PREPARING HOT-DIP GALVANIZED STEEL SURFACES FOR PAINTING OR POWDER COATING: A PRIMER

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For years, protecting steel from corrosion typically involved *either* the use of hot-dip galvanizing *or* some type of paint system. However, more and more specialists are utilizing a combination of both methods of protection in what is commonly referred to as a "duplex system." A duplex system is simply painting or powder coating steel that has been hot-dip galvanized after fabrication.

When paint and galvanized steel are used together, the corrosion control provided is superior to either system used alone. The galvanized coating protects the base steel, supplying cathodic and barrier protection. Additionally, the galvanized coating prevents the underfilm development of iron-oxide, the outward pressure of which can cause paint to blister and peel. Paint, in turn, gives barrier protection to the galvanized coating. The paint slows down the rate at which the zinc is consumed, greatly extending the life of the galvanized steel. In return, once the paint has been weathered down or damaged, the zinc is available to provide cathodic and barrier protection so rust will not grow and paint will not peel. With this synergistic effect, it is typical for a duplex system to provide corrosion protection 1.5 to 2.5 times longer than the sum of the lifetimes of zinc and paint used individually. For example, if the galvanized coating is expected to last 40 years and the paint system is expected to last 10 years, the galvanizing and paint together should last 75 years without maintenance, or, conservatively, 1.5 times the sum of both systems.

THE AFTER-FABRICATION HOT-DIP GALVANIZING PROCESS

The galvanizing process has existed for more than 250 years and has been a mainstay of North American industry since the 1890s. Galvanizing is used throughout various markets to provide steel with protection from corrosion. A wide range of steel products – from nails to highway guardrail to the Brooklyn Bridge's suspension wires to NASA's launch pad sound suppression system – benefit from galvanizing's corrosion prevention properties. Although the process may vary slightly from plant to plant, the fundamental steps in the galvanizing process are:

Soil & grease removal - A hot alkaline solution removes dirt, oil, grease, shop oil and soluble markings. Some surface residues such as mill lacquer, welding slag, varnish, water-insoluble paints, adhesives, and sand used in the making of castings are not removed by the hot alkaline solution cleaning and require removal by mechanical cleaning such as grinding or blasting.

Pickling - Dilute solutions of either hydrochloric or sulfuric acid remove surface rust and mill scale to provide a chemically clean metallic surface.

Fluxing - Steel is immersed in liquid flux (a zinc ammonium chloride solution) to remove oxides and to prevent oxidation prior to dipping into the molten zinc bath. In the "dry" galvanizing process, the item is separately dipped in a liquid flux bath, removed, allowed to dry, and then galvanized. In the "wet" galvanizing process, the flux floats atop the molten zinc and the item passes through the flux immediately prior to galvanizing. Either method effectively promotes the

metallurgical bond between zinc and steel.

Galvanizing - The article is immersed in a bath of molten zinc at temperatures of more than 800 F / 427 C. During galvanizing, the zinc metallurgically bonds to the steel, creating a series of highly abrasion-resistant zinc-iron alloy layers, commonly topped by a layer of impact-resistant pure zinc.

Finishing - After the steel is withdrawn from the galvanizing bath, excess zinc is removed by draining, vibrating or - for small items - centrifuging. The galvanized item is then air-cooled or sometimes quenched in liquid. If the galvanized steel is to be duplex coated, it should not be quenched following galvanizing. Quench-bath surface contaminants will deposit on the newly coated steel and will interfere with paint adhesion. Quenching practices vary by galvanizing facility, so it is wise to specify no quenching in order to ensure that it is not done.

Inspection - Coating-thickness and surface-condition inspections complete the process. For purposes of inspecting galvanized steel to be duplex coated, it is important to understand that, due to the immediate solidification of the zinc upon contact with the air, a galvanized coating occasionally may have runs or drips. Additionally, dross or ash inclusions, or other types of coating imperfections, may also occur. Although these conditions do not affect corrosion prevention properties, they must be removed and the galvanized surface smoothed out prior to painting or powder coating.

COATING CHARACTERISTICS

It is important to understand that the coating characteristics of steel galvanized by the batch process, described above, and the coating characteristics of sheet products galvanized by the continuous process are not the same. Continuous galvanizing involves sheet steel that is galvanized in coils and then fabricated into products. After-fabrication (“batch”) galvanizing involves plate, bar, and structural-shaped steel that has been fabricated into parts and then galvanized. Because the two types of galvanized coatings have very different characteristics, they cannot be considered interchangeable for purposes of duplex-coating preparation.

The most important component of coating batch hot-dip galvanized steel is understanding the zinc coating’s characteristics in each stage of its weathering. Although the zinc begins reacting with the environment immediately upon removal from the galvanizing bath, the zinc coating can take up to two years to weather completely, depending on the environment.

For purposes of determining the stage of weathering, also called the “zinc patina” development (zinc oxides, zinc hydroxides & zinc carbonate), galvanized steel is divided into three categories: newly galvanized, partially weathered and fully weathered. Each stage of galvanized steel weathering must be prepared for duplex coating slightly differently because the galvanized surface has different characteristics and different surface materials.

