

Duplex Systems

*Painting
Over
Hot-Dip
Galvanized
Steel*



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DUPLEX SYSTEMS: Painting Over Hot-Dip Galvanized Steel

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INTRODUCTION

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 corrosion specialists are utilizing both methods of corrosion 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 hot-dip galvanizing are used together, the corrosion protection is superior to either protection system used alone.

Painting galvanized steel requires careful preparation and a good understanding of both painting and galvanizing. Many products have been galvanized and painted successfully for decades; two examples are automobiles and utility towers. Past experience provides excellent historical data for how best to achieve good paint adhesion. Studying past adhesion failures and successes led galvanizers, paint companies, researchers, paint contractors, and other sources to create ASTM specification D 6386, *Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting*. When the galvanized surface is prepared correctly, paint adhesion is excellent and the duplex system becomes a highly successful method of corrosion protection.

HOW A DUPLEX SYSTEM WORKS

Before deciding how to protect steel from corrosion, it is important to understand how steel corrodes. Accelerated corrosion takes place because of differences in electrical potential between small areas on the steel surface that become anodic and cathodic. When an electrolyte connects the anodes to the



cathodes, a corrosion cell is created. Moisture in the air forming condensation on the steel surface is the most common electrolyte. In the electrolyte, a small electrical current begins to flow. The iron ions produced at the anode combine with the environment to form the loose, flaky iron oxide known as rust.

In order to protect steel from corrosion, something must interfere with the corrosion cell, either by blocking the electrolyte or by becoming the anode. Two common methods of corrosion protection are cathodic protection (the formation of another anode) and barrier protection (blocking the electrolyte from the steel surface). Hot-dip galvanizing alone affords both types of protection.

Cathodic Protection

Cathodic protection, also referred to as sacrificial protection, is based on the knowledge that anodic metals have a greater tendency to lose electrons than more noble metals. Metals are ranked in order of their susceptibility to corrosion, with the less noble, anodic metals being listed higher in the galvanic series than the more noble, cathodic metals (see Figure 1, next page). For example,

ARRANGEMENT OF METALS IN THE GALVANIC SERIES

Corrosive End

Anodic, or "less noble"

Magnesium
 Zinc
 Aluminum
 Cadmium
 Iron/Steel
 Stainless Steels (active)
 Soft Solders
 Lead
 Tin
 Nickel
 Brass
 Bronzes
 Copper
 Nickel-Copper Alloys
 Stainless Steels (passive)
 Silver Solder
 Silver
 Gold
 Platinum

Protective End

Cathodic, or "more noble"

Figure 1

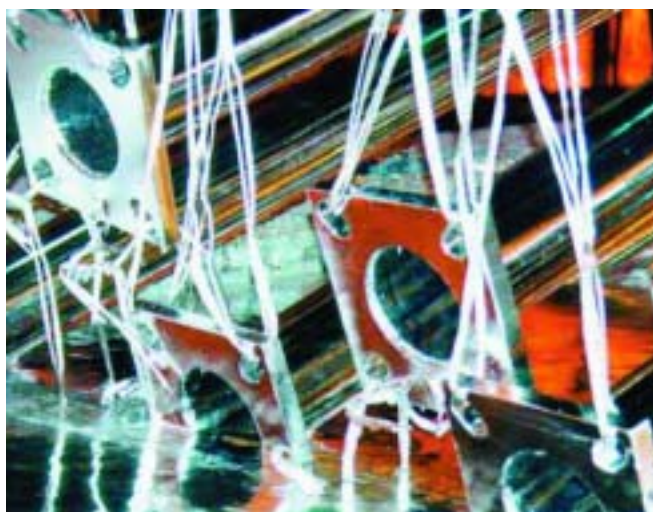
zinc is more anodic than iron. When zinc and steel are connected in the presence of an electrolyte, the zinc becomes the anode in the corrosion cell and is slowly consumed, while the steel acts as the cathode and is protected. By providing cathodic protection, a galvanized coating is able to offer protection where small areas of steel are exposed, such as at scratches, drill holes, or cut edges. The zinc provides cathodic protection through decades of exposure, until all the zinc is sacrificed.



When barrier protection is used alone, rust begins forming as soon as the barrier is breached. This painted handrail at Coors Field in Denver, CO., began rusting just a few short years after its installation.

Barrier Protection

Barrier protection prevents corrosion simply by isolating the steel from the environment and potential electrolytes. The thicker, more dense a barrier coating is, the better the protection that is provided. Without cathodic protection, a barrier system only lasts as long as the coating stays intact and impenetrable. An incomplete or compromised barrier coating allows steel to rust in the exposed area. The rust will undercut the barrier coating near the exposed area and eventually cause failure of the barrier protection.



As this tubing is removed from the galvanizing bath, the integrity of the coating is readily apparent. Galvanizing has the added benefit of providing corrosion protection on both the inside and outside of the product.



When steel is painted, as with these beams, the paint provides barrier protection to the base steel. The integrity of a duplex system relies on the proper application of a uniform paint coating to properly-prepared hot-dip galvanized steel.

