Painting Hot Dip Galvanized Steel

John F. Malone
Galvanizing Consultant, 52 Hemlock Drive, Mashpee, MA 02649

The use of hot-dipped galvanized steel is a highly effective and widely used method of controlling corrosion in atmospheric service. Although effective by itself, hot dip galvanized steel often is topcoated to enhance its corrosion resistance and/or appearance. Although it is relatively easy to topcoat galvanized surfaces, failures (primarily due to loss of adhesion) are not uncommon. This article describes techniques and procedures that help ensure topcoat success.

Before applying coatings over galvanizing, it is important to thoroughly understand the properties of newly galvanized surfaces. Hot dip galvanizing is most often performed by first cleaning the steel to be coated in a caustic bath followed by pickling (de-rusting) in a dilute hydrochloric or sulfuric acid bath. There is not much that can occur during these stages that will have an effect on subsequent painting operations.

After cleaning, the steel is subjected to a "fluxing" operation in which the steel is coated with a zinc ammonium chloride solution. This can be accomplished in one of two ways: the wet method or the dry method.

In the wet method, the flux is placed on the surface of the molten zinc in a semiliquid blanket. The steel is immersed into the galvanizing bath by passing it through the flux blanket. After passing through the layer of flux, the steel is allowed to remain in the galvanizing bath until it reaches the same temperature as the molten zinc (approximately 508°C [945°F]). At this time, the top of the kettle is swept free of flux, and the steel is withdrawn through a clean zinc surface. If the item is to be topcoated, this step is very important. If the sweeping operation is not performed carefully, flux will remain on the galvanized surface, which can interfere with paint adhesion.

When using the wet flux method, it is important that flux not become entrapped in corners, crevices, or overlapping surfaces. This is a particular problem in the case of intricate steel designs or when handling over-length articles that are double-dipped. In this process, one end of the item is immersed in the molten zinc and withdrawn. The item is then tilted and the other end is immersed. Because the entire item is never completely submerged, flux contamination is likely at the double-dip point.

In contrast to the wet flux method, the so-called "dry kettle" method of fluxing involves the use of zinc ammonium chloride flux in an aqueous solution. In this method, the steel is totally immersed in the flux, withdrawn, and allowed to dry prior to galvanizing. Since the flux is in a liquid solution, total coverage is more likely, and the following dip into the molten zinc will occur without the presence of contaminating flux on the surface.

It is the author's opinion that the dry kettle method is the more desirable of the two and that wet kettle type of galvanizing not be permitted when the galvanized item is to be topcoated.

Following galvanizing, most articles are quenched in water, primarily to cool them so that the galvanizer can handle them. If the items are to be topcoated, it is best to skip this step. The reason for this is two-fold:

- Under most circumstances, the quench water is infrequently changed and is, therefore, contaminated, which can leave surface contaminants that may interfere with paint adhesion.
- The quench water is sometimes treated with chemicals, such as 0.2% sodium dichromate, which are designed to leave a film on the surface. This film will most definitely interfere with paint adhesion.

After the steel has air cooled, the outer layer of a typical galvanized coating (commonly referred to as the Bta layer) is essentially pure zinc (bath metal). If left uncoated, the galvanized surface will begin to react with its environment to form a film of various zinc oxides, which will then change to zinc hydroxides, and eventually will form a more stable film of zinc carbonate.
While many coatings can be successfully applied to either pure zinc or zinc carbonate, most coatings cannot be applied to the less stable intermediate zinc oxides and/or hydroxides. For this reason, it is important to know the timespans during which these various films exist.

The initial reaction (zinc to zinc oxide) starts to occur from the moment the surface is exposed to the atmosphere. The early stages will usually not present a problem with coating adhesion until about 24 h after galvanizing. However, this time period can be increased or decreased depending on storage and exposure conditions. It is important to remember that hot dip galvanized surfaces are extremely reactive and that the films that initially form are detrimental to the adhesion of most topcoats.

In addition to films of oxides and hydroxides, it is not unusual for various chlorides and sulfates to combine with the zinc during the first stages' exposure. The films that form in the early stages are loose and powdery and do not provide a good base for topcoating. Even films not visible to the naked eye can cause paint failure.

The final stage in the evolution of the galvanizing film occurs, depending on the severity of the environment, between eight months to two years. This final stage provides a film of basic zinc carbonates, which are essentially inert, slightly water soluble, and tightly adhered. Successful application of paint to hot dip galvanizing is most likely when the outer layer is completely transformed to a zinc carbonate layer. This inert, slightly roughened base may only require pressure washing prior to topcoating. Even without a thorough understanding of zinc film formation and its relationship to topcoat adhesion, the approach of “weathering prior to painting” has been widely accepted and effective method of preparing zinc for topcoating for many years.

From the above, it can be seen that there are three distinct stages in the development of the final protective galvanizing film:

1. pure zinc—present from 0 to 48 h;
2. formation of zinc oxide/hydroxides (and others)—48 h to as much as 2 y;
3. final formation of zinc carbonates (generally from 8 months to 2 y).

It is possible to successfully topcoat galvanized surfaces prior to the formation of undesirable oxides and hydroxides. This has been common in Europe for many years and has been accomplished by some galvanizers in the United States with excellent results. Because timing is critical, the topcoating process is generally performed by the galvanizer in his own plant or by a paint contractor.

It is the second stage, when zinc oxides/hydroxides and other contaminants are present, that is the most critical and has the greatest potential for failures. If careful attention is not given to all details during this stage, the results can be disastrous.