When steel is removed from the galvanizing bath, the zinc immediately begins to react with the environment. Zinc oxide corrosion products form 24 to 48 hours after galvanizing. Zinc oxide is a powdery, lightly adhering corrosion product and is the first step in the development of the protective zinc patina. This newly galvanized steel (before the formation of zinc oxide) requires

little or no surface preparation, perhaps simply slight profiling, to encourage paint or powder-coat adhesion.

When the zinc oxide is exposed to freely moving air, the surface reacts with moisture in the atmosphere, such as dew, rainfall, or even humidity, to form a porous, gelatin-type, grayish-white mixture of zinc oxide and zinc hydroxide. This partially weathered galvanized steel forms typically between 48 hours and 2 years after galvanizing. The zinc has begun to form its protective zinc patina but has not completed the process. The zinc oxide and hydroxides are ball-shaped particles electrostatically connected to the steel surface and must be removed or neutralized using a sweep-blast and/or chemical cleaning. Removal by sweep-blasting (with a medium softer than zinc) or using an etch primer is suggested to slightly roughen the surface and improve paint adhesion. Solvents alone will not remove zinc oxides and hydroxides.

During continuation of the weathering process, the zinc oxides and hydroxides react with carbon dioxide in the atmosphere and progress into a thin, compact, tightly adherent layer of basic zinc carbonate. This progression to zinc carbonate enhances the excellent barrier protection afforded by the galvanized coating. Because the zinc patina is relatively insoluble, it prevents rapid atmospheric corrosion of the zinc on the surface of galvanized steel. This fully weathered galvanized steel is between 8 months and 2 years old and has a completely formed zinc patina. The patina has a very stable and finely etched surface, providing excellent paint adhesion. The only surface preparation needed is a warm-water power-wash to remove loose zinc oxide and zinc hydroxide particles from the surface.

PREPARING GALVANIZED SURFACES FOR PAINTING

Successfully painting or powder-coating hot-dip galvanized steel does not have to be difficult or confusing. Just like painting or powder coating over anything else, proper surface preparation is crucial to ensuring effective adhesion. The two keys to proper surface preparation are:

- cleaning (to remove surface contaminants and zinc corrosion products), and
- profiling (to allow good mechanical bonding).

If these two things are done correctly, a compatible paint or powder-coat system will readily adhere to the galvanized steel.

Cleaning

When cleaning a galvanized surface prior to painting, the goal is to remove any dirt, grease, or oil, with the objective of producing "water-break" cleanliness, i.e. water should not form droplets on the surface but rather maintain a uniformly wet surface. At the same time, care must be taken not to remove too much of the galvanized coating. Highly acidic or basic cleaning solutions remove some of the zinc coating. Alkaline cleaning, ammonia cleaning, and solvent cleaning are the most common ways of removing dirt from a galvanized surface. As some cleaners may react differently with different paint systems, the paint manufacturer should be consulted for specific details about paint/cleaner interactions.

Methods of Cleaning

Alkaline Solution Cleaning

Oil, grease and dirt can be removed by using an alkaline solution in the pH range of 11 to 12, but not greater than 13. The solution can be applied through dipping, spraying or brushing. If brushing, a soft-bristled nylon brush is recommended. If dipping or spraying, the solution temperature should be between 140 to 185 F / 60 to 85 C.

For newly galvanized surfaces, a water-based emulsifier can be used to remove contaminants.

After cleaning, thoroughly rinse the surface with clean, hot water and allow complete drying before profiling or painting.

Ammonia Cleaning

A solution of 1 % to 2 % ammonia applied with a soft-bristled nylon brush also can be used, although this method typically is reserved for cleaning parts with ash residue sometimes left behind after the galvanizing process. After cleaning, thoroughly rinse the surface with clean, hot water and allow complete drying before profiling or painting.

Solvent Cleaning

Mineral spirits, turpentine, high-flash naphtha and other typical cleaning solvents can be used, provided they are applied with lint-free rags or soft-bristled nylon brushes that are frequently changed to avoid re-spreading contaminants. (Solvents used for cleaning contain volatile organic compounds and may affect total paint facility emissions. New non-VOC solvents are available that might achieve equivalent cleanliness.) Because mineral spirits and other solvents may leave behind an oily deposit, surfaces should be thoroughly rinsed with clean, hot water and allowed to dry before profiling or painting.

Because some solvents may react differently with different paint systems, consult the paint manufacturer for specific details about solvent/paint interactions.

Sealers

Penetrating sealers are typically a two-part epoxy that forms a coating approximately two mils (50 microns) thick. They have been used as a surface treatment method on more difficult-to-clean surfaces such as partially weathered galvanized steel. Follow manufacturer directions for application; always use a topcoat over the sealer.