COATING CHARACTERISTICS

The corrosion protection characteristics of hot-dip galvanizing and paint largely affect how the two coatings will perform as a duplex system. Understanding the nature of both coatings helps ensure the success of a duplex system.

Hot-Dip Galvanizing After Fabrication

The two major types of hot-dip galvanizing are after-fabrication and continuous sheet. Continuous sheet galvanizing involves sheet steel that is galvanized in coils and then fabricated into products. After-fabrication galvanizing involves steel that has been fabricated into parts and then galvanized.

These two types of galvanizing have very different characteristics and should not be considered interchangeable. All the information in this publication pertains to materials that are hot-dip galvanized after-fabrication, according to ASTM A 123, *Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*, and A 153, *Zinc Coating (Hot-Dip) on Iron and Steel Hardware*.

After-fabrication hot-dip galvanizing is the factory-controlled process of dipping properly cleaned steel into a bath of molten zinc. Prior to immersion in the zinc, the steel is thoroughly cleaned in both alkaline and acid baths. Zinc will not adhere to unclean steel, so the integrity of the coating is immediately apparent as the steel is removed from the galvanizing bath.

The galvanized coating is metallurgically bonded to the steel through a series of zinc-iron alloy layers capped by a free zinc layer. A galvanized coating is more than just a barrier coating; it actually becomes part of the steel surface and is anodic to the steel substrate.

Because zinc readily reacts with the atmosphere, the galvanized coating is constantly changing. Zinc reacts with the environment to form zinc oxide, zinc hydroxide, and zinc carbonate. These zinc reaction products are known as the zinc patina. The zinc patina actually helps protect the galvanized coating, thus providing additional corrosion protection. These changes and reactions on the surface of the coating affect how paint will adhere to the galvanized surface.

Paint

Painting steel provides a barrier film between the steel and the environment. A paint system involves the use of several layers of coating and, sometimes, different kinds of paint, depending on the type of environment in which the structure will be exposed.

The most important factors for the success of paint systems are adhesion and continuity. If paint does not adhere to the steel, it cannot protect it from the corrosive effects of the environment. Surface preparation is extremely important because the degree of paint adhesion may not be apparent immediately after application. Only after a few months in the field, poor surface preparation may manifest itself in paint failure. Having a clean, properly prepared



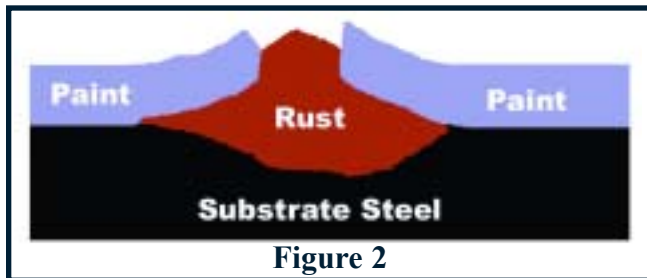
This painted trolley bus frame exhibits extensive corrosion on its entire framework.

surface helps ensure that the full potential of the paint system is realized. This is especially true about duplex systems.

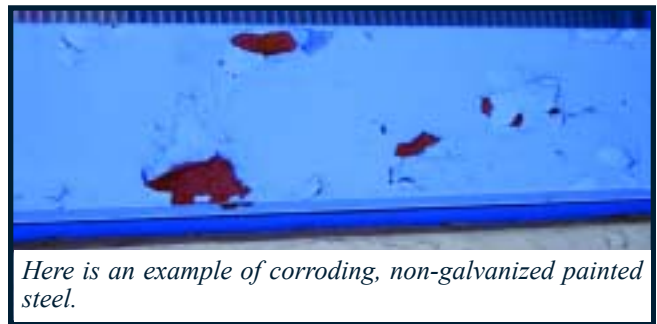
Continuity of the paint systems is extremely important for carbon steel, since pinholes and other imperfections quickly become rust pits. However, continuity is not as important in a duplex system because the zinc coating will not allow the steel to rust at these sites.

Synergistic Effect

When hot-dip galvanized steel is painted, the duplex system provides a more sophisticated manner of corrosion protection, known as the synergistic effect. The galvanized coating protects the base steel, supplying cathodic and barrier protection. Paint, in turn, grants 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 still available to provide cathodic and barrier protection. When ungalvanized, painted steel corrodes, voluminous rust grows under the paint and eventually causes the paint to peel (see Figure 2, below). However, if the steel is galvanized, the zinc corrosion is minimal and the paint will not peel, thereby greatly increasing the life of the structure and minimizing paint peeling.

