

PAINTING OVER HOT DIP GALVANIZED STEEL

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Abstract: Duplex systems, also known as painting over hot dip galvanized steel, are extremely effective corrosion protection systems. However, careful surface preparation techniques need to be used to alleviate potential coating failures. Use the age and characteristics of the galvanized coating to determine what type of surface preparation is needed.

The adhesion of paint onto galvanized steel becomes a very small problem when the galvanized coating has weathered for at least a one-year period. The zinc corrosion products form a very dense, insoluble protective layer that accepts a paint coat readily. A brand new galvanized coating also experiences few adhesion problems within the first 24 to 48 hours after coating.

INTRODUCTION

Hot-dip galvanized steel parts or assemblies are often required to be painted. The reason for painting can be to identify the particular structure, for architectural reasons, to provide a particular type of protection, or to extend the service life of an existing structure. The combination of a paint system with a hot-dip galvanized coating is often referred to as a “duplex system” (1). When paint and galvanized steel are used together, the corrosion protection is superior to either protection system used alone (2).

The application of a paint system onto a hot dip galvanized surface requires careful surface preparation and a good understanding of both corrosion protection systems. The margin for error is very small when dealing with newly galvanized steel surface preparation. However, there have been many examples of paint adhesion problems on older or more moderately aged galvanized steel surfaces, and the most common cause is improper or incomplete surface cleaning and preparation (3). When the surface is cleaned and prepared correctly the combined paint and galvanized steel corrosion protection system gives extremely long lifetimes (4). If the paint is properly maintained on the galvanized surface there is practically no limit on the life of the structure in terms of corrosion attack.

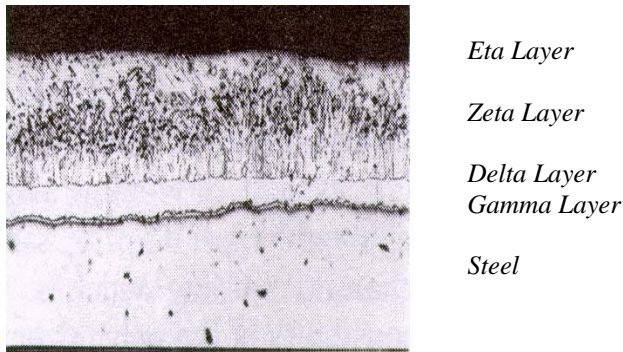
GALVANIZED COATING

Hot-dip galvanized coatings can be applied in two different ways. The parts can be fed into a liquid zinc bath in a continuous roller process where the coating characteristics are highly dependent on the speed of the steel through the liquid zinc bath. The two most common steel products that are hot-dip galvanized using the continuous process are sheet and wire. The objective of the continuous process is to deposit a zinc coating that is smooth, thin and composed of nearly all zinc bath metal with very little zinc-iron intermetallic. The coating can be alloyed to form a dull gray intermetallic coating which has a good surface profile and can be easily painted.

The second type of hot-dip galvanizing process is often called the “batch” process since individual steel pieces or assemblies are dipped in a molten zinc bath as individuals or as groups. The coating is formed by the interdiffusion of zinc and iron. A micrograph of a typical batch hot-dip galvanized coating is shown in Fig. 1. The coating forms four distinct layers or intermetallics. The first layer is called the gamma layer and has 75 % zinc and 25% iron. The next layer is called the delta layer and has 90% zinc and 10% iron. The third layer is called the zeta layer and has 94% zinc and 6% iron. The final layer is called the eta layer and has 100% zinc and no iron.

During the batch hot-dip galvanizing process, a number of process variables can affect the coating thickness. The primary determiner of coating thickness is the steel chemistry, with the most influential elements

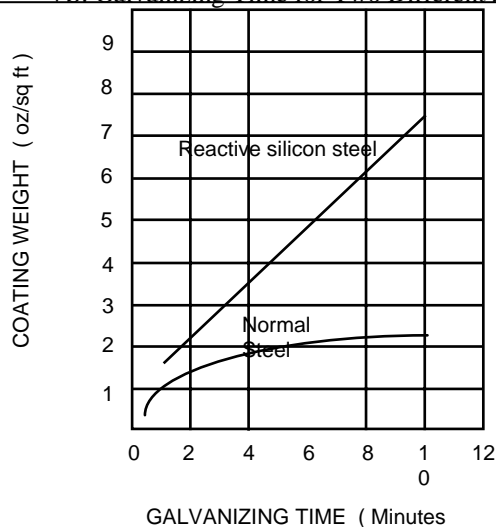
Fig. 1 – Microstructure of Hot-Dip Galvanized Coating on Steel



being silicon and phosphorous. These two elements promote the interdiffusion of zinc and iron and cause the hot-dip galvanized coating to become thick and filled with intermetallic. Fig. 2 shows the coating rate of two different steels versus the time spent in the molten zinc bath. The normal steel curve shows the galvanizing reaction is self-limiting and will cease to increase the coating weight when the diffusion of zinc and iron becomes a very slow process. Whereas with the reactive silicon steel, the reaction continues to add coating weight to the part as long as the steel is in the galvanizing bath. The reactivity of the steel is determined by the amount of silicon and phosphorous in the steel.