Profiling

In order to provide a good adhesion profile for the paint, the galvanized surface must be free of protrusions and slightly roughened to provide an anchor profile. Hand- or power-tools can be used to remove any high spots. Sweep-blasting, phosphating, and using vinyl butyral acid etch wash primers or acrylic passivations are the most common methods of increasing the profile of a galvanized surface. Again, care should be taken to remove as little zinc as possible.

Methods of Profiling

Abrasive Sweep- or Brush-blast

In order to roughen the typically smooth galvanized surface, an abrasive sweep- or brush-blast may be used. Blast material particle size for profiling galvanized steel should range between 8 to 20 mils (200 to 500 microns). Aluminum/magnesium silicate has been used successfully to sweep-blast profile galvanized steel. Organic media such as dried corn cobs, dried walnut shells, corundum, limestone and mineral sands with a Moh's hardness of five or less may also be used. The blast profile on the galvanized surface should be less than 2.0 mils / 51 microns.

The temperature of the galvanized part when blasting can significantly affect the finished surface profile. Sweep-blasting while the galvanized part is still warm (175 to 390 F / 79 to 199 C) provides an excellent profile. Recommended ambient conditions for sweep-blasting are less than 50% relative humidity and a minimum temperature of 70 F / 21 C.

Conversion Coatings

Phosphating is a conversion coating that can increase the adherence and durability of the paint film. The iron or zinc (slightly more effective) phosphate treatment can be applied by immersion, spray or a soft-bristled nylon brush. The phosphate should only be left on the galvanized steel between three to six minutes. The piece should then be rinsed with clean water and allowed to completely dry before painting or powder coating. Product manufacturers should be consulted regarding the specific application time and temperature requirements for their products.

Acrylic Passivations

Acrylic passivations (an acidic acrylic solution) also can be used to passivate the galvanized surface and promote paint adhesion. Acrylic passivation takes place by immersion, and should be applied approximately 0.04 mils / 1 micron thick to a clean galvanized surface. The coating should be completely dry before painting or powder coating. Acrylic passivations are suitable substitutes for vinyl butyral acid etch wash primers.

During cleaning and/or profiling, care must be taken not to remove too much of the zinc coating. Naturally, the more zinc removed, the less corrosion prevention provided.

Paint Formulations

Many types of paint and paint systems have been used quite successfully with galvanized steel. With the exception of some alkyd formulations, a variety of paint formulations have been effectively used for painting galvanized steel. Household alkyd enamels should not be used directly onto galvanized surfaces as the alkyd saponifies, i.e. reacts with the zinc surface to form soaps which cause loss of adhesion of the paint layer. Some types of paint will not adhere adequately to galvanized steel or will only do so under restricted conditions. In order to ensure a successful duplex system, it is important to find a suitable paint system with a first coat that is fully compatible with a zinc surface. The first coat serves as a "tie coat" or interface between the galvanized steel and the topcoat. To achieve a good interface, it is important to understand the characteristics of all the types of paint that will be used. Each individual formulation of paint exhibits unique characteristics that can affect its suitability for use with galvanized steel. Because of this, only individual paint manufacturers can provide specific guidance on the use of their

products. Contact paint manufacturers for specific information regarding the suitability of paint systems for use on galvanized steel.

The following list of combinations provides guidance into which combinations of paint systems can be used, but does not include all combinations available for use:

Wash primer	+	Acrylic latex
Wash primer	+	Acrylic solvent-based topcoat
Wash primer	+	Epoxy topcoat
Epoxy primer	+	Acrylic latex topcoat
Epoxy primer	+	Acrylic solvent-based topcoat
Epoxy primer	+	Epoxy topcoat
Epoxy primer	+	Polyurethane topcoat
Inorganic zinc-rich primer	+	Epoxy topcoat
Inorganic zinc-rich primer	+	Epoxy intermediate coat & polyurethane topcoat
Waterborne acrylic primer	+	Waterborne acrylic topcoat

A duplex coating, either painting or powder coating galvanized steel, is a highly effective, readily applied method of greatly enhancing the service-life of virtually any project. For additional information on preparing after-fabrication hot-dip galvanized steel surfaces for duplex coatings, consult ASTM D 6386, *Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting.*

Kimberlie Dunham, M.S., is the Marketing Manager for the American Galvanizers Association. She travels extensively presenting educational seminars on the hot-dip galvanizing process and its applications, and answers technical questions from architects, engineers, and users of galvanized steel regarding specifying hot-dip galvanizing, the performance of galvanized steel, and the various in-use applications of galvanized steel. She may be reached by e-mail: kdunham@galvanizeit.org.

Additional resources

Duplex Systems: Painting Over Hot-Dip Galvanized Steel, 1998, American Galvanizers Association

Suggested Specification for Painting Over Hot-Dip Galvanized Steel, 2002, American Galvanizers Association

Standard practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting, 1999, American Society for Testing and Materials

For information on the synergistic effect of duplex coatings

Van Eijnsbergen, J.F.H. *Duplex Systems: Hot-dip Galvanizing plus Painting*, 1994 Elsevier

For more information on acrylic passivation agent products

http://www.procoattecnologias.com/

http://ww.betzdearborn.com