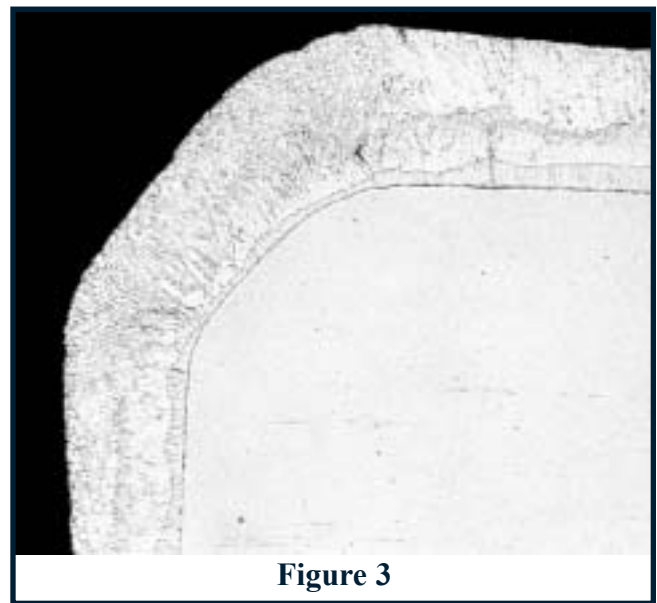


One of the most frequent reasons for paint failure is discontinuity (pinholes) in the paint



coating. A galvanized coating will eliminate early rusting at pinholes, and, thus, the life of the steel product is greatly increased.

The synergistic effect is particularly important at areas such as corners, where paint film tends to be thinner. By contrast, galvanized coatings are often thicker at corners and edges due to the diffusion reaction between zinc and the base steel (see Figure 3, below).



A duplex system affords greater corrosion protection than paint or hot-dip galvanizing can provide alone. In fact, many tests have shown that a duplex system lasts from 1.5 to 2.5 times the normal combined lifetime of both zinc and the paint systems. A periodic maintenance painting schedule can extend this synergistic lifetime even longer.

WHY USE A DUPLEX SYSTEM

Each individual project raises unique reasons as to why a duplex system should be utilized, and the advantages for choosing to do so are many:

Extended Corrosion Resistance

The most obvious and most important reason for using a duplex system is the added corrosion protection it provides. No single corrosion protection system can match the corrosion resistance afforded for most applications by painting over hot-dip galvanized steel.

Synergistic Effect

It's typical for a duplex system to provide corrosion protection 1.5 to 2.5 times longer than the sum of the lifetime of zinc or paint used individually. For example, if a galvanized coating is expected to last 40 years and a paint system is expected to last ten years, galvanizing and paint combined should last at least 75 years without maintenance, or 1.5 times the sum of both systems.

Economic Benefit

Because duplex systems greatly extend the service life of a product, maintenance costs are significantly decreased. Additionally, a product lasts longer before it must be replaced, thus decreasing the life-cycle cost. The cost of a product that has been protected by galvanizing and painting is lower over the entire life of the product than most single system methods of corrosion protection.

Ease of Repainting

As the paint film weathers, the zinc in the galvanized coating is present to provide both cathodic and barrier protection until the structure is repainted. The exposed zinc

surface then can be repainted with minimal surface preparation.

Aesthetics

Galvanizing has an attractive metallic-gray appearance suitable for myriad applications, and painting also offers aesthetic advantages. One might choose to paint over a galvanized coating so that a project matches its specific environment—such as a stadium, theme park, or natural habitat.

Safety Marking

The use of duplex systems allows galvanized steel to be painted in order to conform to safety color regulations. One example of this is the regulation of the Federal Aviation Administration that requires structures over 200 feet tall to be painted in the alternating pattern of white and international orange.



Color Coding

Painting over galvanized steel also increases safety in many environments by color-coding gas, steam, or chemical pipes, identifying hazardous work areas and walkways, and marking high-voltage electrical lines and equipment.

Extend Life of Previously-Galvanized Steel

Paint is a logical choice to extend the life of galvanized structures once the zinc coating has substantially and naturally weathered away. Instead of being completely replaced, the galvanized structure can easily be painted, extending its useful life. Organic zinc-rich paints are specifically suited to this application.

Repair of Hot-Dip Galvanized Steel

Zinc-rich paints can also be used to touch-up and repair damaged areas on a galvanized coating in order to comply with ASTM A 780, *Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*. Repairing a galvanized coating will significantly extend the useful life of a product.

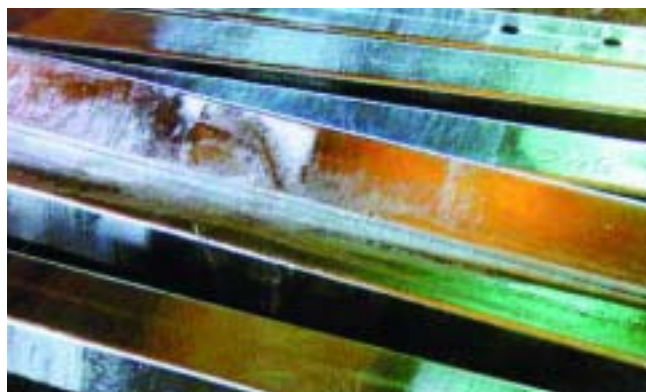
HOW TO PREPARE HOT-DIP GALVANIZED STEEL FOR PAINTING

Surface Characteristics of Galvanized Steel

Depending on steel chemistry, galvanizing bath chemistry, and the age of a galvanized coating, each galvanized steel piece may be very different from the next.