The coating produced when the steel is reactive contains mainly intermetallics of iron and zinc. This means that the surface will not be bright and shiny, but rather dull gray and slightly rough. This intermetallic surface makes a very good anchor for paint systems. The

Fig. 2 - Coating Weight of Hot-Dip Galvanized Coating VS. Galvanizing Time for Two Different Steels



main concern with reactive steel galvanized coatings is the thickness of the coating. If the coating is too thick it may become brittle and will be susceptible to applied stresses that may separate the galvanized coating from the steel underneath. Knowing the silicon and phosphorous content is very important to producing a quality galvanized coating.

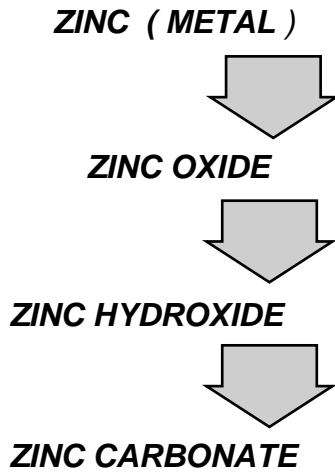
GALVANIZED COATING SURFACE

Many galvanizers apply post treatments to their galvanized coating to prevent the formation of wet storage stain. Additionally, the galvanized part is sometimes quenched in a water bath to accelerate cooling. These treatments and quenching are to be avoided if the galvanized part is to be painted. The post treatments will change the surface chemistry of the coating. While some of these treatments, such as phosphating, produce better surfaces for painting, others, such as chromating, will produce a surface that is difficult to paint. Consult with the galvanizer and paint company before applying a post treatment to galvanized steel that is to be painted. Water quenching in itself is not harmful to the surface but the quench bath often has small amounts of oil, grease or flux on the surface which could interfere with paint adhesion.

A hot-dip galvanized coating of zinc protects the steel by providing both a barrier to atmospheric elements and cathodic protection to the steel. The corrosion protection of the zinc originates from the dense, insoluble corrosion product layer that forms over time on the zinc surface. Newly galvanized steel is bright and shiny, and is pure zinc on the surface. This surface is fairly smooth, so during the first 24 to 48 hours after galvanizing only a slight roughening of the surface is needed to prepare the galvanized coating to be painted. The natural corrosion cycle of the zinc coating is shown in Fig. 3. The conversion of the zinc metal on the surface to zinc oxide occurs within the first 12 months of exposure to the environment. The conversion of zinc oxide to zinc hydroxide occurs soon after the zinc oxide is formed and depends on the amount of available water in the air, or as a result of dew or condensation. The corrosion products, zinc oxide and zinc hydroxide, are water soluble so they are often washed off the zinc surface in the presence of rain or condensation.

The final step in the corrosion cycle is the conversion of zinc hydroxide and zinc oxide to zinc carbonate. This happens in the presence of freely flowing air across the exposed surface. The carbon dioxide from the air reacts with the zinc oxides. This corrosion product, zinc carbonate, is insoluble in water and forms a very dense layer on the surface of the coating. This layer will erode slowly in time but it mainly provides a barrier for the zinc

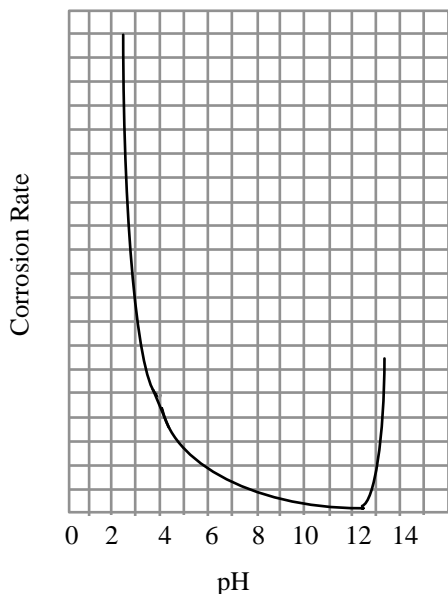
Fig. 3 - Corrosion Cycle of Zinc Surface



metal underneath. The corrosion rate of the overall system depends on the rate of zinc carbonate erosion or dissolution. Very basic or very acidic solutions can dissolve this layer extremely rapidly. The corrosion rate changes most rapidly in the low pH atmosphere because acidic solutions quickly dissolve the zinc carbonate layer. This is seen in the corrosion rate chart of Fig. 4. A high pH atmosphere can also shorten the life of the zinc coating.

