product
expert series

TAKING A DIP

Hot-dip galvanizing experts answer questions about the zinc-rich protective coating system.

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ON THE SURFACE, hot-dip galvanizing may seem fairly simple.

It's silver (or gray). It offers protection from corrosion. And it involves dipping steel into vats of molten zinc.

But there's more to it than that, and there are plenty of questions about the appearance and performance of galvanized steel and the galvanizing process itself. Below are some of the most common ones, and their answers can provide guidance and a better understanding of what to expect when considering hot-dip galvanizing as a proactive coating option for steel.

Why is the appearance sometimes shiny silver and at other times matte gray?

Before explaining the cause of each appearance type, it should be noted that all galvanized coatings naturally progress to the matte gray look somewhere between six to 18 months after galvanizing. That matte gray look is the zinc-carbonate patina that gives galvanized steel its long-term durability.

The shiny appearance is typical of a galvanized coating with three intermetallic zinc-iron alloy layers covered by a layer of pure, shiny zinc metal. To produce this coating look, the recommended silicon composition of the steel being galvanized is either less than 0.04% or between 0.15% and 0.25%. Any steels not within these ranges are considered reactive steels and can be expected to form thicker-than-average zinc coatings. This thicker coating has a matte gray appearance instead of the typical shiny appearance. This difference in appearance is a result of the rapid zinc-iron intermetallic growth that consumes the entire pure zinc layer (the growth of the intermetallic layer is out of the galvanizer's control).

In addition to silicon, the presence of phosphorous influences the reaction between molten zinc and steel. Steel with phosphorous levels over 0.04% can produce dull coating areas and ridges of thicker coating where there is increased intermetallic growth.

Regardless of the coating appearance, the corrosion protection attribute of the galvanized coating is not affected.

Can the galvanizer do anything to deliver a shiny coating every time?

Many galvanizers do add alloys to their molten zinc to help control coating growth and deliver a shiny coating, but there is no absolute guarantee because the reaction between the molten zinc and the various elements in the steel (at unknown percentages) is slightly different each time. Additionally, very thick steel—e.g., base plates for poles—tends to produce dull gray, thick coatings because the thick steel holds residual heat after removal from the molten zinc and thus the reaction between the iron and zinc can continue until all the pure zinc layer is converted to zinc-iron alloy.

Why is it necessary to have holes in hollow structural sections (HSS) and handrails?

In order to ensure all interior and exterior surfaces are protected from corrosion, entire fabricated steel sections are immersed into cleaning solutions, flux solutions and molten zinc. The two primary reasons for vent and drain holes are to evacuate air from within the steel assembly or member, allowing it to be completely immersed in the cleaning solutions and molten zinc, and to let the excess zinc and solutions drain out of and away from the steel. If sections to be galvanized are not properly vented, cleaning

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➤ Holes are drilled in HSS to provide proper venting before the galvanizing process.

solutions or rinse waters trapped inside them can flash to steam or expand rapidly as the temperature of the piece rises. The resulting pressure increase (up to 3,600 psi/25MPa) can rupture the piece and the release of steam or gas can cause a dangerous eruption of molten zinc within the galvanizing plant.

Why do salt-spray tests show the durability of hot-dip galvanizing to be about the same as a zinc-rich paint?

Accelerated laboratory testing of the corrosion rate of galvanized steel coatings is not an accurate predictor of the actual corrosion rate in real-world applications. This is specifically referenced in ASTM B117, *Standard Practice for Operating Salt Spray (Fog) Apparatus*, which states that these tests should not be used to predict service life of zinc coatings. The constant wetting of the zinc coating in the accelerated corrosion test does not allow naturally occurring wet-dry cycles to take place, and these cycles are necessary for zinc corrosion products of zinc-oxide, zinc-hydroxide and zinc-carbonate—collectively known as the zinc patina—to form. This patina is what makes galvanized steel maintenance-free for decades.

What causes wet storage stain and white rust?

Wet storage stain is the bulky white or gray powdery dust formed by accelerated corrosion of the zinc coating when newly galvanized articles are stored or shipped under damp or poorly ventilated conditions. Wet storage stain is found most often on stacked and bundled items, such as galvanized sheets, plates, angles, bars or pipe. In the vast majority of cases, wet storage stain is light and naturally progresses to form the protective zinc patina with no effect on the corrosion protection of the galvanized coating. However, medium and heavy build-up can cause damage to the coating when left untreated and may require re-galvanizing of the steel. Weathered zinc surfaces that have already formed their normal protective layer of zinc corrosion products are not susceptible to wet storage stain.

▲ The molten zinc in a galvanizing kettle is heated to over 800 °F.

What are the specific requirements for painting or powder coating over hot-dip galvanized steel?

The specification for preparing hot-dip galvanized steel surfaces for painting is ASTM D6386; for powder coating, see ASTM D7803. Successfully painting or powder coating hot-dip galvanized steel, also known as a duplex system, does not have to be difficult or confusing. Just like painting or powder coating over bare steel, proper surface preparation is crucial to ensuring effective adhesion.