Most people associate galvanized coatings with the bright, shiny spangle pattern frequently found on zinc-coated products. While this is a common appearance for newly galvanized products, not all galvanized steel will look this way. The spangle pattern forms when the free zinc layer crystallizes as it cools after removal from the galvanizing bath. The rate of speed at which the piece is removed from the kettle, the thickness of the coating, the steel chemistry, as well as different bath additives affect how the free zinc layer crystallizes. Galvanized coatings can also appear dull gray with a slightly blotchy appearance. Variations in coating appearance do not affect the corrosion resistance of the product.

A galvanized coating may occasionally have runs, drips, dross, or ash inclusions or other types of coating imperfections. Although these do not affect corrosion protection, they must be removed and the galvanized surface smoothed prior to painting.



Newly galvanized steel (above) typically exhibits a bright, shiny appearance. Weathered galvanized steel (below) usually possesses a dull, mottled gray appearance. Different ages of galvanized steel require different surface cleaning and profiling prior to painting.



If a galvanizer knows that the steel will be coated after galvanizing, extra care can be taken to help ensure a uniform coating is achieved and that the steel is not quenched—a common final step in the galvanizing process that helps accelerate the cooling process to halt further reaction between the iron and zinc, but may also introduce contaminants onto the coating.

As a galvanized coating begins to age, its appearance changes. Gradually, the zinc reacts with the atmosphere to form the patina of zinc oxide, zinc hydroxide, and zinc carbonate. As the patina forms, the coating slowly begins to take on a matte gray finish.

Zinc patina has different characteristics at each stage of its formation. Although the zinc begins reacting with the environment immediately upon removal from the galvanizing bath, the zinc patina can take up to

two years to completely form, depending on the environment.

Different surface characteristics of the zinc-coated parts need to be treated separately when preparing hot-dip galvanized steel for painting. After galvanizing, the top layer of zinc combines with oxygen and moisture to form particulates of zinc oxide and zinc hydroxide. These particulates are loosely attached to the zinc metal and can be dissolved in water. If paint is applied to the galvanized coating when these particles are on the surface, the paint may experience adhesion problems after some time as the particles detach from the zinc surface.

When the full zinc patina has formed—after about one to two years of exposure to the atmosphere—the surface becomes a thin, solid film. This film is a mixture of zinc oxide, zinc hydroxide, and zinc carbonate, which cannot be dissolved in water and adheres very tightly to the zinc metal. Paint can be applied directly onto this clean surface and exhibit excellent adhesion.

Most people paint galvanized steel during the most difficult time period to do so—between 48 hours and one year after galvanizing. During this timeframe, zinc is very reactive with the atmosphere and proper surface preparation is critical. Successful surface preparation—including the removal of loose zinc oxide or zinc hydroxide particles—will prevent adhesion problems from occurring.

Post-Treatments for Galvanized Steel

After a piece of steel has been galvanized, it is sometimes quenched or treated by the galvanizer in order to halt the reaction between the iron and zinc (and to facilitate immediate shipment of the galvanized steel). The most common post-treatments are water-quenching, chromate-quenching, and phosphating. Water-

and chromate-quenching can adversely affect the bond between the galvanized steel and the paint; communicating with the galvanizer prior to galvanizing helps avoid post-treatments that can be detrimental to paint adhesion.



Use of post-treatments, such as water-quenching, can undermine the success of a duplex system by causing adhesion failure, as illustrated by the peeling paint on this pole.

Water-Quenching

Sometimes freshly galvanized steel is dipped into a water bath to help accelerate the cooling process. Often, the water is contaminated with floating oil or dirt. *If the steel is going to be painted immediately, water-quenching is not recommended. It may leave material on the surface that can cause paint adhesion problems or require additional surface preparation prior to painting.*

Chromate-Quenching

Galvanizers may also chromate-quench newly galvanized steel in an effort to prevent the excessive buildup of zinc corrosion products due to high levels of humidity and poor storage and/or bundling techniques.

Since chromate interferes with paint adhesion, it is not advised to chromate- quench a piece of galvanized steel that is scheduled to be painted.

Phosphating

Phosphating is a conversion coating that reacts with the galvanized coating to form a non-reactive zinc phosphate layer. Phosphating can be used to help promote good adhesion between galvanized steel and paint. It provides a good mechanical bond for the paint due to the etching and fine capillary nature of the crystal it creates. Continuous galvanized steel is often phosphated prior to painting for applications such as automobile parts. *However, if zinc-rich paint is to be used, phosphating should be avoided as it reduces the electrical conductivity of paint.*

Aging Characteristics of Galvanized Coatings

Galvanized steel can be divided into three age categories: newly-galvanized, partially-weathered, and fully-weathered. Since the galvanized surface in each of these weathering

stages possesses different characteristics and must be prepared for painting slightly differently in each case, it is important to know the age of the galvanized steel to be painted. ASTM D 6386 further clarifies how each type of steel should be prepared. The following descriptions also offer some assistance in determining the age category of galvanized steel:

Newly-Galvanized Steel

Newly-galvanized steel is zinc-coated steel that has been hot-dip galvanized, after fabrication, within the past 48 hours. Newly-galvanized steel should not be water- or chromate-quenched, nor should it be oiled. This type of galvanized surface is typically very smooth and the surface may need to be slightly roughened, using one of the profiling methods described on pages 12 and 13. A newly-galvanized surface has little or no zinc oxides or zinc hydroxides, so no major cleaning is necessary.