The zinc carbonate layer is a very dense and slightly rough layer. Paint adhesion to this layer is extremely good with little or no surface preparation. Galvanized articles

Fig. 4 - Corrosion Rate of Zinc versus pH of Atmosphere



that have been exposed to the atmosphere for more than one year are completely covered with the zinc carbonate layer.

The two conditions of galvanized steel that need little or no surface preparation are the newly galvanized part that is less than 24 to 48 hours removed from the zinc bath and the weathered galvanized steel part that has been exposed to the atmosphere for more than one year. The galvanized articles that do not meet these two conditions need surface preparation to remove the zinc oxide and zinc hydroxide from the coating. Unfortunately most galvanized steel articles fall into this last category, as few galvanizing facilities have painting capability in their galvanizing plant. As a result, the parts are galvanized and then shipped to a paint shop or to the field and painted some days after they have been galvanized.

GALVANIZED STEEL SURFACE PREPARATION

Successful surface preparation is the key to producing adherent paint coatings and realizing the benefits of a duplex system. The pole shown in Fig. 5 has peeling

Fig. 5 - Galvanized Pole with Peeling Paint



paint as a result of poor surface preparation. The surface contained zinc oxides and zinc hydroxides when the paint was applied. The coating appeared to adhere to the surface, but after two to three years in service, the zinc oxide began to separate from the underneath zinc metal. As paint was adhering to the zinc oxide, it separated from the pole surface at that time.

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. 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 reaction problems.

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 as this will damage the zinc coating. Most alkaline cleaning solutions are nominally 2 to 5 percent sodium compounds with small additions of emulsifying or chelating agents. The solution can be applied through dipping, spraying or brushing. If brushing is used, apply the solution with a soft bristle brush, preferably of nylon, definitely not copper or steel bristle brushes. If dipping or spraying the solution, the temperature range that works best is between 140 and 185 F. For newly galvanized steel, a water-based emulsifier can be used to remove contaminants. After cleaning, thoroughly rinse the surface with hot water and allow to dry.

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 rags or soft bristle brushes. The rags and brushes must be changed often to prevent reapplying the contaminants. After cleaning, rinse thoroughly with hot water and allow to dry completely.

A solution of 1 to 2 percent ammonia applied with a soft bristle brush can also be used to clean galvanized surfaces, although this method is typically reserved for cleaning parts with zinc ash 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 zinc ash. Ash residue must be removed prior to painting. After cleaning, thoroughly rinse the surface with hot water and allow to dry completely.

Surface Profiling

In order to provide a good adhesion profile for the paint, the galvanized surface must be flat with no protrusions and slightly roughened to provide an anchor

Fig. 6 - Sweep Blasting of Galvanized Steel Surface



profile. During the removal of the galvanized article from the zinc bath, the excess zinc runs down the edges of the part and can sometimes build-up at a protrusion or irregular edge. The zinc can also form tears at the edge where it drains off the part. These high spots and tears must be removed before painting as they will be very difficult to coat. The high spots and tears are usually ground off with hand tools or power grinders. Care must be taken when performing this operation to insure that the galvanized coating is not removed below the specified thickness.

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 200 and 500 microns. Aluminum/magnesium silicate has been used successfully in the sweep blasting of galvanized steel as seen in Fig. 6. Organic media such as corn cobs and walnut shells or minerals such as corundum, limestone and 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 affect on the finished surface profile. Sweep blasting while the galvanized part is still warm from the galvanizing process, 175 to 390 F, provides an excellent profile for painting. Ambient conditions for sweep blasting are recommended to be less

than 50 percent relative humidity and a minimum temperature of 70 F.

The process of sweep blasting should not be confused with the near white blasting that is used to clean uncoated steel before applying paint systems. This near white blasting will remove the galvanized coating and negate the corrosion protection afforded by the zinc. The process of sweep blasting is best performed by an experienced applicator. If the sweep angle becomes near perpendicular to the galvanized part, the blasting can quickly remove the protective zinc rather than the zinc oxide particle on the surface of the coating.

Penetrating Sealers

Two-part epoxy penetrating sealers are sometimes used to form a 50 micron thick coating on the galvanized surface after cleaning. These products can be particularly effective as surface treatment methods on surfaces that have had zinc oxide and zinc hydroxide removed during the cleaning process. Follow the manufacturer's directions for application and always use a topcoat over the penetrating sealer.

Zinc Phosphate Treatment

Zinc phosphating is a conversion coating that passivates the zinc surface and blocks the formation of zinc oxides. The phosphate treatment can be applied by immersion, spray or soft bristle brush. The phosphate should be left on the galvanizing surface between 3 and 6 minutes. The piece should then be washed with clean water and allowed to completely dry. This type of treatment is appropriate for most types of paints but does not perform well with zinc-rich paints.

