Cleaning and Painting Galvanized Steel

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How many times have you seen paint peeling from a galvanized surface? Galvanized steel can be one of the easiest yet one of the most difficult surfaces to clean and paint properly. That's because zinc, used to galvanize steel, is an active metal. The surface starts changing about one day after the piece is removed from the galvanizing kettle, and it does not fully stabilise for about one year. Special procedures for cleaning and painting galvanized are needed in the first year. But after that time, most paints will adhere with just a power wash.

This month's Applicator Training Bulletin will examine what happens on a galvanized surface. It will discuss cleaning the surface of both new (less than one year old) and aged galvanizing, because the requirements differ. Finally, it will present information on painting materials and the painting of galvanized steel.

The Galvanized Surface

Galvanizing is a process in which a coating of zinc is applied to a steel surface from a bath of molten zinc. This can occur in several ways. Coil steel, such as steel used to make automobile bodies, is commonly galvanized in a continuous roller process. The sheet of steel is fed into a bath of liquid zinc where the zinc is deposited on the surface. Alternatively, structural pieces and hardware are galvanized in a batch process by immersing them in a bath of molten zinc. This is called hot-dip galvanizing. Chemical reactions occur between the iron in the steel and the molten zinc. (See sidebar.) An outer layer of pure zinc covers the surface as the piece is withdrawn from the bath.

Paint peeling from galvanizing
All photos courtesy of the American Galvanizers Association

The corrosion protection of unpainted galvanizing comes from the formation of a thin, invisible layer of insoluble corrosion products. Zinc, being an active metal, reacts with oxygen in the air. Zinc oxide starts forming 24 to 48 hours after galvanizing. It takes about a year for the zinc oxide to cover the entire surface. The zinc oxide converts to zinc hydroxide upon exposure to moisture in the form of rain, dew, or high humidity. The final step is the reaction of zinc oxide and zinc hydroxide with carbon dioxide in the air to form zinc carbonate. This requires free-flowing air. Zinc carbonate is the dense, insoluble material that forms the protective layer (sometimes called the patina). Zinc oxide and zinc hydroxide are water-soluble and not very dense. They adhere loosely to the surface, so painting over zinc oxide or zinc hydroxide does not provide good adhesion of the coating to the surface. The practical problem is that zinc oxide, zinc hydroxide, and zinc carbonate are all white. They give the galvanized surface a dull, matte grey appearance, and there is no way to determine visually what form of zinc compound is present. Knowing the compound is important because some forms are not suitable for painting over.

The reactivity of zinc is well known to galvanizers. For instance, they know that if pieces are closely stacked for shipment, there will be no access to carbon dioxide in free-flowing air to form the zinc carbonate. Only loose zinc oxide and zinc hydroxide will form, so consumption of the zinc will be rapid. Unpack closely spaced galvanized pieces and you will see loose, white deposits on the surface. If this reaction process is allowed to continue, it can totally consume all the zinc by reaction with the moisture caught between the pieces. (This condition is, however, very rare.) Rusting of the unprotected steel may then occur, resulting in red rust present underneath the deposit. This white deposit is called "wet storage stain." Galvanizers will apply a light coating of oil to prevent wet storage stain. The oil forms a barrier to prevent moisture from reaching the zinc, thus preventing the zinc from being converted to the oxides and hydroxides. But paints don't stick to oil, so painting this surface without first removing the oil is a disaster waiting to happen, no matter what type of coating is applied. Another process used to prevent wet storage stain is quenching or passivating with chromates or phosphates. Quenching, i.e., cooling in a water bath, is not harmful in itself. But the quench bath can have small amounts of oil and grease on the surface that will be picked up when the piece is removed. Paints also do not stick to chromate-quenched galvanizing, but phosphating improves adhesion. If the galvanizer does perform a post-treatment, you won't know which one was used. It is always recommended to consult with the galvanizer—preferably before items are galvanized—if you know they are to be painted.

Surface Preparation of New Galvanizing

New galvanizing, for the purposes of this article, means galvanized steel that is between one or two days old and one or two years old. (It was noted above that a stable galvanized surface

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is formed in one year, but the possible presence of a light oil layer and weather conditions may actually extend the time.)