Partially-Weathered Galvanized Steel

Partially-weathered galvanized steel has begun to form the protective zinc patina, but has not completed the process. Before painting partially-weathered galvanized steel, it's important to know if the coating was chromate-quenched. The presence of chromate conversion coatings can be determined by spot-testing the galvanized steel according to ASTM B 201, *Testing Chromate Coatings on Zinc and Cadmium Surfaces*. If a chromate coating is detected, the chromate layer must be removed either by abrasive blast cleaning, abrading the steel by sanding, or allowing the steel to fully weather.

Partially-weathered galvanized steel should also be inspected for excessive build-up of corrosion products during storage or transportation. Since these corrosion products



Architects built this suburban Ohio office building to resemble the baskets manufactured by its owner. Painting the galvanized structural steel completes the realistic effect and provides superior corrosion resistance.

are hygroscopic and have a larger volume than the zinc metal, paint adhesion can be seriously affected when corrosion products are top-coated with paint. Excessive build-up of corrosion products is evident by the appearance of a chalky, white film. If the galvanized surface to be painted exhibits this whitish film, carefully remove the film by brushing it with a mild ammonia solution, such as diluted household ammonia. Severe cases of corrosion product build-up stain should be brushed with a mild acidic solution, such as one part acetic acid mixed with 25 parts water. Follow these cleaning procedures with a clean, warm water rinse.

Partially weathered galvanized steel also should be slightly roughened to improve paint adhesion. Any of the surface profiling methods explained on pages 12 and 13 can be used to prepare the surface.

Fully-Weathered Galvanized Steel

Fully-weathered galvanized steel has a completely formed zinc patina. The patina has a very stable and finely etched surface that provides for excellent paint adhesion. The only surface preparation needed is a warm water power wash to remove loose surface particles; the power wash should not exceed 1450 psi. Allow the surface to dry completely before painting.

SURFACE PREPARATION

Surface preparation is a critical factor in achieving good paint adhesion. Proper cleaning and profiling are essential to effective surface preparation. If these are done correctly, there should be no problems with a compatible paint system adhering to the galvanized surface.

Cleaning

When cleaning a galvanized surface prior to painting, the goal is to remove any dirt, grease, or oils. 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, as does high-pressure sweep blasting. The more zinc that is removed from the surface, the less corrosion protection provided. 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 cleaning instructions).

Alkaline Cleaning

Oil, grease, and dirt can be removed by using an alkaline solution in the pH range of 11-12, but not greater than 13. An alkaline solution is nominally two to five percent sodium compounds with small additions of emulsifying or chelating agents. The solution can be applied by dipping, spraying, or brushing. When brushing, use a soft nylon-



In an aggressive environment such as this commuter rail maintenance facility for the Boston Mass Transit Authority, a duplex system provides superior corrosion protection. All of the exposed steel from the beams to the handrail were hot-dip galvanized and then painted. Proper surface cleaning and profiling ensure the success of this duplex system.

bristle brush; do not use brushes made with copper, steel, or other highly abrasive and/or metal bristles. If dipping or spraying the alkaline solution, the temperature should range between 140 and 185 degrees F. For newly galvanized surfaces, a water-based emulsifier can be used to remove contaminants. After cleaning, thoroughly rinse the surface with hot water and allow to dry completely.

Solvent Cleaning

Mineral spirits, turpentine, high-flash naphtha, and other typical cleaning solvents can be used to clean galvanized surfaces, provided they are applied with lint-free cloths or soft, nylon-bristle brushes that are frequently changed in order to avoid the re-spreading of contaminants. After cleaning, thoroughly rinse the surface with hot water and allow to dry completely.

Ammonia Cleaning

A solution of one to two percent ammonia applied with a soft nylon bristle brush can also be used to clean galvanized surfaces, although this method is typically reserved for cleaning parts with skimmings residue. As a piece of steel is removed from the galvanizing kettle, it may pick up particles of oxidized zinc from the bath surface (otherwise known as skimmings) that must be removed prior to painting. After cleaning, thoroughly rinse the surface with hot water and allow to dry completely.

Profiling

In order to provide a good adhesion profile for paint, the galvanized surface must be flat with no protrusions and slightly roughened to provide an anchor profile for the paint system. Filing high spots, sweep blasting, phosphating, and using wash primers or acrylic passivations are the most common methods of increasing the profile of a galvanized surface. Again,

care must be taken not to damage the galvanized coating.

High Spots

Any high spots or rough edges should be removed and smoothed out in order to provide a level surface for paint. Use hand or power tools to grind down the high spots. Care should be taken to remove as little zinc as possible.



A worker files off a high spot on a piece of handrail. Proper surface preparation is essential for good paint adhesion.

Sweep Blasting

In order to roughen the typically smooth galvanized surface after cleaning, an abrasive sweep or brush blast may be used. Care should be taken to prevent removing too much of the zinc coating. Particle size for a sweep blast of galvanized steel should range between 8 and 20 mils.