Additionally, slightly different methods may be recommended according to the condition of the galvanized surface (newly galvanized, partially weathered galvanized or fully weathered galvanized). Those methods include cleaning with solvents, alkaline solutions or ammonia, and profiling using a media softer than zinc, such as corn cob granules, or a conversion coating. One key to success is notifying the galvanizer

◀ All galvanized coatings naturally progress to a matte gray somewhere between six to 18 months after galvanizing.

that the material will be painted or powder coated after the galvanizing process and consulting with the paint or powder manufacturer to specify a paint or powder specifically formulated for use over zinc coatings. Although duplex coatings are most commonly specified for aesthetics/color, the net result is a coating that lasts from 1.5 to 2.5 times as long as the sum of the two coatings would last if used independently. This is called the synergistic effect and is an excellent reason to specify a duplex coating for projects designed to be maintenance free for several decades.

Why does hot-dip galvanized steel perform differently in industrial areas versus rural areas?

The corrosion rate of zinc is directly influenced by atmospheric conditions. Just as for bare steel, factors that specifically affect the corrosion rate of zinc include: temperature, humidity, rainfall, sulfur dioxide (pollution) concentration in the air and air salinity. None of these factors can be singled out as the main contributor to zinc corrosion, but they all play a role in determining the corrosion protection hot-dip galvanized coatings can provide against atmospheric exposure.

When galvanizing is exposed to the natural wet and dry cycles of the atmosphere, it develops a series of zinc corrosion products on the surface, called the patina. The patina is stable and non-reactive unless exposed to aggressive chlorides or sulfides. The patina is a key component in the longevity of the hot-dip galvanized coating.

Independent and industry testing of galvanized steel samples over decades in industrial, urban, rural and marine environments—with varying degrees of chlorides, sulfides and other corrosive elements—has yielded performance data for galvanized steel in real-world applications; see the Time to First Maintenance chart at the American Galvanizers Association (AGA) website, **www.galvanizeit.org**.

Can hot-dip galvanized steel be welded?

Yes, it can be welded and the suggested practice is to grind the zinc away from the weld area and proceed with normal welding practices, including wearing personal protective equipment. The ground area and the weld should be zinc coated by employing one of the three accepted methods specified in ASTM A780: zinc solder, zinc metal spray or zinc-rich paint.

Is hot-dip galvanized steel always more expensive than paint?

Because the galvanizing process efficiently handles small assemblies and parts (in other words, many can be galvanized simultaneously) it is almost always more economical on an initial cost basis to galvanize them. Medium to large pieces and assemblies are also usually less expensive initially to galvanize when compared to paint systems—at least when it comes to paint systems that provide 15 to 20 years of protection before their maintenance cycles begin. This may not appear to be true if the steel fabricator who is responsible for delivering the coated steel to the job site needs to recover significant extra costs for the galvanizing portion.

However, the true analysis of cost should be conducted on a life-cycle cost (LCC) basis—i.e., the total cost in today's dollars to maintain the corrosion protection system over the planned life of the steel. A tool that compares initial and life-cycle cost of galvanizing to 30 other corrosion protection systems is available at **www.galvanizingcost.com**.

How is G90 galvanized steel different from hot-dip galvanized steel?

Both are produced via the hot-dip process but with slightly different processing steps. Actually, G90 is a coating grade/thickness within the specification ASTM A653 and is produced by uncoiling 20-ton sheet steel coils and running it at high speed through the cleaning steps and molten zinc before it passes through an air curtain, which creates the very smooth finish to the specified thickness. (Sheet steel is also available in other thicknesses such as G60, G120, etc.). Because there is very little zinc applied, (0.45 oz./ft^2 for G90 grade), sheet steels are either used for interior applications or painted for exterior applications such as automobile body panels. The hot-dip galvanizing—to ASTM A123—of structural steel, grating, guiderail, handrail, poles, etc., is approximately four to six times thicker and intended to protect steel placed outside in harsh weather conditions.

What is the environmental impact of galvanized steel?

As zinc corrodes to its oxide, hydroxide and carbonate forms, it does make its way back into environment. However, zinc is a natural component of the earth's crust and an inherent part of our environment. Zinc is present not only in rock and soil, but also in air, water and the biosphere. Plants, animals and humans contain zinc.

Zinc is an essential micronutrient for human health. It is vital for activating growth as well as physical and neurological development in infants, children and teenagers. Zinc is found in all parts of the body, is a component in more than 300 enzymes and influences hormones. It also accelerates cell division and enhances the immune system. Zinc is vital in protecting the body from illnesses and fighting infections, and can also reduce the duration and severity of a common cold.

At present, approximately 70% of the zinc produced worldwide originates from mined ores and 30% comes from recycled zinc. The level of recycling is increasing each year, in step with progress in the technology of zinc production and zinc recycling. Today, over 80% of the zinc available for recycling is indeed recycled. MSC

For more on the hot-dip galvanizing process, see "Good Chemistry" (03/2007).