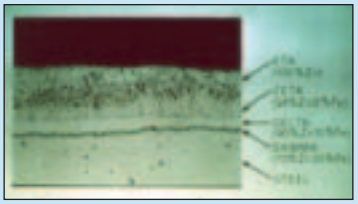
Wet storage stain, if present, must be removed before surface preparation. This can be done by brushing the stain with a 1–2% ammonia solution such as diluted household ammonia. Severe cases of wet storage stain will require a mild acid solution such as one part of acetic or citric acid diluted with 25 parts of water. Remove the ammonia or acid with a warm water rinse.

The first step in surface preparation is to wash off oil, grease, and dirt. In North America, this is accomplished by solvent cleaning (SSPC-SP 1). (This standard is not commonly used in Europe.) Water-based emulsifiers or alkaline cleaners work best. Make sure that an alkaline cleaner has a pH of less than 12 or 13, because zinc will dissolve in highly alkaline solutions. Apply the cleaning solution by dipping, spraying, or brushing with soft bristle brushes. A temperature range of 60–85 C (140–185 F) works best, especially when dipping or spraying. Thoroughly rinse the surface with hot water after cleaning and allow it to dry. In countries where organic solvents can also be used for cleaning purposes, lint-free rags should be used. Change them often so as not to cover the surface with fibres.

One way to determine if oil was applied to the galvanized surface to prevent wet storage stain is to contact the galvanizer. Another way is to perform a water bead test. Place a drop of water on the surface. If it beads, oil probably is present. The best advice is that when in doubt, clean the entire surface as described above.

The Galvanizing Process

Hot-dip galvanizing is a batch process in which the coating is applied in a molten bath of zinc at about 450 C (840 F) after the workpiece has been cleaned and a flux has been applied to promote fusion of the zinc to the steel.

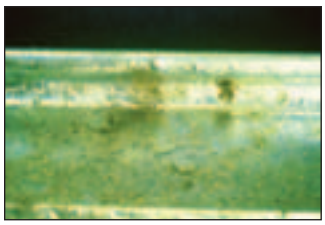


Chemical reactions between the iron in the steel and the molten zinc take place, forming four distinct layers, as shown at left. The gamma layer closest to the steel is 75% zinc and 25% iron. This is followed by the delta (90% zinc), zeta (94% zinc), and eta (100% zinc) layers.

The overall thickness of the galvanizing is determined primarily by the chemistry of the steel, provided the workpiece has remained in the bath for a sufficient length of time. The thickness of the eta layer is also affected by how quickly the molten zinc can drain from the surface when the item is removed from the bath.

Galvanizing is known for its bright, spangled surface. However, bath chemistry can affect the appearance and a dull finish can occur. This is an aesthetic issue and does not affect the corrosion protection of the galvanizing. Exposing the zeta layer will result in a brown appearance due to the presence of an iron alloy.

After washing the surface, examine it for zinc ash. Zinc ash residue consists of particles of oxidized zinc that float on the surface in the galvanizing bath. It can be removed by washing the surface with a 1–2% ammonia solution. Thoroughly rinse the surface with hot water and let it dry.



Zinc ash residue on galvanized item

The next step in surface preparation is to repair any defects or handling damage. Galvanizing can leave high spots and zinc droplets. High spots occur when excess zinc runs down the edges as the galvanized piece is withdrawn from the bath, and the zinc runs into a protrusion or irregular edge. Droplets form at edges where zinc drains from the piece. Droplets are knocked off with hand tools. High spots are usually ground off with power tools, but care is needed not to remove so much zinc that the thickness is below the specified minimum.

Damaged galvanizing can be repaired with organic zinc-rich paints. Consult the coating manufacturer about specific products and the method of surface preparation required. SSPC-Guide 14, Guide for Repair of Imperfections in Galvanized or Inorganic Zinc-Coated Steel Using Organic Zinc-Rich Coating, may be consulted.

The unstable zinc oxide or zinc hydroxide may not have been entirely removed during the initial cleaning process. There is no simple method for identifying the presence of either, so the surface must be further treated. The common methods for treating the surface in the field are phosphating, use of wash primers, acrylic passivation, and sweep blasting.