Wash Primers

This treatment uses a metal conditioner to neutralize surface oxides and hydroxides, as well as etch the galvanized surface. Wash primers should be applied to the galvanized surface to form a protective layer 7 to 13 microns thick. If the thickness exceeds 13 microns, paint adhesion can become a problem. The critical thickness layer dictates that this process be done in shop conditions. Field application of this treatment results in thick and irregular protective layers. When using wash primers, follow the manufacturer's directions for maximum performance.

Acrylic Passivation

This treatment uses an acidic acrylic solution to passivate the galvanized surface, as well as to roughen the smooth zinc coating. Acrylic passivation should be applied approximately one micron thick to a clean galvanized surface. The passivation layer should be dried completely before applying paint to the surface.

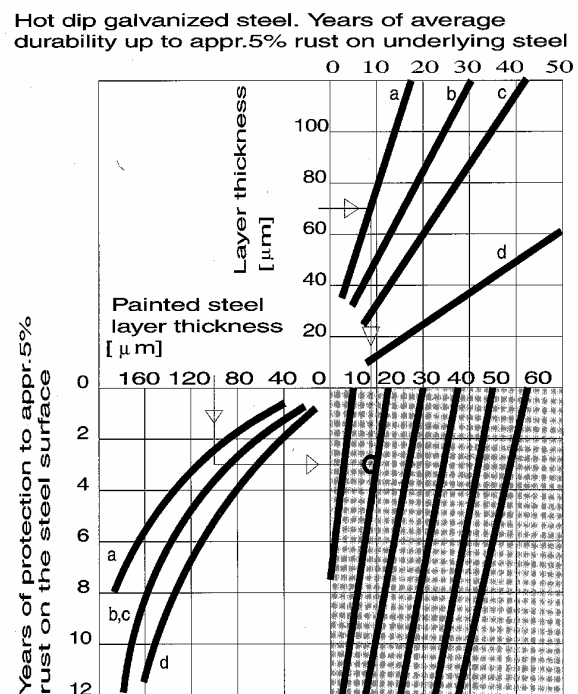
PAINT SELECTION

The proper selection of a paint system for a certain engineering need is the province of the architect and the engineer. There are many options depending on the intended use of the duplex coated part, the application method and place for the paint system, environmental concerns, and aesthetics of the total system. Many paint companies offer good paint systems that are designed to work with galvanized steel. Consult your paint manufacturer for the proper paint selection.

DUPLEX SYSTEM PERFORMANCE

When hot-dip galvanized steel is painted, the duplex system provides a more sophisticated manner of corrosion protection. The galvanized coating protects the base steel by providing both cathodic and barrier protection. The paint coating acts as a barrier protection for the hot-dip galvanized coating and significantly reduces the corrosion rate of the zinc. The overall affect on the base steel is that the duplex system not only provides hot-dip galvanized life plus the paint life but also provides a multiplication factor of 1.5 to 2.3 on the sum of these two lifetimes.

Fig. 7 – Duplex Systems Lifetimes (1)



The combined effect of the two corrosion protection systems is shown in Fig. 7 from van Eijnsbergen (1). The graph in the top right section shows the lifetime of galvanized coatings in four types of atmospheres: a: industrial atmosphere, b: urban atmosphere, c: marine atmosphere, and d: rural atmosphere. The number of years for the coating is shown across the top and the coating thickness is shown along the side. The lifetime of a typical paint system is shown in the lower left section of the figure. In this graph the number of years is shown along the side and the coating thickness is shown along the top. The third graph in this figure is the actual lifetime of duplex systems with the number of years shown along the top. An example is plotted for a galvanized coating of 70 microns which has a lifetime of 9 years in an industrial atmosphere along with a paint coating of 100 microns which has a lifetime of 3 years in an industrial atmosphere. The combined lifetime should then be 12 years but the actual lifetime of this duplex system is 18 years.

The increased lifetime that can be provided with a combination of paint over galvanized steel makes this type of corrosion protection system very attractive for structures designed to last a long time in aggressive atmospheres. If periodic maintenance is an option, the repainting of galvanized steel can provide virtually unlimited lifetimes for a structure.

SUMMARY

The painting of galvanized steel has been a difficult task for many people. The secret of good painting on galvanized steel is the surface preparation of the galvanized surface. If the surface is newly galvanized, that is less than 48 hours out of the zinc kettle, the surface can be painted after a surface roughening procedure. If the surface of the galvanized part has been exposed to the environment for more than one year then the surface can be painted after the dirt, grease and oils have been removed. The most difficult time to paint galvanized steel is between one day and one year after it has been galvanized. Following the correct surface preparation procedures can give a satisfactory duplex system.

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