alloy	19.4 across grain	0.09	2.29
Titanium	8.4	0.04	1.02
Gold	14.2	0.05	1.27

DIAMOND PATTERNS: THERMAL MOVEMENT

In standard facade designs, the diamond pattern is inherently strong. By using interlocking plates of the surrounding panels, the load is taken out at the seam. Correctly installed, diamond pattern systems have shown centuries of performance due to the inherent strength and the reduction of stress maintained by the overlapping pattern.

Dimensional changes of the panel elements caused by thermal effects are handled efficiently with the diamond pattern. The top edges of each panel are fixed, usually with clips; and the bottom edges interlock into the single-lock seam along the top edge of the row of panels below. Expansion and contraction are away and toward the clips, effectively sliding over the single lock of the panel element below.

Thermal movement is one of the big considerations in developing a metal panel system that lays flat and doesn’t buckle or oil can. Other considerations include metal thickness (and thus its tendency to bend or bow), reflectivity (highly reflective surfaces reveal more discrepancies in flatness), and wind forces.

Each of these issues can be resolved through careful planning and proper detailing. Learn more about how to develop a high-quality metal system by contacting an expert at Zahner.

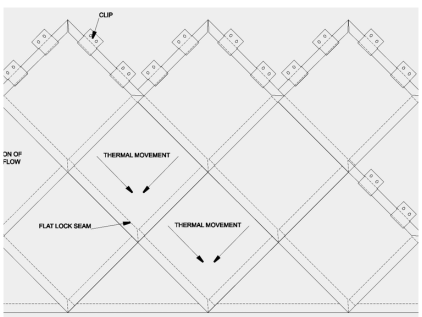
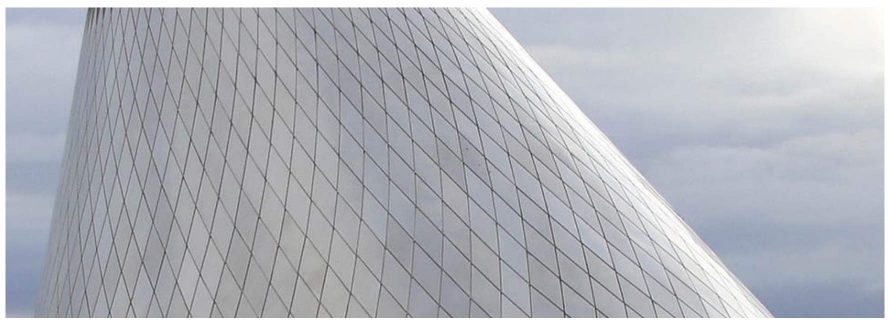


DIAGRAM OF A TYPICAL DIAMOND-PATTERN FLAT-LOCK SEAM METAL SYSTEM.



TACOMA MUSEUM OF GLASS USES A CUSTOM DIAMOND-PATTERN SYSTEM.

METAL AGING

Many of the basic construction metals physically transform over time. As natural environmental conditions interact with the metal, its surface changes in texture and color. Initially, a basic oxide layer is formed. It doesn't take too long for the oxide layer to convert to a hydroxide. Soon after, the hydroxide layer begins to combine with other elements in the atmosphere. In the end, the surface of the metal has a stable mineral composition that is very resistant to further alteration. This aging process is apparent in natural aluminum, copper and the copper alloys, lead, steel and zinc.

Zahner engineers have created a range of surfaces that enhance the weathering process to bring the metal surface to a texture and color desired by clients. For interior applications, these patinated surfaces can be locked in by using inhibitors that will essentially freeze the texture and color at a particular state of patina.

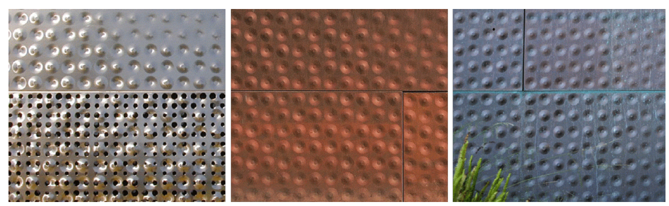
Exterior applications are more complex, because the combined heat, moisture and pollution cause the metal surfaces to continue to change. Certain measures can be taken to delay this transition, and certain patinated surfaces are more resilient than others.

Adjacent is the patination of the metal surface apparent on the de Young Museum, a project that Zahner completed in 2005. The architects originally desired a light golden-hued appearance for the museum, but this intent evolved as the conversation evolved, and the design team desired the museum to blend and emerge from its forested surroundings like an ancient indigenous structure.

Zahner helped guide this decision. A champion of the integrity, resilience, and evolution of copper, we asked the clients for a little faith in the material, explaining that over time it would transition from its bright golden red, to a dark brown, to a black, and finally, it will slowly emerge into earthy greens.

Other exterior installed metals, such as zinc and steel patinas maintain their color over time, darkening subtly or lightening in some cases based on the weather, pollution, and proximity to water.

The results are far from a static painted appearance; Zahner finishes tend to reflect the natural beauty of the metal and its surrounding elements. Paint yellows, cracks, peels, and scratches quite easily. Natural metal surfaces age in more sophisticated ways, growing and deepening in intensity.



STAINLESS STEEL VERSUS ALUMINUM

These two metals are somewhat similar in appearance, but they could not be further apart in the way that they perform over time. Stainless steel is a stunning material for its ability to maintain its appearance over decades, while aluminum performs well structurally, but as a finished surface, it is less than desirable.

Aluminum has a tendency to scratch easily, and it whitens over time. The surface of aluminum will become murky as the rain and sun beat down on it. Therefore Zahner rarely uses this material as a finished surface, instead using the material for its structural properties.

FINGERPRINTS ON METAL

Like glass, reflective metal surfaces are prone to fingerprinting. Like glass, these surfaces can be cleaned. The oils from people's hands can become impregnated in the surfaces of the metal, but with the right cleaner, many of these surfaces can be cleaned.

Typically, if a surface is going to be in a highly trafficked area, we recommend a pre-weathered surface such as pre-weathered zinc, which is a series of matte surfaces that are less prone to showing fingerprints.

In some cases, fingerprints on metal are actually desirable. For instance, certain copper materials in heavily trafficked areas will actually brighten the finish as people's hands prevent the copper from oxidizing. On metals such as the Dirty Penny patina on copper, the result of oils on the surface increases the iridescent qualities inherent in the metal surface.

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