Phosphating

Phosphating (use of acidic zinc phosphate solution, mordant solution, or T-Wash) is accomplished by applying a phosphate-containing solution that forms a non-reactive zinc phosphate layer on the surface. The process slightly etches the surface and blocks the formation of zinc oxides.

The solution is applied by immersion, spray, or soft bristle brush. It should be left on the surface for 3 to 6 minutes and then washed off with clean water. The treatment will give a black colouration to the surface. Therefore, any areas that were missed will be visible after washing, and they can be re-treated. Allow the surface to dry before painting.

Phosphating can also be done at the galvanizing plant in a process called phosphate quenching. The workpiece is placed in a phosphating bath after galvanizing. If you're involved with a new construction project, contact the galvanizer to see if the pieces will be treated with phosphate. It will be less expensive, and the quality will be more consistent compared to field phosphating.

Phosphating is not recommended if a zinc-rich primer is going to be applied. Zinc-rich primers require intimate con-

tact between the zinc particles in the paint and the zinc metal on the galvanized surface. Zinc phosphate acts as an insulator in the same way that iron oxide (rust) acts as an insulator on steel surfaces.

Wash Primers

Wash primers are coatings used to neutralise the surface oxides or hydroxides and to etch the galvanized surface. The most common wash primer is polyvinyl butyral (e.g., SSPC-Paint 27), although other products are available.

These materials are applied very thin (i.e., 7–13 microns [0.3 to 0.5 mil]) by brush or spray. Follow the manufacturer's instructions. The galvanized surface should shadow through the coating at this thickness. If the galvanized surface is completely hidden, the wash primer is too thick.

Wash primers have poor cohesive strength and will split apart if they are too thick, resulting in paint disbondment.

Acrylic Passivation

Acrylic passivation is accomplished with an acidic acrylic solution that passivates and roughens the surface. Acrylic passivating materials are applied at 1 micron (0.04 mils). In essence, acrylic passivation is a surface treatment. It must dry completely before the paint is applied.

Sweep Blasting

Sweep blasting—a method of lightly blast cleaning—can remove zinc oxides on the surface and roughen it without significant removal of the galvanizing.

Sweep blasting should be performed with soft abrasives such as aluminium/magnesium silicate, corn cobs, walnut shells, limestone, or some mineral sands. Use an abrasive with a Mohs' scale hardness of 5 or less. The particle size should be in the range of 200–500 microns (8–20 mils).

Use a relatively low angle when blasting. Holding the nozzle perpendicular to the surface can quickly remove the galvanizing layer rather than just the zinc oxide particles on the surface. The recommended ambient conditions for sweep blasting are a minimum temperature of 21 C (70 F) and relative humidity of 50% or less.

Fully Weathered and Aged Galvanizing

Fully weathered galvanizing (i.e., galvanizing that has been outdoors for at least one year and preferably two) should have a fully formed layer of protective zinc carbonate. All that is normally needed to prepare the surface is power washing at about 97 bar (1,450 psi). Spot repairs of any damage also would be necessary.

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Old, aged galvanizing that has been in service, uncoated, for a number of years and is showing signs of failure introduces a different concern. There may be areas of reddish-brown staining, which many people think is corrosion of the base steel. However, just below the pure zinc on hot-dip galvanized steel are zinc-iron alloy layers. What might be visible is the staining from these layers. Zinc-iron alloy is brown, while rusted steel is redder, but telling the difference can be difficult. The best way to do this is with a magnetic or electronic dry film thickness gauge. Measure the layer of galvanizing at any rusted or stained areas. Since galvanizing is non-magnetic, the gauge will measure it as if it were paint. If the gauge finds no layer of galvanizing, the area is most likely rusted. Mark the area for repair. The specified galvanizing thickness is related to the steel thickness and is usually in the range of 50–125 microns (2–5 mils).

Surface preparation of old, aged galvanizing involves cleaning any rusted or stained areas as well as power washing the entire surface. Areas with red rust should be cleaned to bare metal while areas with brown staining from the zinc-iron alloy require only hand or power tool cleaning. Care must be taken when cleaning areas of red rust to remove as little galvanizing from the edges of the spot as possible.