Aluminum/magnesium silicate has been used successfully in the sweep blasting of galvanized steel. Organic media, such as ground corncobs, walnut shells, corundum, limestone, and mineral sands with a Mohs hardness of five or less, may also be used. The temperature of the galvanized part when blasting can have a significant effect on the

finished surface profile. Sweep blasting while the galvanized part is still warm—175 to 390 degrees F—provides an excellent profile. Ambient conditions for sweep blasting are recommended to be less than 50 percent relative humidity and a minimum room temperature of 70 degrees F.



Thorough removal of surface contaminants greatly improves adhesion of the paint to the galvanized surface and is integral to the success of a duplex system.

Penetrating Sealers

These products are known as a two-part epoxy penetrating sealer that forms a coating approximately two mils thick. They have been used as a surface treatment method on difficult-to-clean surfaces such as partially-weathered galvanized steel. Follow the manufacturer's directions for application and always use a topcoat over the sealer.

Zinc Phosphate Treatment

As discussed on page 10, phosphating is a conversion coating that can increase the adherence and durability of the paint film. The phosphate treatment can be applied by immersion, spray, or soft nylon bristle brush. The phosphate should only be left on the galvanized steel between three and six minutes. The piece should then be washed with clean water and allowed to dry completely. Begin painting when the surface is dry. Do not use phosphate treatments in

conjunction with zinc-rich paints.

Wash Primers

This treatment uses a metal conditioner to neutralize surface oxides and hydroxides as well as to etch the galvanized surface. Wash primers should be applied to the galvanized surface at a thickness between 0.3 and 0.5 mils. Thickness above 0.5 mils can cause adhesion problems. As a result, this profiling method is best applied in shop conditions, not in the field. When using wash primers, follow the manufacturer's directions for maximum performance.

Acrylic Passivations

This treatment uses an acidic acrylic solution to passivate the galvanized surface, as well as promote paint adhesion. Acrylic passivation products should be applied approximately 0.04 mils thick to a clean, galvanized surface. The coating should be completely dry before painting.

PAINTING OVER TOUCHED-UP AND REPAIRED GALVANIZED STEEL

Occasionally, galvanized steel is damaged during handling, installation, or welding. These damaged areas should be repaired according to ASTM A 780. Proper repair ensures the galvanized coating provides the best corrosion resistance possible. When using a duplex system, any damaged area on the galvanized surface must be repaired prior to painting. The following steps help ensure that the galvanized steel is adequately repaired and able to perform compatibly with a paint system:

1. Depending on the age of the galvanized product, properly prepare and clean the surface of the material to be painted before applying the touch-up product.
2. Touch-up damaged areas with a product conforming to ASTM A 780. These include paint products commonly known as zinc-rich paints that can be sprayed or brushed onto the damaged area.
3. After touch-up, prime the surface of the area to be painted. As a protective system, zinc-rich paints provide the best galvanic protection for long-term exposure of the duplex system.
4. Finish with a topcoat to complete the duplex system. Follow the manufacturer's guidelines for proper dry times and surface preparation between coats.



PAINT SELECTIONS

Beyond the need for surface preparation, the paint itself must be compatible with the galvanized coating in order to create a successful duplex system. Many types of paint and paint systems have been successfully used with galvanized steel. However, 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's 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.

Zinc-Rich Paint

Zinc-rich paint has long been recognized for its excellent adherence to both new and weathered galvanized surfaces—it has been used in the U.S. for more than 75 years and in Europe for well over a century. In a 1960s study by the American Iron and Steel Institute and the Steel Structures Painting Council, zinc-rich paint outperformed all other classes of paint. Significantly, at a nine-year inspection in 1970, there was no loss of adhesion of the paint to the galvanized zinc surface.

Zinc-rich paint possesses similar characteristics to a hot-dip galvanized zinc coating. With a high percentage of zinc in the dry film, this paint can synergistically combine with the corrosion-inhibitive properties of metallic zinc. The zinc dust in the paint is integrated with organic binders. Using zinc-rich paint is an accepted method of repairing damaged galvanized coatings according to

ASTM A 780. Zinc-rich paint containing at least 65 percent zinc meets the specification designations. Widely used for touch-up and repair of damaged galvanized coatings because of its relative ease of application, zinc-rich paint is useful as a primer to gain surface adherence and is also satisfactory as a finish coat when a neutral or matching gray color is desired.

Zinc-rich paint can be used alone but, for a more attractive finish, a topcoat is often employed. While most topcoats are easily used, some with very strong solvents may result in a lifting of the primer. Successful topcoats include polyvinyl, acrylic latex, polyurethane, and polyamide-cured epoxy. Specific manufacturer's recommendations should be followed for application and top-coating.

Acrylic

Acrylic is a single-component coating, generally applied over a primer due to thin film build. A wash primer may be used with acrylic paint, or it may be applied directly over the hot-dip galvanized surface. If the pH of the paint is high, problems may occur due to ammonia reacting with the zinc. Acrylic provides exceptional gloss and color, combined with an extremely durable finish.