Surface Preparation

As previously described, little or no surface preparation is necessary during the first stage of galvanizing exposure (within zero to 48 hours). In addition, little or no surface preparation may be required during the latter stages of zinc carbonate formation. Although stable zinc carbonates can form in as little as eight months, it is generally agreed that one year to 18 months represents a safer time frame.

Surface preparation, therefore, is most important during the critical time between two days and one year after galvanizing. During this period, it is mandatory that any oxides or hydroxides be thoroughly removed or neutralized prior to the application of any paint coating. This can be accomplished in one of two ways: sweep blasting or chemical cleaning.

The author's preference is sweep blasting. In this process, the galvanized steel is subjected to light sweep blasting with abrasive blasting equipment. The abrasive action of the blast media removes the contaminated film (exposing new pure zinc) and roughens the surface slightly, resulting in an improved surface profile. There are pros and cons to this method, as there are with any type of surface preparation. On the positive side is the fact that this method promotes excellent adhesion. Sweep blasting of galvanized steel prior to painting has been used in Europe for many years with outstanding success.
On the negative side, the blast procedure requires a good deal of expertise on the part of the operator. Too little blasting will not remove the contaminated film; too much blasting will remove excessive amounts of zinc. Fabricated items with numerous surfaces and angles pose a particular problem. If blasted too heavily, too much zinc will be removed and/or disbondment of the zinc can occur, causing extensive flaking.

Blast media selection is important. Hard abrasives may strip off too much zinc while a soft media may polish the surface and not remove contaminants or provide sufficient surface profile. Successful applications in Holland indicate that the best results are obtained using aluminum/magnesium silicate abrasive with a particle size in the range of 0.2 to 0.5 mm. Properly used, this abrasive will remove all of the oxide and surface contamination with a loss of only about 10 μm of zinc. Dutch authorities also have reported good results with the use of used alumina (corundum). In addition, the successful use of limestone abrasive has been reported in the United States.

Automated blast facilities that use steel abrasive should be avoided due to problems with embedded steel particles in the relatively soft zinc coating. This embedment can cause rust to bleed through after topcoating.

Following abrasive blast cleaning, surfaces should be blown down with clean, compressed air and coated immediately. Because zinc oxide films tend to reform rapidly, brush blasting of galvanized surfaces should not be performed when relative humidity is greater than 50 percent and/or the ambient temperature is less than 21.1°C (70°F). In any case, topcoating should always take place the same day that the material is blasted.

Because of the problems associated with abrasive blasting, not the least of which is high cost, applicators have sought other methods of surface preparation. Some of these work reasonably well, others do not work at all. Attempts made using vinegar or some other form of acetic acid, while ecologically "safe," are rarely effective. Even when thoroughly rinsed with water, this method is ineffective on most forms of oxides and hydroxides. If improperly rinsed, the vinegar itself can leave a residual film, which may interfere with paint adhesion.

Solvent wiping is ineffective unless a specific foreign material is present that can be removed by that particular solvent. The use of high pressure water, with a slightly alkaline pH, is somewhat more effective, but does not provide surface profile. The addition of proprietary cleaning agents, detergents, etc., is not recommended, because of the possibility of leaving residue on the surface if not completely rinsed. Physically brushing the surface usually does not remove all of the oxides and hydroxides.

Other than abrasive blast cleaning, the next best method is high pressure washing followed by the use of a metal conditioner or "wash primer." Metal conditioners (known by such trade names as Surfa-etch, Galva-prime, T-Wash, etc.) generally consist of some form of phosphoric acid in combination with a solvent such as methylated spirits or ethyl cellulose. A common generic metal conditioner is available under military specification MIL-P-15328. These metal conditioners (which are more than just a primer) are designed to neutralize surface oxides and hydroxides and etch the surface.

It is critical that these products be mixed in conformance with the manufacturer's instructions and applied at a thickness of no greater than 0.5 mils (or in accordance with the manufacturer's instructions). Poor adhesion of topcoats can be expected if these products are applied at excessive thicknesses. This type of product dries rapidly (usually in 10 to 12 minutes) and should be topcoated within 12 hours.
It is good practice to pressure wash the surface, apply the metal conditioner, and apply the next coat—all on the same day. This procedure may be followed by the application of a topcoat at a later date. While numerous methods and products exist for this purpose, it is best to carefully investigate manufacturers' claims and test anticipated systems before making a selection.

Choosing a Topcoat

The best treatment system, in the author's opinion, is the use of a wash primer (or sweep blasting) followed by application of an intermediate coat of epoxy and a topcoat of urethane (for ultraviolet resistance in most industrial environments).

Alkyd-based paint formulations should be avoided because they tend to saponify at the zinc/paint interface resulting in poor adhesion.

Equally suspect are paints advertised as being suitable for application to galvanized surfaces without surface treatment of some kind. This is because the "galvanizing" over which the paint was tested may turn out to be sheet metal galvanizing (ASTM 525), which may behave differently than galvanizing performed under ASTM A123.

It has been the author's experience that the "self priming" and "one-coat" type formulations simply do not provide the performance of two-coat systems, although there are numerous quality paint manufacturers that manufacture products that will perform well over properly prepared galvanized surfaces.

Anyone setting up a system of painting over hot dip galvanizing would be well advised to establish a solid working relationship with the paint manufacturer/supplier, with both parties committed to undertaking the necessary QA/QC procedures and testing programs to make the system work.

With a thorough understanding of the galvanizing process and the steps required to ensure a good coating system, a duplex system of topcoated galvanizing will perform for many years in most industrial environments.