It is common to use an organic zinc-rich primer when refurbishing old, aged galvanizing. Usually some of the galvanizing has been consumed, and the intent is to add more zinc for corrosion protection. Sweep blasting would be recommended prior to applying the primer to promote adhesion.

Coatings For Galvanizing

Many types of coatings can be applied over galvanizing. The choice sometimes depends, in part, on how the surface was prepared. However, there are certain types of coatings that are not recommended, especially oil-based alkyds. Most coatings can be applied by brush, roller, or spray. Check with the coating manufacturer on application methods. The most common coatings applied directly to galvanizing are epoxies and water-bornes.

Epoxies come in many varieties. Those selected must be specifically formulated for use over galvanizing. Make sure the manufacturer's technical data sheet for a particular product says it can be applied to galvanizing. Epoxies generally chalk in sunlight, so a topcoat would be needed for outdoor exposure. Aliphatic urethanes give good appearance and chemical resistance, so they are commonly used for this purpose.

Water-borne acrylic coatings are fast drying. They make good topcoats and are easy to maintain. Acrylic latexes are preferred. Other water-borne latexes

have properties similar to acrylic latexes. However, although the water-borne latexes dry quickly, they can take two to four weeks to thoroughly cure. Therefore, their adhesion and abrasion resistance will initially be low. This can present a problem for new construction because of possible handling damage.

Chlorinated rubbers and vinyls have been used in the past, but environmental regulations concerning volatile organic compound (VOC) content have severely limited their availability and use. They are best used on galvanizing that has been prepared by sweep blasting or with a wash primer.

Acrylics can be applied directly to a galvanized surface, although a wash primer is preferred. However, some acrylics contain ammonia, and if the pH of the paint is high, the ammonia may react with the zinc, causing the paint to peel.

Galvanized steel that is to be buried is typically painted with bituminous materials or coal tar epoxy. Coal tar epoxies are best applied over a sweep blasted surface or a wash primer.

Organic zinc-rich primers, such as an epoxy zinc-rich, can also be applied directly to galvanizing. However, not all organic zinc-rich primers are formulated for application to galvanizing, so check the product data sheet or with the manufacturer.

Oil-based and alkyd paints are not recommended unless they are specifically formulated for use on galvanizing. The problem is that zinc is an alkaline material. The zinc and the binder react in the presence of alkalinity to form a metal soap. (Sometimes, you can actually form lather by adding a little water to this soap.) This process, which is called saponification, breaks the bond between the galvanizing and the paint. Saponification requires moisture, so it occurs in a well-adhered coating film only after moisture starts permeating the film. The coating then falls off, or it can be completely removed in large sheets. Experience has shown that it takes six months to a year in outdoor exposure before the peeling occurs.

Some alkyds are formulated for application to galvanizing. To prevent saponification, manufacturers add portland cement to the coating as a pigment.

No matter what coating material is used, the total coating thickness generally should be no greater than 100–150 microns (4–6 mils). Don't forget that galvanizing is non-magnetic, so the thickness of the galvanizing will be included in the paint thickness measurement when using magnetic or electronic gauges. Specifications for structural steel generally require the galvanizing to be 50–125 microns (2–5 mils), depending on the thickness of the steel. (The galvanizing thickness on sheet steel is lower.) The thickness of the galvanizing should be measured before any paint is applied so it can be subtracted from the overall coating thickness measured after each coating layer is applied. Galvanizing is often specified by weight of zinc per unit area, e.g., grams of zinc per square metre (ounces of zinc per square foot). These correspond to galvanizing thicknesses. The conversion is 250 g/sq m equals 43 microns (1 oz/sq ft equals 1.7 mils).

Finally, if sweep blasting is used to prepare the surface, it should be painted within 24 hours because the blasting exposes fresh zinc that will start converting to zinc oxides. Wash primers and acrylic passivators will give you more time to apply the paint, but check with the coating supplier on how much more time you have.

Conclusion

Surface preparation is critical for galvanized steel surfaces to be painted. Zinc is very active and takes one to two years to stabilise. It is during this period that galvanizing is usually painted on new construction projects. Check with the galvanizer, if possible, to determine how the pieces have been treated. Then prepare the surface as appropriate. Use only paints intended for galvanizing. Always check the product data sheet or with the manufacturer to determine if the coating is appropriate for galvanizing.