Aliphatic Polyurethane

This is a two-component, high-performance system generally applied over a polyamide epoxy primer or a wash primer. Polyurethane has superior weathering and chemical resistance characteristics with good adhesion, as well as an enamel-like finish. This system requires strict attention to application procedures. If top-coating is necessary, a light abrading or roughening of the surface is generally required.

Alkyd

In moist areas, zinc will produce an alkaline surface causing alkyds to saponify, resulting in premature peeling and flaking of the paint system, despite initial satisfactory adhesion. Due to this chemical incompatibility with zinc, alkyd paint is very difficult to use on galvanized surfaces unless it is specifically formulated for using over galvanized steel. Contact the paint manufacturer for more specific recommendations on using an alkyd paint system.

Asphalt

Asphalt paint is generally a petroleum-based product that is not recommended for use on galvanized steel.

Bituminous

This type of paint is thicker than conventional paint systems. As it is a coal tar product, unlike asphalt, it can be used successfully with galvanized steel. Bituminous paint is often used over galvanized steel that will be buried.

Chlorinated Rubber

Although difficult to apply, chlorinated rubber is fast drying and provides good protection for exterior exposures and chemical resistance to acids, alkalis, and moist gases. However, it chalks readily and needs a high surface profile for good adherence. In addition, its high VOC content has severely limited its availability and end-use.

Coal Tar Epoxy

This type of epoxy is rarely used over galvanized steel. While it provides outstanding resistance to acidic conditions in splash and spill areas, it is difficult to apply and requires brush blasting or a wash primer to adhere to galvanized steel. Coal tar epoxy

is used over galvanized steel that will be buried.

Epoxy

In most cases, epoxy-esters and epoxy-amines are not generally recommended for use directly on galvanized steel as they are typically high-stress materials and may react with the zinc in certain environments. However, epoxies do have some limited success if the paint is specifically formulated for use over galvanized steel. Contact the paint manufacturer for more specific recommendations on using an epoxy paint system.

Epoxy-Polyamide Cured

This epoxy generally has superior adherence to any type of galvanized surface. Because it isn't resistant to sunlight, it is typically used as a primer or for corrosive interior applications. A galvanized steel/polyamide epoxy primer/aliphatic urethane topcoat system is considered to be a superior high-performance duplex system.

Latex-Acrylic

Fast-drying and water-based, latex-acrylic has great adhesion, durability, and weathering characteristics. This system is often top-coated with itself and is suitable for new and weathered galvanized steel. This paint has the added benefit of being environmentally friendly.

Latex Water-Based

This type of latex paint is also fast-drying and weathers well, but takes time to cure before it can provide acceptable adhesion and abrasion resistance. Therefore, latex water-based paint is not recommended for shop application. Adhesion and abrasion resistance do improve with time (two to four weeks).

Oil-Based

Oil-based paint is poorly suited for use directly over galvanized steel—with very few exceptions—because this type of paint must be cured with the help of air dryers. This paint is easy to apply but has unsatisfactory chemical and solvent resistance. Oil-based paint is not generally used over galvanized steel as the oil can react with the alkalinity of the zinc and saponify in moist or humid environments (see alkyd paint, page 15).

Portland Cement in Oil

This single package paint incorporates Portland cement as part of the pigment. It has outstanding adhesion to galvanized steel, but is often top-coated because it doesn't weather as well as other coatings, and often yellows with age. This paint does occasionally become brittle with time, so formulas with special resins designed to preclude embrittlement may perform better.

Silicone

The suitability of silicone for use directly over galvanized steel is poor and, therefore, it is not widely used. However, silicone is sometimes employed in high-temperature applications where cross-link silicates develop that prevent oxidation of the zinc coating. Silicone-alkyd compounds typically do not perform as well as silicon-acrylic compounds.

Vinyl

Vinyl has exceptional resistance to acid and alkali environments and can be supplied as either a thin film needing top-coating or as a high-build coating. As a rule, vinyl exhibits only fair adhesion and should be assisted by the use of surface profiling such as a sweep blast or a wash primer. Vinyl acrylic has a great glossy finish with good color retention. The high VOC levels found in vinyl paint has

extremely limited its availability and use in certain areas.

Powder Coating

Powder coating on hot-dip galvanized steel provides an excellent corrosion-resistant system. The selection of this duplex system has two major attractions: the duplex system provides a high-grade architectural finish that contains no volatile materials, and it is particularly abrasion-resistant.

The surface preparation required to promote good adhesion between the powder coating and the galvanized surface is similar to that of paint. A profiled galvanized surface will provide an excellent surface for applying a powder coating. Due to the equipment required, powder coating is usually shop applied to newly galvanized steel; it is recommended that the galvanized surface be coated within 24 hours of galvanizing. To promote superior adhesion of the powder coating, the following process details should be understood and followed:

- The galvanized steel should not be quenched after it has been galvanized.
- The surface of the hot-dip galvanized steel should remain clean. When transporting the part, be sure to cover loads and keep them dry.
- If surface contamination has occurred, clean the steel with a proprietary solvent/detergent that will remove the contamination and can be rinsed from the surface of the galvanized coating.
- Maximum adhesion is best achieved by using a zinc phosphate treatment before powder coating the steel. The hot-dip galvanized surface must be thoroughly clean, as this treatment has no cleansing action.
- Preheat hot-dip galvanized steel prior to powder coating.

- Use “degassing” grade polyester powder only. Anti-blistering agents, such as polyethylene oxide, can be added to the powder to prevent pinholing and promote good adhesion.
- The curing temperature of the powder should be between 280 - 390 F. Curing at higher temperatures can result in adhesion loss between the zinc and powder coating.



Powder coating adds extra durability and corrosion protection to these hot-dip galvanized utility poles, which were powder coated immediately after galvanizing and then packaged for shipping. Instead of field painting, many products are galvanized and painted in the shop prior to installation.

Only a partial listing of available paint, paint systems, and powder coatings has been provided. The paint manufacturer can provide more thorough information about the compatibility of specific systems with galvanized steel. **Always consult the paint manufacturer prior to painting galvanized steel.** Different physical and chemical characteristics of the same types of paint may have varied reactions with a galvanized surface. The paint manufacturer and galvanizer can assist in the creation of a successful duplex system.

REPAINTING GALVANIZED STEEL

Repainting galvanized steel can include the spot-repair of isolated areas or total reconditioning of an entire structure. When spot-treating, only areas free of old paint should be recoated.

Total reconditioning of a painted galvanized structure should be carefully evaluated. Coating thickness measurements should be taken to determine how many mils of zinc remain and what percentage of the surface area is exhibiting red rust. A distinction should be made between red rust of the base steel and the brown staining of the zinc-iron alloy layers in the galvanized coating. It is difficult to visually distinguish red rust from brown staining; by using a coating thickness gauge, the presence of zinc can be detected. Red rust will be present only if there is no mil reading on the thickness gauge. For information on using thickness gauges, refer to ASTM E 376, *Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods*.

The type of paint system used to repaint a structure depends on the extent of deterioration of the original duplex system. If the steel substrate shows rusting over a substantial area, then a zinc-rich paint can be used with appropriate preparation and application techniques.

Obviously, the major problem with repainting galvanized structures is obtaining a good surface profile that will accept and mechanically bond with the new paint system. Sweep blasting may be necessary to produce an acceptable surface. Extreme care should be taken not to strip any more of the zinc coating than needed; the more zinc that is removed, the less cathodic protection provided to the base steel.



By reconditioning a weathered duplex system or galvanized coating, the life of the product can be significantly extended, as with this handrail that is being prepared for repainting. Extreme care should be taken not to damage the weathered galvanized coating.

CONCLUSION

Duplex systems generally perform extremely well when care is taken with surface preparation and paint selection. Be sure to take the following simple, logical steps to ensure a successful duplex system:

- Let your galvanizer know your steel is to be painted. This will facilitate proper surface preparation—such as making sure the steel is not quenched after galvanizing and smoothing out coating imperfections.
- Take the time to correctly determine the age and characteristics of the galvanized coating. Duplex systems require proper surface preparation, and newly-galvanized, partially-weathered, and fully-weathered galvanized steel each require different methods and amounts of surface preparation.
- Proper cleaning and profiling is key prior to painting. Be sure to choose the cleaning and profiling methods appropriate to your situation, closely following the recommended guidelines.
- Select a paint system that is compatible with the galvanized coating on the steel.

- Discuss coating characteristics with the galvanizer, and always consult the paint manufacturer prior to painting galvanized steel.

As with any paint system, proper surface preparation of the hot-dip galvanized coating to be painted is critical. The combination of the zinc of the galvanized coating and paint synergistically provides an excellent corrosion prevention system that has been utilized for over 40 years.



Remember the corroding trolley frame pictured on page 5? Here is the completely refurbished trolley, after it was thoroughly cleaned, repaired, hot-dip galvanized, and painted.

RELATED SPECIFICATIONS

American Society for Testing and Materials (ASTM)

100 Barr Harbor Drive, PO Box C700 — West Conshohocken, PA 19428-2959 USA

Phone: 610-832-9585, Fax: 610-832-9555, Web: www.astm.org, Email: service@astm.org

A 123 *Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*

A 153 *Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

A 780 *Specification for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*

B 201 *Practice for Testing Chromate Coatings on Zinc and Cadmium Surfaces*

D 6386 *Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Product and Hardware Surfaces for Painting*

E 376 *Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Test Methods*

Canadian Standards Association (CSA)

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G 164-M *Hot Dip Galvanizing of Irregularly Shaped Articles*

The Society for Protective Coatings (SSPC)

40 24th Street 6th Floor — Pittsburgh, PA 15222-4656 USA

Phone: 1-877-281-7772/412-281-2331. Fax: 412-281-9992, Web: www.sspc.org, Email: sroka@sspc.org

Surface Preparation Specification No. 1 *Solvent Cleaning*

Surface Preparation Specification No. 2 *Hand Tool Cleaning*

Surface Preparation Specification No. 3 *Power Tool Cleaning*

Surface Preparation Specification No. 7 *Brush-Off Blast Cleaning*

Paint Specification No. 27 *Basic Zinc Chromate-Vinyl Butyrol Wash Primer*

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